

Clinical Procedures in

PRIMARY EYE CARE



David B. Elliott

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FOURTH EDITION



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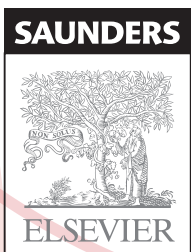
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PREFACE

This textbook was written primarily as a teaching aid for undergraduate optometry students and for practitioners wishing to review their clinical practice. Chapter 1 discusses evidence-based optometry and how clinical tests and procedures are assessed in the research literature and how such reports should be critiqued. It also compares the various formats of an eye examination and discusses the theory behind the use of screening tests in primary eye care. Chapter 2 introduces the communication skills used in an eye examination and discusses the case history and how it should be performed. Tests are subsequently grouped together in terms of which system they assess: visual function (Chapter 3), refraction and prescribing (Chapter 4), binocular vision and accommodation (Chapter 6) and ocular health (Chapter 7). This layout was chosen because the organisation of the book is directed towards the assimilation of a problem-oriented approach that is built upon a systems examination (Section 1.3). Grouping the tests in this way, rather than in the order they are typically used in an eye examination, may also help students to better appreciate the relationship between the various tests that assess a particular system. To develop ocular health skills in discriminating between disease and the normal eye, it is essential to know many presentations that a normal eye can make and a brief description and collection of photographs of these normal variations is presented in Chapter 8 and the accompanying website to supplement the information provided in atlases of ocular disease. Chapter 9 completes the book with an introduction to some physical examination procedures that may be used in primary care eye examinations.

The 4th edition has been adapted to reflect the increasing use of technology in optometric practice and the ever-increasing ageing of the optometric patient population. This includes a section on optical coherence tomography (OCT) and suggestions of how to adapt some tests for older patients. Other improvements over the 3rd edition include:

- A dedicated website that includes video-clips of many clinical procedures, several in multi-screen format, and a large selection of fundus and slit-lamp photographs.
- An increased number of diagrams and photographs that are all provided in full colour throughout the text.
- A new chapter that introduces contact lens fitting and aftercare (Chapter 5).

Comments and suggestions for future editions

The advantages and disadvantages of each procedure are provided and where possible, the measurement procedure is based on evidence from the research literature. However, there is no doubt that tests and test methodologies have been included which may reflect our biases due to our particular training, research and clinical experience. There may also be errors and omissions. We therefore welcome any comments and suggestions that would improve any further editions. Please e-mail the editor, Professor David Elliott on: d.elliott1@bradford.ac.uk

Information relevant to students

There are many ways of conducting an eye examination and different ways to properly perform various tests or procedures and some may not appear in this textbook. In particular, in University primary care clinics it is the supervising clinician's decision as to which techniques or tests should be used in an eye examination. They are taking legal responsibility for the examination. If they indicate that a particular test needs using, use it! Once the patient has left and you are discussing the case with your supervisor, to further your learning, you should ask them about the advantages and disadvantages of their suggested technique and details of any supporting research evidence.

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EVIDENCE-BASED EYE EXAMINATIONS

DAVID B. ELLIOTT

1

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1.1 EVIDENCE-BASED OPTOMETRY

Evidence-based optometry means integrating individual clinical expertise with the best currently available evidence from the research literature.¹ A significant amount of evidence-based eye care is associated with treatments and their effectiveness and this information is typically provided by the results from randomised controlled trials (RCTs) or the collation of results from several RCTs within systematic reviews and meta-analyses.² However, the diagnostic tests and procedures used in optometric practice should also be evidence based and what should always be avoided is the use of exam procedures based on anecdotal evidence, tradition or habit. The research literature should be regularly reviewed. There may be reports of newly developed techniques or instruments that are superior to the ones you typically use or even studies indicating that old and forgotten tests are actually better than commonly used ones.³

1.1.1 Reviewing the research literature

Currently professional bodies provide clinical guidelines that are based on research evidence and academic researchers write review articles, books and give lectures and this seems to be the preferred source of information for many optometrists.⁴ You may not need to review the research literature yourself, although it seems likely that this will become more common in future years as evidence-based optometry becomes an integral part of the undergraduate and postgraduate curriculum.^{4,5} If you wish to review the literature, one very useful free access website is PubMed (www.pubmed.com), which is provided by the US National Library of Medicine and includes the abstracts or summaries of all the main optometry and ophthalmology research journals. An increasing desire for research evidence to be freely provided to as many

people as possible means that a growing number of the full articles are also free to access. Questions from clinicians on optometric internet/e-mail discussion groups can often be fully answered by a quick PubMed search that can provide a much better level of evidence than anecdotal suggestions based on one or two patient encounters. Full access to one or more of the main international optometry research journals, *Ophthalmic and Physiological Optics*, *Optometry and Vision Science*, *Clinical and Experimental Optometry*, *Journal of Optometry* and *Contact Lens and Anterior Eye* depends on which professional bodies you belong to, but note that the first three journals provide free access to a number of hot topic papers at www.whatshotoptometry.org.

1.1.2 Evaluating the usefulness of optometric tests

The usefulness of optometric tests is typically assessed by either comparing the test against an appropriate gold standard and/or assessing its repeatability.⁶ For example, a test that is being used as an objective measure of subjective refraction should be assessed by how closely the results match subjective refraction results and new tonometers are assessed by their agreement with the results of Goldmann Applanation Tonometry (GAT).

Clearly the appropriateness of the gold standard test in these studies is critical. For example, Calvin and colleagues used the von Graefe phoria measurement as the gold standard test to assess the usefulness of the cover test and suggested that the cover test was occasionally inaccurate.⁷ The gold standard in this area should be the cover test and not the von Graefe. The cover test is the only test that discriminates between strabismus and heterophoria, it is objective and not reliant on subject responses and subsequent studies have shown it to be far more repeatable than the von Graefe, which they indicate is unreliable and does not appear to warrant its widespread use.^{3,8,9} The Calvin study⁷ should have used the cover test as the gold standard and they would then have reported the limitations of the von Graefe. The gold standard test must also be appropriately measured. For example, Salchow et al. compared autorefraction results after LASIK refractive surgery against the gold standard of

subjective refraction.¹⁰ Subjective refraction was an appropriate choice of gold standard, but was inappropriately measured. The authors concluded that autorefraction compared very poorly against subjective refraction post-LASIK. However, inspection of the results clearly indicates that the majority of the subjective refractions (particularly of the hyperopes) provided a result of plano. This suggests that a normal or near normal VA resulted in a 'brief' subjective refraction and a result of plano. Finally, any limitations of the gold standard test must be recognised. For example, GAT is known to provide high intra-ocular pressure (IOP) readings on thick corneas and low readings with thin corneas.¹¹ This has tended to be ignored until recently when significant reductions in IOP have been found after refractive surgery (section 7.7). If a tonometer that was resistant to corneal thickness effects had been compared to GAT, it would have been shown to be variable. The conclusion would have been that the new tonometer was somewhat variable compared to GAT.

The use of subjective refraction as a gold standard assessment of refractive error has meant that there has been little or no comparison of the various methods used in subjective refraction. Previous studies have tended to compare the various tests against each other. For example, West and Somers compared the various binocular balancing tests and found that they all gave similar results and concluded that they were therefore all equally useful.¹² Johnson and colleagues reported a similar finding when comparing subjective tests for astigmatism.¹³ These are not surprising findings and are limited by an unhelpful study design. A very good but under-utilised approach is to use some measure of patient satisfaction as the gold standard. If patients are happy with the results of subjective refraction using a particular test, then the test must be providing appropriate results and vice-versa. Hanlon and colleagues used this approach in a comparison of techniques used to determine the reading addition.¹⁴ They examined 37 patients that were dissatisfied with the near vision in their new spectacles. From the case history information in the review (recheck) examination, it was determined whether the improper add was too low or too high. For each patient, their reading addition was then determined using four methods (age, $\frac{1}{2}$ amplitude of accommodation, NRA/PRA balance and binocular cross-cylinder). The percentage of adds for each test that gave the same result as the improper add or worse (higher than an improper add determined too high or lower than an improper add determined as too low) was calculated (section 4.14). The study would have been even better if they had confirmed that the patients

were subsequently satisfied with their changed spectacles (i.e., that it really was the gold standard). This technique of using patient satisfaction as the gold standard test could be usefully employed to compare the various techniques used in distance refraction, particularly those that assess astigmatism and binocular balancing.

1.1.3 Analysis in clinical test comparison studies

In the past, test comparison studies tended to quantify the relationship between the test and gold standard using correlation coefficients. This is not appropriate for two reasons. First, a high correlation coefficient just indicates there is a strong relationship between the two sets of data and does not necessarily mean that agreement between the tests is good.^{6,15} For example, if the test results were always twice as big as the gold standard test, the correlation coefficient would be 1.0, but agreement would be very poor. In addition, correlation coefficients are very much affected by the range of values used in the analysis.^{6,15,16} If a small range of values is used in calculations the correlation coefficient is likely to be much smaller than if a larger range is used. This is highlighted in Figure 1.1, which shows a plot of correlation coefficients between visual acuity and other clinical measures of visual function versus the range of visual acuity of the subjects used in the studies. A much better analysis, commonly known as a Bland-Altman plot, shows the 95% confidence limits of the difference between the test and gold standard (Figure 1.2).^{6,15} The extent to which the 95% Bland-Altman agreement figures are clinically acceptable should be discussed by the authors of a paper and ideally acceptable limits should be determined prior to any assessment.⁶

1.1.4 Analysis of test repeatability

Repeatability assesses the ability of a measurement to be consistently produced. It is sometimes called precision or reliability and particularly in older reports has been quantified in terms of correlation coefficients. The limitations of correlation coefficients have already been discussed and it is better to assess repeatability in terms of the coefficient of repeatability (COR) or similar.⁶ This represents the 95% confidence limits of the difference between the test and retest scores and can be displayed using Bland-Altman plots (Figure 1.2).¹⁵ Correlation coefficients can be used when comparing tests that do not use the same units, but their limitations need to be realised. In particular, a large

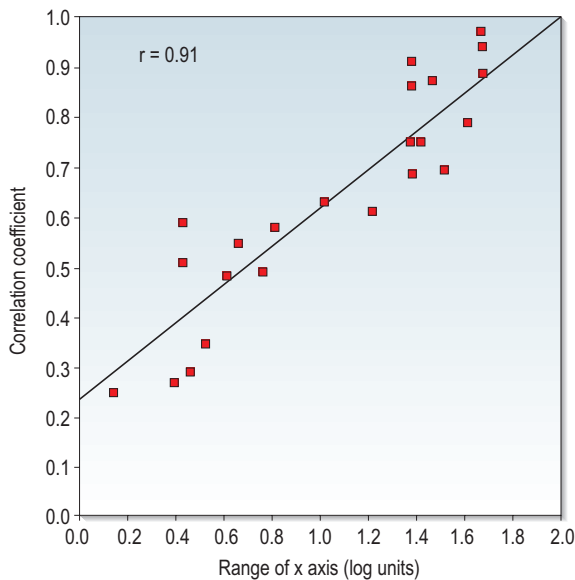


Fig. 1.1 Correlation coefficients from the literature between high contrast visual acuity and other spatial vision measures are plotted as a function of the range of high-contrast acuities in those studies. The solid line is the regression line and the correlation coefficient for the plotted data points is 0.91. (Redrawn with permission from Haegerstrom-Portnoy G, Schneck ME, Lott LA, Brabyn JA. The relation between visual acuity and other spatial vision measures. *Optometry and Vision Science* 77:653–62, ©The American Academy of Optometry, 2000.)

range of values should be used, so that correlation coefficients are not artificially low. Concordance values (the percentage of patients getting exactly the same score on test and retest) have also been used to indicate that a test is repeatable. However, a high proportion of patients often obtaining exactly the same score on follow-up visits indicates that the step sizes on the test are too big rather than that the test is repeatable.¹⁷ For example, a visual acuity chart containing only 20/20 (6/6) and 20/200 (6/60) lines would provide very high concordance but would be of very little value.

Repeatability studies providing COR data indicate the size of the change in score due to chance and a clinically significant change in score is anything larger than the COR (at least for tests with a continuous scale).¹⁸ Repeatability appears to be a very important quality of a test, as an unreliable test is likely to correlate poorly with a gold standard and have poor discriminative ability.¹⁹ As these studies are also relatively

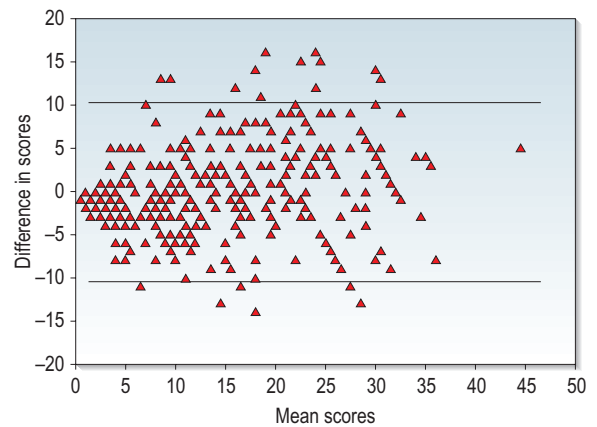


Fig. 1.2 A Bland-Altman plot showing agreement between optometrist grading of melanocytic fundal lesions and the gold standard assessment by an ocular oncologist versus the average score for each lesion. (Reprinted with permission from Hemmerdinger C, Beech M, Groenewald C and Damato B. Validation of an online referral guide for melanocytic fundus lesions. *Ophthalmic and Physiological Optics* 31:574–9. ©The College of Optometrists, 2011.)

quick and simple, the results of repeatability studies should be available for all clinical tests.

1.1.5 Critically appraising a research paper

Research journals such as those listed earlier include a rigorous review process so that the majority of papers include minimal problems and many list the limitations of the study within the report. However, not all research reports necessarily provide accurate information and a study could be flawed for a variety of reasons.^{20,21} In addition, articles on the internet and in professional magazines are unlikely to provide the same level of scrutiny and it is very useful to be able to critique a research report, rather than just accept its conclusions. Various criteria can be used to assess the methodological quality of research articles and a high quality paper should include the following^{20,21}:

- The paper should be easy to read and understand. Particularly in the area of the assessment of clinical and diagnostic techniques, there should be little that a clinician cannot understand. The rationale behind any complicated statistical analyses should be explained in a simple way. A paper that is difficult to understand often indicates a poorly

written paper rather than any lack of understanding on the part of the reader.

- The introduction of a paper should include the purpose of the study and discuss pertinent previous work.
- The methods section should be clear and precise. Another researcher should be able to replicate the study from the information provided in the methods section. It is usually necessary to randomise the order in which tests are performed to ensure that there are no significant learning or fatigue effects that could affect the data.
- In studies where tests are compared against a gold standard, the clinicians should be blind to the results from the other test.
- The subject sample should be clearly outlined. A sufficiently large sample and a broad spectrum of subjects should be used to ensure no recruitment bias. In assessments of diagnostic tests, the patient sample must be representative of patients you would be examining in practice. For example, some Primary Open Angle Glaucoma (POAG) research studies include patients with moderate to severe POAG and healthy controls. This may be reasonable for an initial study, but likely tells you little about how well a new test would perform in discriminating between very early POAG and normal, healthy eyes in practice.
- In diagnostic studies, it is sometimes reported that a significant difference was found between a group of patients with an ocular abnormality and a control group. It should be noted that this only indicates that there is a difference between the averages of the two groups. It does not indicate how well the test predicts whether an individual patient has the abnormality or not.
- The authors may indicate the limitations of the study. The majority of research studies have some limitations and it is very helpful to the reader if the authors indicate them. It also suggests that the authors are not exaggerating the findings of their study.

1.2 'SCREEN EVERYBODY, SO I DON'T MISS ANY GLAUCOMA': IS THIS REASONABLE?

In many countries, glaucoma and other eye diseases are detected by 'opportunistic case finding' in that patients are self-selecting and they are detected as part of an eye examination that includes some assessment

of ocular health and visual function.²² Professional bodies within different countries generally provide evidence-based guidelines which tend to suggest which tests are appropriate for different patient demographics and perhaps for certain signs and symptoms. There has been a tendency, however, particularly with the increased use of clinical assistants within optometric practice (section 1.3.5) to increasingly 'screen' patients with tests such as visual fields and non-contact tonometry to attempt to 'not miss anything'.²³ This approach is examined below and highlights the importance of understanding diagnostic indices of optometric tests.

1.2.1 Diagnostic test indices and what they can tell us

New diagnostic tests must have their diagnostic ability compared to a gold standard reference. The research study will therefore determine how well a test can correctly identify 'abnormal' or 'normal' eyes as classified independently by a gold standard test or battery of tests. For example, new instruments or techniques that attempt to identify POAG are typically assessed against classifications of patients into glaucomatous and control groups by clinical evaluation of optic nerve head assessment, visual fields and tonometry.²⁴

Please note that the following figures of sensitivity, specificity and prevalence are not accurate and have been simplified. Imagine a POAG test that correctly detects patients with POAG 95% of the time (the sensitivity of the test is 95%); if the test indicates that a patient has POAG, what are the chances that they actually have the disease? Is it 95%? If lower, how much lower? When considering this question, you must not only consider how good the test is at identifying POAG, but you must also consider how good the test is at correctly identifying someone as normal. Unfortunately all tests provide false positives: patients who have normal, healthy eyes who the test results suggest are abnormal. There are four possible outcomes from the results of a diagnostic test (Table 1.1)

Table 1.1 Possible outcomes of a screening test

	Diseased eye	Normal eye
Test says diseased	True positive, TP (hit)	False positive, FP (false alarm)
Test says normal	False negative, FN (miss)	True negative, TN

and this information is used to quantify how well the test discriminates between 'normal' and 'abnormal' eyes, by providing sensitivity and specificity values.

- Sensitivity is the ability of the test to identify the disease in those who have it.
- Sensitivity = $TP / (TP + FN)$.
- Specificity is the ability of the test to correctly identify those who do not have the disease.
- Specificity = $TN / (TN + FP)$.
- The false positive rate is simply 1 minus the specificity.
- Another important term to understand is the Predictive Value (PV), which has positive and negative forms.
- PPV or +PV is the proportion of people with a positive test result who have the disease. $PPV = TP / (TP + FP)$.
- NPV or -PV is the proportion of people with a negative test result who do not have the disease. $NPV = TN / (TN + FN)$.

The reported sensitivity and specificity of a test will differ depending on the pool of patients examined, the gold standard used to determine the presence or absence of disease and the cut-off criteria used. Sensitivity and specificity values and plots of one against the other for a range of cut-off values in receiver

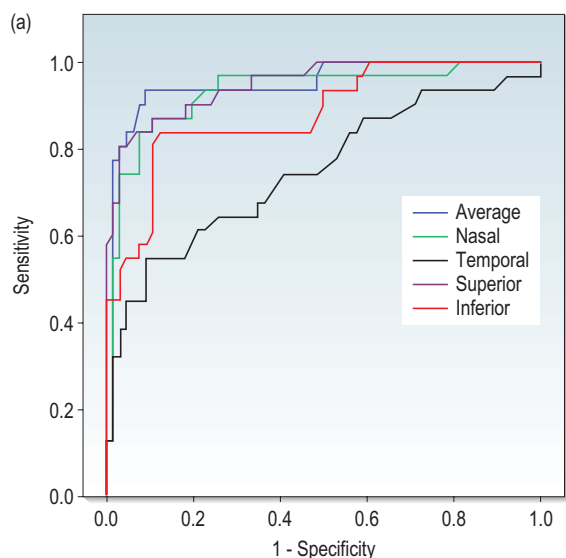
operating characteristic (ROC) curves (Figure 1.3) are usually presented.

The ability of a diagnostic test to correctly identify patients with disease is highly dependent upon how prevalent the condition is (Bayes Theorem). For example, let us consider POAG and assume a prevalence in the over 40 population of 1%, and a diagnostic test for glaucoma with 95% sensitivity and 95% specificity. Table 1.2 shows the likely outcomes from 1000 patients. Nine or all 10 patients with POAG have a positive test result, but so have 50 patients with normal, healthy eyes. Returning to the question at the beginning of this section, if a POAG test that correctly detects patients with POAG 95% of the time (95% sensitivity) indicates that a patient has POAG, the chances that they actually have the condition (given a test specificity of 95%) is 17%! Detecting disease that has a low prevalence is very difficult no matter how good your diagnostic tests are because there are so few patients with the disease and so many people who don't have that disease. This also highlights that with diseases with low prevalence, you are better off using tests (or cut-off scores for a test) that have the highest specificity (limiting false positives) even if this lowers sensitivity and a small number with POAG (in its early stages) are missed.

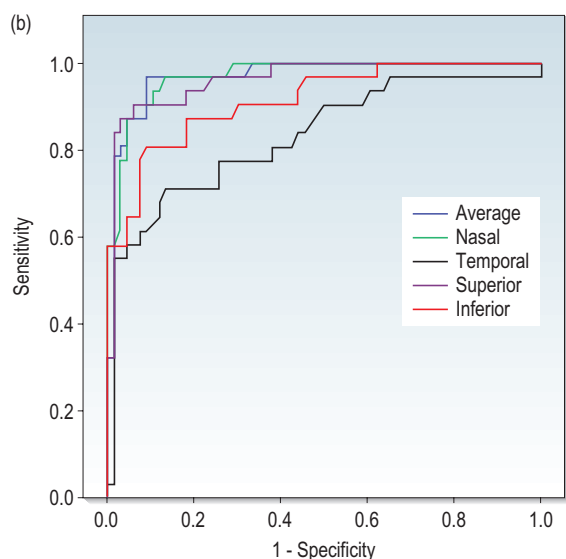
In addition to the diagnostic indices of sensitivity, specificity, PPV and NPV, likelihood ratios (LR) are

Table 1.2 Results for 1,000 patients from a 'glaucoma test' with 95% sensitivity and 95% specificity where the prevalence of primary open angle glaucoma (POAG) is either 1% or 10%. Data are also provided for the 1% prevalence group when the test is repeated

	Sensitivity 95% and specificity 95%		
	POAG prevalence, 1%	POAG prevalence, 10%	Repeated testing (POAG, 1%)
Patients with POAG	10	100	10
Patients without POAG	990	900	990
True positive	9.5 (9 or 10)	95	9
False positive	50	45	2.5
True negative	940	855	47.5
False negative	0.5 (0 or 1)	5	1
PPV	17%	68%	78%
NPV	~100%	99.4%	98%
LR+	19		
LR-	0.05		



	Superior	Inferior	Temporal	Average thickness
Nasal	0.633	0.153	0.001	0.601



	Superior	Inferior	Temporal	Average thickness
Nasal	0.839	0.138	0.005	0.962

Fig. 1.3 Receiver-operating characteristic (ROC) curve showing OCT ability (using nerve fibre layer thickness in various quadrants) to discriminate between optic nerve head drusen and optic disc oedema. (Redrawn with permission from Flores-Rodríguez P, Gili P and Martín-Ríos MD. Sensitivity and specificity of time-domain and spectral-domain optical coherence tomography in differentiating optic nerve head drusen and optic disc oedema. *Ophthalmic and Physiological Optics* 32:213–21. ©The College of Optometrists, 2012.)

becoming increasingly used to indicate diagnostic accuracy and unlike the predictive values, they are not dependent on the prevalence of the disease. A positive likelihood ratio (or LR+, sensitivity/1–specificity) expresses how much a positive test increases the odds that a patient has the disease. A negative likelihood ratio (or LR–, 1–sensitivity/specificity) indicates how much a negative test decreases the odds of having it. Charts have been developed that link a pre-test probability that a patient has a particular disease via a likelihood ratio column to indicate the post-test probability that a patient has the disease given either a positive or negative test result. The evidence-based medicine approach encourages the use of these indices and calculations for individual patient diagnosis. However, physicians still struggle to use these concepts and this would appear to have some way to go to be useable, but suggests the future direction of this area.²⁵

1.2.2 Are there a lot of false positive referrals from primary eye care?

Figures for false positive referrals will vary dependent on the disease type (most of the reports present data from suspect glaucoma referrals, which will obviously have higher false positive rates than referrals for conditions such as cataract), the structure and funding model of the primary-secondary eye care system, the level of training, expertise and equipment, the introduction of locally agreed guidelines, etc, etc.²⁶ For these reasons, it is perhaps enough to say that it can be high and perhaps higher than you might expect. For example, in the most comprehensive study of its type to date, Bowling and colleagues reported a 46% false positive rate for suspect glaucoma from 2505 optometric referrals to the Oxford Eye Hospital over a 10-year period (1994–2004).²⁷

1.2.3 Do false positive referrals matter?

Elmore and colleagues reported the false positive rate of the two main breast cancer screening tests to be 6.5% and 3.7%.²⁸ These translate to very good specificity values of 93.5% and 96.3%. Despite this good specificity, over a ten-year period, nearly one-third of the women screened had at least one false positive mammogram or clinical breast examination. This highlights that if you test healthy people often enough, they will sooner or later obtain a positive test result, i.e. a false positive. It has been shown that these false positive results have negative psychological effects on these women and likely their families.²⁹ Similarly, there is considerable and unnecessary worry and stress caused by a false positive result leading to referral to a secondary eye care system, in that some patients worry that they might be going blind. Patients should not be referred to secondary eye care on the basis of a slightly high intra-ocular pressure using a non-contact tonometer or a single positive visual field screening result. In addition to the psychological effects on patients and their families, the costs in terms of secondary eye care staff and patient time (including the delay that other patients will suffer because of busy clinics) prompted by a positive screening result should be considered.²³

1.2.4 Reducing false positives 1: Only screen 'at risk' patients

Due to the high number of false positive results when screening patients for a disease with low prevalence (Bayes Theorem), it may be better to only screen those patients that are 'at risk'. In these patients, the prevalence of the disease is higher than in the general population. Table 1.2 considers the likely outcomes using the same test discussed earlier on patients with a family history of POAG where the prevalence of the disease is higher and for simplicity we will assume a figure of 10%. In total, 140 patients gave positive results, of which 95 had the disease (PPV = 68%). Note how much better the test performs when it is used in patients at higher risk of having the disease. The positive predictive value is also significantly improved if you just perform screening on all patients over 75 years of age or patients over 40 years of age who are black (African American or African Caribbean) or those with suspicious optic discs or high intra-ocular pressure. Burr and colleagues in their systematic review suggested that screening of patients with 'minor' risk factors including myopia and diabetes did not improve the PPV sufficiently and was not cost-effective.²²

1.2.5 Reducing false positives 2: Repeat testing

Another way of keeping false positive referrals to a minimum, and imperative if you are intending to screen more than 'at risk' patients, is to repeat positive results. For example, as part of the ocular hypertension treatment study, Keltner and colleagues found 703 Humphrey visual field test results that showed abnormal (positive glaucoma hemifield test and/or Corrected Pattern Standard Deviation, $p < 0.05$) and reliable visual fields.³⁰ On retesting, abnormalities were *not* confirmed for 604 (86%)! The vast majority of visual field abnormalities were not verified on retest and confirmation of visual field abnormalities is essential for distinguishing reproducible visual field loss from long-term variability.

If the same glaucoma diagnostic test from Table 1.2, which suggested that 60 patients had POAG (only 10 did, a PPV of 17%), was repeated on these 60 patients, 9 or all 10 of the glaucoma patients would be identified, but 95% of the false positives (47 or 48) would now give a normal result. On retesting, positive results are found for 13 patients, of whom 10 have the disease (PPV = 77%). Of course, you could also combine both approaches by only screening at risk patients and repeating positive tests.

1.3 PRIMARY EYE CARE EXAMINATION FORMATS

The primary eye care examination must first and foremost adhere to the legal requirements where you are working. However, legal requirements tend to be provided in very broad terms. Some professional organisations that you belong to may also provide clinical guidelines of what your eye examination should include. These may be prescriptive or for guidance only. There are three main styles for a primary eye care examination, which could be used singularly or in combination: the database format, which uses a predetermined series of tests, the systems approach, which ensures an assessment of several systems and/or the problem-oriented approach, which focuses mainly on the patient's problems.^{31,32} In addition, some parts of the eye examination could be performed by clinical assistants.

1.3.1 The database examination

A database examination style means using essentially the same set of clinical procedures in every

Table 1.3 Classification of tests/procedures into one of four clinical oculovisual systems

Visual*	Binocular*	Refractive	Ocular health
Case history	Case history	Case history	Case history
Visual acuity	Cover test	Visual acuity	Visual acuity
Colour vision	Motility	Retinoscopy	Biomicroscopy
Visual fields	Convergence tests	Autorefraction	Ophthalmoscopy
Contrast sensitivity	Accommodation tests	Subjective	Tonometry
Disability glare	Suppression tests	Near add determination	Gonioscopy
Pupil responses	Pupil responses Stereopsis	Keratometry	Pupil responses
*Other classifications discuss the sensory and motor systems rather than the visual and binocular systems and place suppression and stereopsis within the sensory system.			

examination. A large 'complete' database of information is collected to ensure that most patients' problems can be addressed using the information provided. This is the style of examination that will be used by students, because they need to practice the various clinical techniques to gain technical competence. Technical competence should be the aim for students in the early years of clinical teaching. A much greater task is gaining clinical competence and understanding the tests and their results, how they interact and how they can be used in differential diagnosis and to solve the patient's problems. Only once a student/practitioner has gained a high level of clinical competence should the database style of examination be abandoned and another approach used.

Although the database examination style is ideal for students, it is not for experienced practitioners. Often, if a large database is used, some data collected provide no useful information regarding the clinical diagnosis or treatment options. If patients require additional testing, because of the inflexibility of the approach, practitioners either perform the tests at the end of the examination, which can lead to them being late for subsequent examinations, or another appointment is made at a later date. At its worst, this style of examination could be said to provide some test data which are not used and of little value and provides a bias against performing additional procedures which may be of real benefit.

1.3.2 Systems examination

A systems examination style includes an assessment of visual function, the refractive and binocular systems

and an ocular health assessment. The optometric examination is defined not by tests used, but by the systems that are assessed (Table 1.3). This approach is much more flexible as it does not demand that a certain collection of tests is used. In such an examination style, a minimum database has been gathered when each system has been tested. In summary, think in terms of assessing systems and not of using individual tests.

1.3.3 Problem-oriented examination

The problem-oriented examination aligns the examination around the problems reported by the patient. However, it does not only use tests that help solve the patient's problems as it is built upon a systems examination approach.^{31,32} To perform a problem-oriented examination, the case history is critical as it guides the whole examination. From the information gained in the case history, you should attempt to deduce a list of tentative diagnoses (or several lists if more than one condition is suspected). For example, symptoms of blurred distance vision with normal near vision in a teenager could suggest the following tentative diagnoses (in order of likelihood): myopia, non-organic visual loss (section 4.12.6) and pseudomyopia. It is likely that visual acuity, retinoscopy and subjective refraction are all that is required to enable a differential diagnosis, although a cycloplegic refraction may be required if pseudomyopia is suspected. Other tests ensure an assessment of all the systems and depending on legal requirements and as a minimum these could include a cover and motility test (binocular system), assessment of pupil reflexes,

slit-lamp biomicroscopy and fundus biomicroscopy (ocular health assessment).

Although the problem-oriented examination requires a minimal database as required for legal reasons and to ensure that each system is assessed, this is not its major characteristic. Rather, it is distinguished by its variability. For example, if a 15-year-old patient complains of frontal headaches and eyestrain when reading, the most likely tentative diagnoses are uncorrected hyperopia or decompensated near heterophoria. Depending on results from other tests, tests used may include measuring fusional reserves, AC/A ratio, fixation disparity and cycloplegic refraction. If a 30-year-old patient complaining of sudden painless vision loss in one eye (>24 hours), the most likely tentative diagnoses would include a unilateral change in refractive error (i.e., suddenly noticed rather than sudden onset), optic neuritis and idiopathic central serous choroidopathy. None of the additional tests used in the previous example would be used. Instead, fundus biomicroscopy, photostress recovery time, central visual field and contrast sensitivity testing would be considered. In the latter case, an assessment of the refractive system may be limited to focimetry (lensometry), visual acuity and pinhole visual acuity. If the pinhole visual acuity suggests that visual acuity improvements are unlikely with an altered refractive correction, then a full objective and subjective refraction may not be necessary. The results from each test used in the examination are then considered and used to update the tentative diagnosis list(s) until a firm diagnosis (if possible) is made.

When using this style of examination, you must also be aware that any new or changed prescription should not produce symptoms. For example, the possible effect of an increased myopic correction on an esophoria should be determined prior to dispensing the spectacles: the increased myopia would likely increase the esophoria and you need to know whether it could become decompensated. Disadvantages of the problem-oriented examination include its dependence on the patient's symptoms. Obviously if a case history is not possible for any reason, a problem-oriented approach cannot be used and a database style of examination is necessary. In addition, there are also a variety of reasons why some patients may not disclose all their symptoms. These include:

- The patient might believe that their headaches are not associated with their vision or their eyes.
- The patient may assume that the clinician will identify a problem and would ask specifically about it if it was important.

- The patient could think that their slightly blurred vision is a normal consequence of ageing and so not mention it.
- The patient might not mention some symptoms such as flashes and floaters because they may think that they are not important and they may even believe that mentioning such symptoms would make them look foolish.

This further highlights the need to use the problem-oriented examination within a system assessment approach. It also indicates the importance of developing a good rapport with the patient to obtain a comprehensive case history (section 2.1). A further disadvantage of the problem-oriented approach is its complexity. To perform a problem-oriented examination, excellent communication skills are required to obtain a complete case history. A competent grasp of the information provided in the case history and how it relates to various ocular abnormalities is also needed, plus a knowledge of which tests are required to perform the huge variety of differential diagnoses. It is not suitable for the student clinician and can only be developed after significant experience has been gained.

1.3.4 Combination approach

Another approach is to gain a complete database of information during an initial examination of a patient, and then use a problem-oriented approach during subsequent examinations. This necessitates different appointment slots for first time and subsequent examinations, with the first time appointment slot being longer than for subsequent visits.

1.3.5 The use of clinical assistants

The rationale behind the use of clinical assistants in pre-examination is twofold:

- As clinical assistants perform certain tests that the optometrist would previously have performed, some of the optometrist's time is freed up. They could use this time to perform additional procedures or examine more patients per day.
- These procedures generally become more routinely performed.

After a period of training, clinical assistants should be able to competently perform any automated procedure, such as automated visual fields and focimetry, autorefraction and non-contact tonometry. The dangers of routinely screening all patients or all patients over 40 years of age with visual field tests and tonometry

(unless you are committed to repeating any positive test results) has been discussed in section 1.2. In addition, other simple tests could be performed such as colour vision and stereopsis screening and interpupillary distance (PD) measurement. It is not possible for a clinical assistant to complete the full case history, since history taking continues throughout the examination. However, assistants could record a baseline history that could be reviewed and augmented by the clinician. However, this approach provides less likelihood of a good rapport being established between patient and clinician, which is vital for an optimal examination result (section 2.1). Clinical assistants could also measure visual acuity with the patient's spectacles. However, important information can be obtained during visual acuity measurement in addition to the acuity score (section 3.2) and as an important part of the subjective refraction is to compare the final visual acuity (which the optometrist measures) with the habitual acuity, it appears best to have both measurements made by the clinician.

1.3.6 Should dilated fundus examinations be routine?

There has been considerable debate about whether a primary care eye examination should routinely include a dilated fundus examination (DFE).^{33–36} Two main arguments, supported by clinical data, are proposed in favour of the DFE. The first is that a DFE increases the number of posterior pole anomalies detected.^{33,34} In these studies, a non-dilated fundus examination with direct ophthalmoscopy was compared to a DFE using headband binocular indirect ophthalmoscopy (BIO) and direct ophthalmoscopy. Siegel et al. also used a monocular indirect ophthalmoscope examination as part of the non-dilated exam.³³ The poor field of view of the direct ophthalmoscope was particularly blamed for missing anomalies in the posterior pole as it is too small to examine the area quickly and easily. The second argument in favour of a DFE is that significant anomalies would otherwise be missed in the peripheral retina. Although many of the anomalies found in the peripheral retina are benign and do not need treatment, studies assessing the optomap system have shown that it missed treatable conditions in both the mid-peripheral and particularly the far peripheral retina when compared with a dilated fundus examination.^{33–35,37,38}

Further study seems to be required. This should compare DFEs against an undilated fundus examination with fundus biomicroscopy, and most importantly the comparison should be made only for those patients

where there are no symptoms, signs (including a small undilated pupil that would restrict the view) and/or risk factors that would normally prompt a DFE. It is possible that the better field of view and stereoscopic image provided by fundus biomicroscopy would limit the advantage of a DFE for the posterior pole in a patient with a reasonable pupil size and that very few treatable peripheral conditions would be missed. The majority of patients with peripheral retinal disease reported by Batchelder and colleagues had important risk factors including previous anterior segment

Box 1.1 Approximate order of testing for performing various procedures in a routine optometric examination of an adult patient

1. Case history
2. Focimetry (lensometry or vertometry)
3. Vision (unaided visual acuity)
4. Unaided cover test
5. Habitual visual acuity
6. Aided cover test
7. Near point of convergence
8. Worth 4-dot
9. Motility testing
10. Interpupillary distance measurement
11. Retinoscopy (and/or autorefraction)
12. Subjective refraction
13. Distance modified Thorington (or alternative)
14. Distance fusional reserves (or associated phoria measurement)
15. Amplitude of accommodation
16. Reading add determination (if required)
17. Near modified Thorington (or alternative)
18. Near fusional reserves (or associated phoria measurement)
19. Stereoacuity
20. Pupil reflexes
21. Slit-lamp biomicroscopy
22. Undilated fundus biomicroscopy (if patient has large pupils)
23. Tonometry
24. Visual field screening (or analysis)
25. (If dilating the pupils): anterior angle assessment
26. Binocular indirect ophthalmoscopy (and fundus biomicroscopy)
27. Post-dilation tonometry
28. Discussion with the patient

surgery, previous retinal detachment, strong family history of retinal detachment and high myopia.³⁵

1.3.7 Test order

Box 1.1 provides a suggested order of testing for performing an efficient optometric examination. The exact testing to be performed will depend on the presenting complaint of the patient. Other test procedures should be inserted at appropriate times when the test result is not jeopardised by a preceding test and will not jeopardise tests that follow it in the eye examination. For example, refraction and pupil reflexes must be assessed prior to mydriasis and near muscle balance tests must be performed prior to cycloplegia. If the patient attends for an eye examination wearing their contact lenses, you may consider altering the order of your examination routine so that tests that can be completed with the lenses in situ are performed first (e.g. ophthalmoscopy, as issues associated with minimification or magnification of the fundus image due to ametropia are minimised), then the lenses are removed before the remainder of the tests are completed.

REFERENCES

- Greenhalgh T. *How to Read a Paper: The Basics of Evidence-Based Medicine*. 3rd ed. Oxford: Blackwell Publishing; 2006.
- Rudnicka AR, Owen CG. An introduction to systematic reviews and meta-analyses in health care. *Ophthalmic Physiol Opt* 2012;32:174–83.
- Rainey BB, Schroeder TL, Goss DA, Grosvenor TP. Inter-examiner repeatability of heterophoria tests. *Optom Vision Sci* 1998;75:719–26.
- Suttle CM, Jalbert I, Alnahedh T. Examining the evidence base used by optometrists in Australia and New Zealand. *Clin Exp Optom* 2012;95:28–36.
- Graham AM. Finding, retrieving and evaluating journal and web-based information for evidence-based optometry. *Clin Exp Optom* 2007;90:244–9.
- McAlinden C, Khadka J, Pesudovs K. Statistical methods for conducting agreement (comparison of clinical tests) and precision (repeatability or reproducibility) studies in optometry and ophthalmology. *Ophthalmic Physiol Opt* 2011;31:330–8.
- Calvin H, Rupnow P, Grosvenor T. How good is the estimated cover test at predicting the von Graefe phoria measurement? *Optom Vision Sci* 1996;73:701–6.
- Wong EP, Fricke TR, Dinardo C. Interexaminer repeatability of a new, modified prentice card compared with established phoria tests. *Optom Vision Sci* 2002;79:370–5.
- Casillas EC, Rosenfield M. Comparison of subjective heterophoria testing with a phoropter and trial frame. *Optom Vision Sci* 2006;83:237–41.
- Salchow DJ, Zirm ME, Stieldorf C, Parisi A. Comparison of objective and subjective refraction before and after laser in situ keratomileusis. *J Cataract Refract Surg* 1999;25:827–35.
- Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. *Surv Ophthalmol* 2000;44:367–408.
- West D, Somers WW. Binocular balance validity: A comparison of five different subjective techniques. *Ophthalmic Physiol Opt* 1984;4:155–9.
- Johnson BL, Edwards JS, Goss DA, et al. A comparison of three subjective tests for astigmatism and their interexaminer reliabilities. *J Am Optom Assoc* 1996;67:590–8.
- Hanlon SD, Nakabayashi J, Shigezawa G. A critical view of presbyopic add determination. *J Am Optom Assoc* 1987;58:468–72.
- Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307–10.
- Haegerstrom-Portnoy G, Schneck ME, Lott LA, Brabyn JA. The relation between visual acuity and other spatial vision measures. *Optom Vision Sci* 2000;77:653–62.
- Bailey IL, Bullimore MA, Raasch TW, Taylor HR. Clinical grading and the effects of scaling. *Invest Ophthalmol Vis Sci* 1991;32:422–32.
- Elliott DB, Bullimore MA, Bailey IL. Improving the reliability of the Pelli-Robson contrast sensitivity test. *Clin Vision Sci* 1991;6:471–5.
- Elliott DB, Bullimore MA. Assessing the reliability, discriminative ability, and validity of disability glare tests. *Invest Ophthalmol Vis Sci* 1993;34:108–19.
- Harper R, Reeves B. Compliance with methodological standards when evaluating ophthalmic diagnostic tests. *Invest Ophthalmol Vis Sci* 1999;40:1650–7.
- Lai TY, Leung GM, Wong VW, et al. How evidence-based are publications in clinical ophthalmic journals? *Invest Ophthalmol Vis Sci* 2006;47:1831–8.
- Burr JM, Mowatt G, Hernández R, et al. The clinical effectiveness and cost-effectiveness of screening for open angle glaucoma: a systematic review and economic evaluation. *Health Technol Assess* 2007;11:1–190.

23. Vernon SA. The changing pattern of glaucoma referrals by optometrists. *Eye* 1998;12:854–7.
24. Hutchings N, Hosking SL, Wild JM, Flanagan JG. Long-term fluctuation in short-wavelength automated perimetry in glaucoma suspects and glaucoma patients. *Invest Ophthalmol Vis Sci* 2001;42:2332–7.
25. Puhan MA, Steurer J, Bachmann LM, ter Riet G. A randomized trial of ways to describe test accuracy: the effect on physicians' post-test probability estimates. *Ann Intern Med* 2005;143:184–9.
26. Ang GS, Ng WS, Azuara-Blanco A. The influence of the new general ophthalmic services (GOS) contract in optometrist referrals for glaucoma in Scotland. *Eye* 2009;23:351–5.
27. Bowling B, Chen SD, Salmon JF. Outcomes of referrals by community optometrists to a hospital glaucoma service. *Br J Ophthalmol* 2005;89:1102–4.
28. Elmore JG, Barton MB, Mocerri VM, et al. Ten-year risk of false positive screening mammograms and clinical breast examinations. *N Engl J Med* 1998;338:1089–96.
29. Brett J, Austoker J. Women who are recalled for further investigation for breast screening: psychological consequences 3 years after recall and factors affecting re-attendance. *J Pub Health Med* 2001;23:292–300.
30. Keltner JL, Johnson CA, Quigg JM, et al. Confirmation of visual field abnormalities in the Ocular Hypertension Treatment Study. *Arch Ophthalmol* 2000;118:1187–94.
31. Amos JF. The problem-solving approach to patient care. In *Diagnosis and Management in Vision Care* (JF Amos, ed.), Boston: Butterworths; 1987. pp. 1–8.
32. Elliott DB. The problem-oriented optometric examination. *Ophthalmic Physiol Opt Suppl* 1998;18:S21–S9.
33. Siegel BS, Thompson AK, Yolton DP, et al. A comparison of diagnostic outcomes with and without pupillary dilatation. *J Am Optom Assoc* 1990;61:25–34.
34. Parisi ML, Scheiman M, Coulter RS. Comparison of the effectiveness of a non-dilated versus dilated fundus examination in the pediatric population. *J Am Optom Assoc* 1996;67:266–72.
35. Batchelder TJ, Fireman B, Friedman GD, et al. The value of routine dilated pupil screening examination. *Arch Ophthalmol* 1997;115:1179–84.
36. Bullimore MA. Is routine dilation a waste of time? *Optom Vision Sci* 1998;75:161–2.
37. Mackenzie PJ, Russell M, Ma PE, et al. Sensitivity and specificity of the optos optomap for detecting peripheral retinal lesions. *Retina* 2007;27:1119–24.
38. Cheng SC, Yap MK, Goldschmidt E, et al. Use of the Optomap with lid retraction and its sensitivity and specificity. *Clin Exp Optom* 2008;91:373–8.

COMMUNICATION SKILLS

DAVID B. ELLIOTT

2

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2.1 TURNING ANXIOUS PATIENTS INTO SATISFIED ONES

2.1.1 Patient satisfaction

Patient satisfaction is vital for a thriving optometric practice as it is associated with greater patient retention, increased patient referrals, greater profitability and lower rates of malpractice suits.¹ The medical research literature consistently indicates that patient satisfaction is linked with health care practitioners having good communication skills: being able to explain diagnoses, prognoses, treatment and prevention using clear, non-technical terms¹ and being honest, empathic and able to listen well and address patient concerns.²

2.1.2 Understanding patient anxiety

Poor patient satisfaction is linked with pre-consultation patient anxiety.³ A significant number of patients are anxious about attending for an optometric exam^{4,5} and particularly fear receiving 'bad news' of one form or another.⁵ Anxiety reduces patient-practitioner communication and causes reduced attention, recall of information and compliance with treatment.⁵ This limits the usefulness of the examination as an anxious patient is unlikely to provide a full case history and reveal all their visual problems, unlikely to attend appropriately to your instructions, could provide unreliable responses in the subjective refraction and

could easily misinterpret or forget what you said about their diagnoses and management plans. Possible reasons for patient anxiety include:

- (a) Being told they need glasses.³ This can be a worry for both pre-presbyopic⁶ and presbyopic patients⁴ who are often concerned about the effect on their appearance.
- (b) Fear of vision loss. Particularly true of elderly patients where eye disease is a greater risk.⁴ This could be due to the fact that a friend or family member has lost their vision due to eye disease and this could even have been detected at a routine visit to their optometrist.
- (c) Cost issues. Some patients are very worried about the potential cost of glasses and contact lenses^{4,6} and even that they will be 'sold' glasses that aren't necessary.
- (d) Fear of making a mistake. Some patients are worried about making mistakes during the subjective refraction part of the examination. This may be because they believe that a mistake on their part could lead to the provision of an incorrect refractive correction in their glasses and/or are worried about feeling foolish if they make a mistake (note that some patients can feel educationally inferior to the optometrist⁷).
- (e) Fear of increased ametropia. Young ametropes can worry that the increasing myopia or hyperopia will mean thicker and less attractive glasses. Vision-related quality of life has been shown to be reduced in pre-presbyopic spectacle wearers with high prescriptions.⁸
- (f) Being told that they cannot wear contact lenses any more. Young contact lens wearers typically report a better vision-related quality of life than spectacle wearers⁸ and some may worry about being told that they cannot wear contact lenses any more.
- (g) Adaptation problems. Many patients report concerns about being able to adapt to their new glasses.⁴
- (h) Fear of looking foolish. Some patients are very tentative about admitting some of their concerns about their vision in case they are made to look foolish by raising the issue. Concerns about vitreous floaters are a typical example of this.

2.1.3 Building a rapport: relaxing the patient

A good communicator will be able to relax an anxious patient and increase patient satisfaction with the eye exam.^{1,3} There are many ways to relax a patient and build a rapport and these include:

- (a) Provide information about the eye examination (via a leaflet or website, [section 2.6](#)) prior to the appointment as this can reduce anxiety and improve satisfaction with the consultation.^{3,9}
- (b) Provide a comfortable and welcoming setting in the practice waiting room. Comfortable chairs, a selection of magazines, some low level music, etc., can all help to relax the patient. Framed copies of your qualifications, either in the waiting room or the exam room, can provide reassurance to some patients.
- (c) Your attire is important and medical research suggests that patients prefer a formal, 'professional' appearance.¹⁰ This is linked with patients' trust and confidence, particularly if providing sensitive information in the case history.
- (d) First impressions count and some practitioners like to greet a patient by name and escort them to the examination room.
- (e) Beware of making the examination room frightening to the patient. For example, a poster containing a cross-sectional diagram of the eye can be very useful for explanation purposes, but one that portrays a variety of eye diseases is not likely to relax the patient!
- (f) Change the chair height to ensure you are at the same eye level as the patient.⁷
- (g) Some practitioners like to chat about non-clinical issues (weather, holidays, sports teams, parking, etc.) prior to the examination to help relax the patient. In this respect, it can be useful to make a note of any relevant information (a child's favourite sport, sports player, team, author; the patient's pets and their names, their children successes, etc.) to allow you to start a conversation at subsequent visits.
- (h) Your posture and style should be relaxed but attentive. Maintain regular eye contact and use the patient's name at appropriate times during the eye examination.
- (i) An open question is typically used to start the case history ([section 2.3.1](#)) as this allows the patient to tell you about any problems with their vision or glasses. A balance is required between allowing the patient plenty of time to discuss their problems and not rushing them but at the same time retaining control of the discussion. You need to ensure that the patient feels that you have fully listened and understood their problems and you may even need to allow the patient to talk about information that you know is not necessary from a diagnostic viewpoint. However, you also need to develop the skill of being able to interrupt an overly talkative patient without appearing rude.
- (j) Some patients are very shy and an open question provides little information and may make the patient feel uncomfortable. Closed questions can be useful at the beginning of the case history with such patients. An open question can be used later in the case history if the patient relaxes and conversation becomes easier.
- (k) Listening is a hugely important communication skill. It is vital that you have fully listened to the patient and understood their problems (e.g. Dawn et al.²). There are a variety of ways that indicate to the patient that you are listening and these include maintaining eye contact and demonstrating attention by nodding and/or using affirmative comments such as 'I see', 'I understand', 'OK, go on', etc. Listening is also indicated by using follow up questions to comments, such as asking about the location, onset, frequency, etc., of headaches when the patient indicates that they suffer with them. Finally, summarising the patient's problems at the end of the case history ([section 2.3.1](#), step 11) is a very useful way of indicating to the patient that you have listened to what they have to say and fully understand what problems they are having, whilst it also provides the patient with an opportunity to inform you if you have missed anything.
- (l) Provide a brief explanation to the patient of each test that you use during the eye examination. Suggested information, in lay terms, is provided for each test described in later chapters.

2.1.4 How to improve your communication skills

All students should gain adequate communication skills. You are taught which questions to ask during the case history, what instructions to give for each test, an explanation of why you are doing the test and what

to record. In clinics, you will be taught how to provide diagnoses, prognoses and management plans. How do you become a better communicator? You can obviously read about what they are. A brief summary is provided here and further reading is suggested (e.g., Ettinger⁷). Video recording your case history and/or eye examination can be a valuable tool and will particularly highlight your non-verbal communication skills. Review the video with a colleague and critique your listening skills, your tone of voice, your attentiveness and your eye contact. A helpful quality about communication skills is that you can learn them anywhere and from anybody. Obviously observing an optometrist or other health professional who is popular with patients could be particularly beneficial. You can also learn by experience so that any summer job that involves working with the general public can be beneficial. Indeed, when supervising in student clinics, it is very obvious from the level of communication skills which students have had jobs that involved working with the general public and which ones have not.

2.2 RECORD CARDS AND RECORDING

In the descriptions of clinical procedures in the following chapters, a subsection on recording is included in each case. It is essential that all test results (including the 'results' from case history) are recorded. If they are not recorded, subsequent legal analysis of the records will conclude that they were not performed. Clearly, it is important to write legibly on your record cards, for legal reasons and so that they can be read by colleagues who may examine the patient subsequently. Illegible record cards are a significant source of error in primary eye care.¹¹ Similarly, it is hugely important to ensure that record cards are stored in an efficient and organised manner.¹¹

2.2.1 SOAP

The format of record cards can vary hugely. Many include various designated areas for certain test results that are commonly performed. This is an attempt to save time, as you do not have to write down the test or procedure used, but merely the result. As students will typically use the database style of examination, university clinic record cards (e.g. [Figure 2.1](#)) tend to include the majority of tests performed. More experienced optometrists will tend to use the problem-oriented examination which uses the acronym SOAP for its record format.¹² The record card itself is a plain

white sheet. This reflects the fact that this style of examination is distinguished by its variability, so there is little point in making boxes for individual tests. SOAP stands for Subjective, Objective, Assessment, and Plan. The subjective information is that obtained from the case history and the objective information is the various test results obtained during the examination. The assessment and plan refer to the problem-plan list that is described in detail in a later section. These sections must 'close the loop' and link the assessment and plan back to the complaints of the patient.

2.2.2 Computer-based systems

Computer-based systems avoid the problem of illegible records and should reduce the likelihood of lost records (assuming appropriate backup arrangements), which are surprisingly common with paper records.¹¹ Systems vary widely and will continue to improve, but other advantages of current systems include that information from a previous record can be uploaded and then amended with information from the current examination (this can also be done for the right and left eyes); they can be linked to digital ocular photographs; the systems typically learn the information you input and subsequently provide it in drop-down lists and referral letters are easier to produce and print. Disadvantages include the inability to sketch various features (e.g. cataract and fluorescein staining patterns) if digital photography of both the external and internal eye is not available; getting used to different systems can be difficult for locum optometrists; going to a complete computer system means that some companies scan old paper records which can become more illegible by that process; copying information from previous records or the other eye can mean that you forget to put in details; drop down lists can become very long and it can be difficult to get an overall picture of a patient because of the fragmented nature of the information. The latter can mean it is difficult to highlight important details as with a paper record card you can write it in large capitals/highlighter on the front page.

2.3 THE CASE HISTORY

The case history is the cornerstone of an eye examination and contact lens check up. It puts you in the position of detective: there may be problems to discover and you must use all your skills of observation, listening, and questioning to identify them as completely as possible. Undoubtedly the case history can

THE EYE CLINIC: EXAMINATION RECORD CARD						Date:
Family name:		Other names:				Age 47
Address:		DOB:				
		NI no:				
		GP & surgery:				
Tel no:		Postcode:		Occupation/Dept:		
				Graduation year:		
Date last NHS test:		NHS eligibility		not		Evidence seen? ☐
CC: NV blur, "Needs longer arms", last 6/12. PC is ok, DV ✓ Never worn glasses or CLs. No h/a's, dip or other Sxs. OH - None. LEE - 4 yrs ago, Leeds D&A. FOH - None, no glaucoma or cataracts GH - good, no meds or allergies. LME - 1 yr ago, Dr Thomas FMH - none, no HBP or DM Px drives, PC - 4/24, 6/7, hobbies, reading and squash (no eye protection)						
Preliminary testing	sph	cyl	axis	prism	ADD	Details: No previous Rx
	R					
	L					
	Distance Vision/VA					Near Vision/VA
R 6/5 L 6/5					R N8 L N8 @40cm	
Muscle balance:			Convergence:		Motility:	
CT NMD, D 4° XOP, N			to nose		SAFE *	
PD: 63 / 60 @ 40						
Refraction	Objective:			Technique:		
	R) + 0.25 / -0.25 x 100			VA: 6/5	L) + 0.25 / -0.25 x 80 VA: 6/5	
	Subjective:			Technique: Binocular		
	R) + 0.50 / -0.25 x 105 VA: 6/5			L) + 0.25 / -0.25 x 70 VA: 6/5		
	Vertex Distance: 10 mm			Binocular Add: None		
	Tentative Reading Add. R) + 1.00 L) + 1.00			From ☒ Age ☐ WD ☐ Accom ☐ Other		
READING ADD @ 40 cm R) + 1.00 VA: N5			L) + 1.00 VA: N5 Range: 30 to 65			
Intermediate ADD @ cm R)			VA: L) VA: Range: to			
Binocular vision	Muscle balance:			Amplitude of Accommodation:		
	  4° XOP, M, Wing			3D OU		
	Technique: Moddox rod			Technique: push-down		
Other motor/sensory status:						

Fig. 2.1 A university clinic record form detailing a fictional young patient.

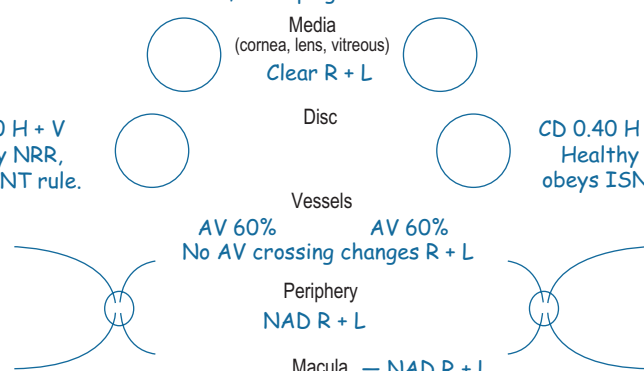
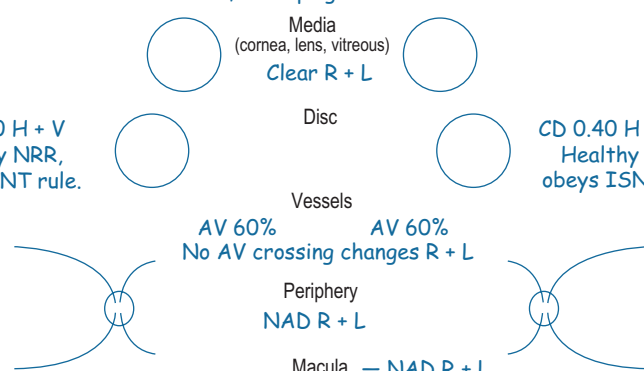
Ocular health	Tonometry: Time: 10:30 R) 15 L) 16 Instrument: Goldmann		Anterior angle: R) IV T L) IV T Technique: Van Herick																																					
	Pupils: D&C 3+, R+L -ve RAPD		Sensitivity to diagnostic drugs? ☐ YES ☒ NO Mydriatic used: Tropicamide 0.5% Post-dilation IOP: 16 T ₁₆																																					
Supplementary	R L S-lamp / Direct ? Anterior eye (lids, conjunctive, sclera, iris) NAD R + L, small pinguec nasal R+L  Media (cornea, lens, vitreous) Clear R + L CD 0.40 H + V Healthy NRR, obeys ISNT rule. Disc CD 0.40 H 0.35 V Healthy NRR, obeys ISNT rule. Vessels AV 60% AV 60% No AV crossing changes R + L Periphery NAD R + L Macula — NAD R + L Direct / Volk / BIO ?  Media (cornea, lens, vitreous) Clear R + L CD 0.40 H + V Healthy NRR, obeys ISNT rule. Disc CD 0.40 H 0.35 V Healthy NRR, obeys ISNT rule. Vessels AV 60% AV 60% No AV crossing changes R + L Periphery NAD R + L Macula — NAD R + L Direct / Volk / BIO ? (e.g. Visual fields, cycloplegic refraction, colour vision, contrast sensitivity) SITA - Fast: WNL R + L																																							
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		sph	cyl	axis	prism	ADD																																		
R	0.50	0.25	105		+																																			
L	0.25	0.25	70		1.00																																			
Student name and signature:		Supervisor's signature:		Suggested re-examination time: 24 months																																				

Fig. 2.1, Cont'd

differentiate an experienced clinician from a novice. It is common for clinical supervisors to have to ask several additional questions of a patient after a student has completed the examination. As a student, you should not worry about this, as you will improve with experience. However, never underestimate the value of history taking and how much there is to learn to be competent at it.

2.3.1 Procedure (Summary in [Box 2.1](#))

 See online video 2.1.

1. Make sure that the room lights are on before the patient enters the examination room.
2. Consider the patient's age (gender and ethnicity may also be important) as this can provide useful clues to what their problems might be given the known epidemiology of certain ocular problems. For example, a 47-year-old patient attending for their first eye exam for many years is likely to complain of presbyopic-related symptoms.
3. Observe the patient's stature, walking ability and overall physical appearance. Pay particular attention to any head tilt or obvious abnormalities of the face, eyelids and eyes that will require further investigation such as facial

Box 2.1 Summary of case history procedure

1. Determine the chief complaint. Use LOFTSEA or similar to collect all the appropriate information.
2. Spectacle and/or contact lens wear: full description, including quality of vision with them.
3. Symptom check: Check the following if not part of the chief complaint: headaches, eyestrain, pain or discomfort and diplopia.
4. Ask about the patient's ocular history, family ocular history and LEE.
5. Obtain general health information: All systemic diseases, medications, allergies, family medical history and LME.
6. Vocation, sports, hobbies, computer use and driving.
7. Summarise the case history.
8. Remember that a case history continues throughout the examination.

asymmetry, lid lesions, ptosis, epiphora, entropion, ectropion, a red eye or strabismus.

4. You should sit about 1 m from the patient at eye level. Your posture and style should be relaxed but attentive. Lean slightly forward towards the patient. Try to avoid long silences while writing notes and learn to write down answers in abbreviated form (see [Table 2.1](#)) as the patient is talking, while retaining intermittent eye contact.
5. Chief complaint (CC) or reason for visit (RFV): Determine the chief complaint by asking a very general open-ended question such as 'Do you have any problems with your vision or your eyes?' or 'Is there any particular reason for your visit, Mr Smith?'
6. In a patient who reports no problems to the question above and is attending for their regular annual/biennial examination, ask the following questions (see recording example in [2.3.3.a](#)):
 - (a) If the patient wears glasses (ask if you are unsure), you need a complete description of them. This may include:
 - (i) 'When do you wear your glasses?'
 - (ii) 'How is your distance vision in your glasses?' followed up by 'Do you feel it is as good as it was when you first got them?' This can be adapted to suit the patient. For example, a student could be asked 'Any problems reading from the whiteboard?' and 'Is everything clear on the TV?'
 - (iii) 'Any problems with reading with the glasses?'
 - (iv) 'How is your distance/near vision without your glasses?'
 - (v) 'How old are your glasses?'
 - (vi) 'How many pairs of glasses do you have?'
 - (vii) 'Where did you get these glasses from?'
 - (viii) 'How old were you when you first wore glasses?'
 - (ix) 'Do you have prescription sunglasses?'
 - (b) If you are unsure, ask if the patient wears contact lenses. If they do wear lenses, even if only occasionally, then you need a complete description of the contact lenses used:
 - (i) 'What type of lens are they?' (soft, gas permeable, toric, multifocal, etc., and brand if known)

Table 2.1 Abbreviations that could be used during the recording of a case history

Abbreviation	Stands for	Abbreviation	Stands for
Px (or Pt)	Patient	OK or ✓	Okay
Rx	Prescription/spectacles	Sxs	Symptoms
CC (or PC or RFV)	Chief complaint or Presenting complaint or Reason for visit	CLs	Contact lenses
		OH	Ocular history
		FOH	Family ocular history
DV	Distance vision	FMH	Family medical history
NV	Near vision	GH	General health
R	Right	HBP	High blood pressure
L	Left	DM	Diabetes Mellitus
RE (or OD)	Right eye	CVA	cerebrovascular accident
LE (or OS)	Left eye	cat	cataract
B (or binoc)	Binocular	AMD/ARMD	age-related macular degeneration
BE (or OU)	Both eyes	meds	Medication
$\bar{c}$ (or c)	With	Ung.	Ointment
$\bar{s}$ (or s)	Without	o.d.	once daily
1/7, 3/7	1 day, 3 days	b.i.d. (or b.d.)	Twice a day
1/52, 3/52	1 week, 3 weeks	t.i.d.	Three times a day
1/12, 3/12	1 month, 3 months	q.i.d.	Four times a day
H	Horizontal	p.r.n.	When needed
V	Vertical	q.h.	Every hour
H/as (or HA)	Headaches	LEE	Last eye examination
↑	Increase	LME	Last medical examination
↓	Decrease		

- (ii) If relevant (i.e. not single use lenses): 'How often do you replace your lenses?' and 'What care solutions do you use?'
- (iii) 'How long do you usually wear the lenses each day?' and 'How many days per week?' The first question can be confirmed by asking when they typically put their lenses on and when they typically remove them as average wearing times are typically underestimated.
- (iv) 'How many hours of comfortable wear do you get with your contact lenses?'
- (v) 'How is your vision with contact lenses and how does it compare with the vision you get with your glasses?' If the patient wears both glasses and contact lenses, you will have to ask about visual symptoms (i.e. distance blur, near blur, headaches, eyestrain, etc.) for both forms of correction.

- (vi) 'Are you having any problems with your contact lenses currently?'
 - (vii) 'When was your last contact lens aftercare and when is your next aftercare check scheduled for?'
 - (c) A patient who does not wear glasses or contact lenses should be asked about the clarity of the distance and near vision.
 - (d) Complete a symptom check by asking about the most common symptoms: Have you experienced any of the following: 'regular or severe headaches?', 'eyestrain?', 'double vision?', 'any pain or burning/discomfort in your eyes?', 'any flashes of light or floaters?', 'any other symptoms connected with your eyes or vision?'
7. Patient reporting visual symptoms (see recording examples in 2.3.3b).
With some patients, you may get a good description of their problem(s) during the discussion of the chief complaint with little prompting. However, you are unlikely to obtain all the information you require and so will have to ask some questions to 'fill-in-the-holes' of what the patient has told you. If you have not already been told, you must first find out whether the symptoms occur with or without the patient's glasses and/or contact lenses. If they have several pairs of glasses, you need to determine whether the symptoms are better in one pair compared to the others. Subsequent information required regarding the chief complaint is described below to provide a reasonable mnemonic **LOFTSEA** for students, rather than a logical question set and sequence for all symptoms and with experience you will likely ask questions in a different order. Some example questions are provided for symptoms of blurred distance vision, headaches and diplopia.
- (a) **L - Location/laterality.** Examples:
 - 'Is it more blurred in one eye or is it the same in both?'
 - 'In which part of the head is the headache located?' *For a frontal headache, ask 'Is it above one eye more than the other?'*
 - 'Is the double vision in all directions of gaze or just one?'
 - (b) **O - Onset.** Examples:
 - 'How did you first notice the blurred distance vision?'
 - 'When did the headaches start?'
 - 'How long have you had double vision?'
 - (c) **F - Frequency/occurrence.** Examples:
 - 'How often do you get headaches?' Prompt if the patient is unsure: 'Every day? Once a week? Once a month?', 'Are they any better on weekends?', 'Do they tend to occur at any particular time of day? Morning mainly or evening?'
 - 'How often do you get double vision?', 'How long does it last?', 'Does the double vision occur after a lot of reading or at anytime?'
 - (d) **T - Type/severity.** Examples:
 - 'Did the blurred vision start suddenly or gradually?' *If sudden vision loss, ask 'Was the vision loss partial or total?'*
 - 'Is it a throbbing, sharp or dull headache?'
 - 'Is the double vision one-on-top-of-the-other or side-by-side?'
 - (e) **S - Self-treatment and its effectivity:**
 - 'How have you coped with the blurred vision?' (possibly by squinting, sitting at the front of the class, sitting close to the TV, using ready readers, borrowing a family member's glasses, etc.)
 - 'Does anything make the headaches go away?' 'Do you take any painkillers for the headaches?'
 - 'Does the double vision disappear if you close one eye?'
 - (f) **E - Effect on the patient:**
 - 'How is your son's school work progressing?', 'Does it affect your hobbies or sports?', 'Is your poor vision affecting how well you can do your job?', 'Have you restricted your driving?', 'How well do you manage driving at night?'
 - 'How badly do the headaches affect you?', 'Have you been to see your GP about the headaches?'
 - (g) **A - Associated factors:** 'Are there any other symptoms associated with the problem?'
8. Completion of information gathering for a patient with a chief complaint.
Once details regarding the chief complaint have been gathered, you then need to ask about

visual issues not yet discussed (i.e. you complete the questions set in point 6). For example, if a patient has a chief complaint of headaches, once you have a complete description of the headaches and whether they are better with or without any glasses or contact lenses, you need to ask about their use of glasses and/or contact lenses, distance vision, near vision, eyestrain, pain or discomfort and diplopia. If a positive response to any of these questions is obtained, you then need to obtain a complete description.

9. Ocular history (OH) and family ocular history (FOH):
 - (a) If you do not already know, ask the patient when and where was their last eye examination (LEE).
 - (b) Ask whether the patient has had any previous eye injuries, infections, surgery or treatment. Follow up any positive responses by asking the patient how old they were at the time, who managed the condition and over what period and what treatment they received. For example, if a patient indicates they have amblyopia, discover the age they were diagnosed and whether and at what time they had an 'eye-patch', 'eye exercises', glasses or surgery.
 - (c) Family ocular history (FOH): An open-ended question such as 'Has anybody in your family had any eye problem or disease?' should be asked. This can be clarified by providing examples of common hereditary conditions (in lay terminology) for their age, gender and race if pertinent. For example, ask about any family history of cataract, age-related maculopathy and glaucoma for patients over 60, glaucoma for patients over 40, glaucoma for black (African American, African Caribbean) patients over 30, short-sightedness, squint or lazy eyes with children, colour vision for male patients attending their first exam.
10. General health information:
 - (a) 'How is your general health?' and add a follow-up question such as '... any high blood pressure or diabetes?' If you receive a positive response, ask the patient how long they have had the condition. For some conditions, such as diabetes and hypertension, ask whether the condition is well controlled.
 - (b) 'Do you take any medications?' If you receive a positive response, ask the patient how long the medication has been taken, the present dosage and the number of tablets taken per day.
 - (c) 'Any allergies?'
 - (d) Family medical history (FMH): Ask an open-ended question, clarified by examples, such as 'Has anybody in your family had any medical problem?' This can be clarified by providing examples of common hereditary conditions such as 'any diabetes or high blood pressure in the family?'
 - (e) Last medical examination (LME): Ask the patient when they last visited their physician and obtain the name of the physician.
11. Vocation, sports, hobbies, computer use and driving: Determine the patient's visual demands, including the safety hazards/ protection for the patient's vocation as well as their sports and hobbies. For presbyopic patients, you need to discover the distance used for reading and other near tasks and the use of any additional reading lights (e.g., anglepoise or goose-neck lights, etc.; section 4.14). Question whether they use a computer on a regular basis and determine approximate weekly usage. Determine whether the patient drives and whether they wear contact lenses or glasses when driving. It can be particularly useful to ask patients about contact sports (football, rugby, hockey), swimming, fishing and racquet sports and whether ametropic patients wear their glasses or contact lenses for these sports and activities, so that they can be advised appropriately (see [section 2.4.3](#)).
12. Summarise the case history: Summarise the pertinent information from the case history and allow the patient to clarify any misunderstanding on your part or to add any additional information that has been missed. For example, 'So, Mrs Wilson, the main reasons for your visit are that reading has become a little difficult, even with your glasses, and that you particularly want me to perform all the glaucoma diagnostic tests because your mother has glaucoma. Is that correct?'
13. Remember that a case history continues throughout the examination. Certain signs or

test results during the examination may suggest the need for further questioning.

2.3.2 Additional questions regarding public health issues

Increasingly optometry is becoming involved in public health issues, so that your case history may include questions regarding falls and cigarette smoking (section 2.3.4d). Elderly patients, particularly those with risk factors for falls, should be asked: 'Do you have any problems with falls at all?' or 'Have you had any falls in the last year?'

You may wish to ask all teenage and adult patients about cigarette smoking, but you should certainly ask patients with a family history or early signs of age-related cataract and macular degeneration: 'Do you smoke?' If the patient appears uncomfortable with you asking this question (or you do), you can indicate the reason for asking: 'Cigarette smoking is strongly linked with two major eye diseases' or similar. Follow-up questions of 'For how long?' and 'Typically how many per day?' can be used to determine whether they are a heavy or light smoker. These questions are probably best asked as part of the 'general health' section of the case history (point 9).

2.3.3 Recording

Both positive and negative patient responses must be recorded. Remember that from a legal viewpoint, if the response was not recorded the question was not asked. Abbreviations are essential to allow a sufficiently complete case history to be recorded, while retaining intermittent eye contact with the patient, which is required for good communication and building a rapport. Use standard abbreviations (Table 2.1) and avoid personal ones. Using the patient's own words, recorded in quotation marks, can be useful. Here are some examples:

- (a) Case Hx: 68-year-old Asian female (retired).
 RFV: Routine 2 yr exam. No problems. DV and NV good $\bar{c}$ Rx. Bifs, worn all time. No ha, eyestrain, pain, dip or other Sxs.
 OH: 1st wore bifs age 50, this Rx 2 yrs old.
 No other OH. Never worn CLs. LEE: 2 yr, Dr Armitstead, Otley. No FOH.
 GH. Type II DM for 15 yrs, Metformin 500 mg bid, well controlled; High BP for 15 yrs, Propranolol 100 mg, bid, well controlled, CU every 6/12; High cholesterol last 2 yrs, 'Statins' 40 mg od now under control; Aspirin

od, last 3 yrs to 'thin blood' and 'help avoid heart attack', CU every 6/12; Non-smoker and no history of falls.

- LME: 2/12, Dr Brownlee, Bramhope. No allergies, FMH: None. Hobbies: Walking, watching TV. No PC use. Doesn't drive.
 (b) 25-year-old Px. Caucasian. Secretary.
 CC: DV $\downarrow$ for driving, $\bar{c}$ CLs and $> \bar{c}$ specs, esp. @ night last 2/12, OD blur>OS. Better $\bar{c}$ squinting. NV $\bar{c}$ CLs and specs OK. No HA, dip, eyestrain, discomfort. No other Sxs.
 OH: Specs ~ 4 yrs old – not updated last EE 2 yrs ago. Worn soft CLs last 6 yrs: 6/7 and ~10/24. Comfortable for ~8/24 then sl. gritty. Monthlies brand X, multipurpose sol'n brand Y. Fitted by Dr Adams, Leeds. Last AC 18/12 ago. Overdue a check. No probs $\bar{c}$ CLs and no other OH. FOH: parents both myopic.
 GH = OK, no meds. No allergies. Non-smoker.
 LME: 12/12, Dr Campbell, Hull. FMH: pat grandfather has heart disease.
 Hobbies: Tennis, climbing. Uses PC ~ 5/24, 6/7.

2.3.4 Interpretation

The rationale behind the phrasing of some of the questions asked in the case history is provided below, in addition to their interpretation.

- (a) General health issues: A general question of 'how is your general health?' can be misleading because some patients think that systemic diseases are not relevant when they are borderline or are controlled by medication. It is better to follow up the initial question and give some examples of what is being specifically sought after, such as '... any high blood pressure or diabetes?' If you get a positive response to this question, you must ask the patient how long they have had the condition as ocular effects of systemic diseases are more likely the longer the patient has had the condition. For example, the duration of diabetes is a major risk factor for diabetic retinopathy.¹³ If the patient has diabetes or hypertension, ask how well the condition is controlled. The risk of diabetic retinopathy is greatly reduced with good glycaemic control in diabetic patients¹⁴ and by good blood pressure control in a patient with diabetes and hypertension.¹⁵ An alternative or additional question for a female who may be pregnant is to ask the patient if they see their physician or a practice nurse regularly (asking about the last medical exam helps in this

example). The medical history may indicate that you should particularly look for certain ocular disorders which manifest in certain systemic disease (most commonly diabetes) and whether it is safe to use certain diagnostic drugs such as phenylephrine.

- (b) Medications and adverse effects: It is important to ask patients whether they are taking any medication even if they indicate that their general health is fine. Patients may believe their general health is fine because it is controlled by medication. Patients may also be taking medications, but are unsure why because the medical diagnosis was not properly explained or was poorly understood. It is important to determine any medications that the patient is taking as some can have adverse ocular effects. For example, it is well known that beta-blockers prescribed for systemic hypertension can cause dry eyes which will have implications for successful contact lens wear and oral corticosteroids can cause posterior subcapsular cataracts. Typically, the higher the dosage of the drug and the longer the patient has been taking it, the more likely are adverse ocular effects. Therefore it is important to ask about the dosage and number of tablets taken per day and how long they have taken the drug. Note that patients may not consider 'over-the-counter' tablets, such as travel sickness pills, antihistamines, sleeping pills and painkillers as medications, so it can be useful to ask about them specifically, particularly with patients with unexplained symptoms. Similarly, female patients may not consider birth control pills to be medication, yet the drugs in these pills can have adverse ocular effects. Topical eyedrops for hayfever will have implications for contact lens wear and should be instilled at least 20 minutes before lens insertion.¹⁶
- (c) Occupation, sports and hobbies: This information is very useful in the eye exam when determining the near add. For example, you want to know whether the reading or near addition needs to provide clear vision for computer work, reading, sewing or all three. It is particularly important when providing advice to the patient about whether glasses or contact lenses should be worn for sports and hobbies and whether protective eyewear is necessary (see [section 2.4.3](#)).
- (d) Falls and cigarette use: A history of falls is an important risk factor for subsequent falls and patients at high risk of falling need to be identified as they should have more regular eye examinations, earlier cataract surgery and an altered spectacle prescribing strategy (section 4.15).¹⁷ Falls are very common in the elderly, with about a third of people over 65 falling at least once per year and they cause significant morbidity and mortality, with more than 80% of accidental deaths in this age group being due to falls.^{17,18} Other risk factors include being over 75 years of age, using more than three medications, antidepressant use, systemic conditions that reduce mobility, cardiac problems, etc.
- (e) Cigarette smoking is a significant preventable risk factor for both age-related macular degeneration and cataract and this is well known to optometrists.¹⁹ However, it would appear that some optometrists do not ask about cigarette smoking and/or do so at initial examinations only and that relatively few assess whether patients want to stop smoking and provide support for tobacco cessation.²⁰ This may vary across countries and it seems likely that optometrists would be more involved in this process where there are national social marketing campaigns linking blindness and smoking. Australia became the first country to include a picture warning label on cigarettes to link blindness and smoking in 2007 and this has increased levels of awareness compared to other countries that have not yet introduced these warning labels.²¹ Optometrists are in an excellent position to help people to stop smoking because fear of blindness is a potentially important motivator.²²
- (f) Problem-oriented exams for experienced clinicians: Once all the demographic and verbal information is accurately collected the experienced examiner should have a list of tentative diagnoses in mind for each of the identified problems. The remainder of the eye examination is based on testing to differentiate which of the tentative diagnoses is correct as well as gathering information so that each system (visual function, refractive and binocular systems and an ocular health assessment; Table 1.3) has been assessed.^{23,24} This means that the case history decides to some degree which tests/procedures you are going to perform. Some differential diagnoses, such as a red eye, may rely heavily on case history.

2.3.5 Most common errors

1. Not fully investigating the patient's chief complaint.
2. Not maintaining intermittent eye contact with the patient.
3. Not using standard abbreviations.
4. Not following through the case history in an organised manner.
5. Forgetting that the case history taking can continue throughout the examination.
6. Assuming the same information is still current from the previous case history.

2.4 DISCUSSION OF DIAGNOSES AND MANAGEMENT PLAN

Patients expect you to provide information about the cause of their visual problems, the prognoses and any management plans, all in a clear non-technical language.¹ See online videos 2.2 to 2.4.



2.4.1 Cause of the chief complaint: provide the diagnoses

1. Indicate the eye examination has finished and you wish to discuss your findings. You may put down your pen and even turn off the projector chart. Make eye contact with the patient and make sure that the patient is comfortable and attentive.
2. Introduce your diagnosis by reminding the patient of their symptoms and then link them with the diagnosis.
3. Explain what the ametropia or eye disease is in simple lay terms. Give the patient time to digest the information and encourage them to ask questions. Most computer-based optometry programmes include an atlas of photographs and diagrams to help you in this explanation.
4. Demonstrate any refractive correction changes to the patient. The effect of any refractive correction changes can be shown to the patient by alternatively showing the patient the vision (distance and/or near) obtained with their optimal refractive correction in a trial frame compared to their current glasses. This can be awkward and it can be easier, if there are negligible cylindrical changes (which is relatively common), to place appropriate spherical trial case lenses over the top of their current glasses to allow a comparison.

2.4.2 Offer reassurance where possible

1. If the cause of the chief complaint or other problem is not determined, then present your negative findings in a positive manner.²⁵ For example, non-ocular headaches: 'I do not believe that your headaches are due to a problem with your eyes or vision, Mr Wiggins. Your eyesight is excellent and there is no need for glasses/change in glasses; your eye muscles and focusing muscles are all working normally and are working well together and there is no sign of eye disease from any of the tests that I have performed.'
2. If the condition can be diagnosed, but no treatment is necessary, in addition to providing diagnosis and prognosis information in lay terms, provide reassurance to the patient that they were correct in attending for examination.²⁵ An example would be pingueculae.
3. If a patient's attendance for an eye examination was because of increased risk of a certain condition, but you found no problems, provide reassurance that you have performed the necessary tests and confirm the reasons that the patient should continue to regularly attend for examination. An example would be a patient with a family history of glaucoma that showed normal values for all assessments.
4. Reassurance can be particularly beneficial to a patient with non-organic/psychogenic visual loss (section 4.6.3).^{26,27} First, present your negative findings in a positive manner and highlight that there is no need for glasses, that the eye looks healthy and that the eye's muscles work well together. With children, follow this up by asking them whether anybody they know well wears glasses. This can be followed up by asking 'Do you want to wear glasses like your friend/dad?' A discussion with the parent can highlight that social problems at home or school can cause this condition and/or their child may be seeking extra attention (is there a new baby in the home?). In adults, you may also discuss the effects of stress, anxiety and mild depression on general health and that it can also cause visual loss. It can then be useful to ask the patient if there are any areas of stress in their life that could be causing the problems.²⁶ In all cases, finish by repeating the reassurance that the eyes are healthy and their vision is good and arrange to see them again in 3–6 months.

In many cases, this reassurance is all that is needed for recovery.^{26,27}

2.4.3 Discussion of treatment or further investigation

1. Present the various treatment options and/or referral options available, with advantages and disadvantages, and involve the patient in the decision of the most appropriate management.
2. Explain when the patient should wear glasses. Do not assume that the patient will understand when to wear them. For example, if a patient's chief complaint was distance blur when driving, it may not be enough to indicate that they should wear the glasses for driving and assume they understand that they can wear them for any other distance vision task. Indicate that the glasses could be used for TV, cinema and theatre, watching sports and when walking about outside if the patient wants to wear them for those tasks. In this regard, it is very important to inform a patient who drives without glasses whether they are legally allowed to do so.
3. Discuss possible adaptation problems (section 4.15). If making a relatively large change in refractive correction, particularly with older patients, warn them of possible adaptation problems. This is most important when making any cylinder changes, particularly with oblique cylinders. Take note of a patient's previous reaction to refractive correction change. It is better to overestimate the time that adaptation will take rather than underestimate the time.
4. Occupation, sports and hobbies: Most clinicians tailor spectacle lens information to match the patient's requirements, based on the patient's occupation and hobbies.⁴ Contact lens wearers are advised not to wear their lenses for swimming and to wear prescription swimming goggles, or to wear a single use lens with standard swimming goggles, and dispose of the lens immediately after swimming.²⁸ Ametropes who play contact sports benefit from using contact lenses as they usually do not wear their glasses while playing, although some football/soccer players do wear glasses and should be informed of protective eyewear.²⁹ Contact lenses will also have benefits for many other sports and leisure activities in that they can provide a wider field of view and they are not affected by fogging up or rain, for example. At the same time, contact lenses provide no eye protection, which can be important for sports that involve a high speed ball/puck and a stick, such as cricket, baseball, hockey (ice and field), lacrosse and squash.²⁹ The potential eye injuries from squash are particularly poorly known and appropriate protective eyewear should be recommended.³⁰ Finally, safety glasses may be needed for DIY enthusiasts and keen gardeners and fishing is made easier and more comfortable with polarised sunglasses.
5. Provide the patient with an appropriate information leaflet and website details, if available, and indicate that they can return or phone with any questions.
6. Instructions regarding contact lens care and maintenance and ocular disease management should be clear and unambiguous, with appropriate emphasis placed on the importance of procedures from a safety viewpoint.³¹ Written instructions at an easy reading level (age ~8–12 years) are essential.^{31,32} Checking compliance, explaining the benefits of compliant behaviours and repeating the instructions at follow-up visits can improve matters.^{31,33,34}

2.4.4 Giving bad news

With patients with an untreatable condition, be aware that giving bad news is known to be difficult for practitioners and can cause some clinicians to delay or avoid it or provide overly optimistic information.³⁵ Remember that although the information will be very sad for the patient, they need factual, honest information, provided empathically, to properly plan for the future. Points to consider include the following:³⁵

1. Indicate the eye examination has finished and you wish to discuss your findings. You may put down your pen and even turn off the projector chart. Make eye contact with the patient and make sure that the patient is comfortable and attentive. It can be helpful to have some tissues ready in case the patient becomes upset. It can be very useful to explain all this information to one or two family members if they are present³⁵ and if the patient is happy for you to do so.
2. Introduce your diagnosis by reminding the patient of their symptoms and then link them with the diagnosis. Explain what the eye disease

is in simple lay terms. Give the patient time to digest the information and encourage them to ask questions.

3. For a patient with macular degeneration, for example, you should explain that they will not go 'blind' and should keep their peripheral vision. However, at the same time you must be honest and do not attempt to avoid difficult questions or even 'sugar the pill'.³⁶ Indicate that their central, detailed vision that allows them to drive, read and see faces, is likely to get worse. Blunt statements such as 'I am afraid that there is nothing more that we can do' are not helpful. This may be correct for conventional treatment with glasses, but low vision aids may be helpful for a variety of tasks, household modifications can be made and smoking cessation can slow progression.^{37,38} Note that there is some debate regarding the usefulness of multivitamin supplements.³⁹
4. Empathic statements such as 'I know this is not what you wanted to hear. I wish the news were better' can be helpful.³⁵
5. You need to be aware of the possible emotional responses to such news. Various models have been proposed and a common model suggests stages of denial, anger, bargaining, depression and acceptance. These stages are not universal and some patients skip stages while others get 'stuck' at a particular stage. In the denial stage, patients will often seek a second opinion. You should not see this as a slight on your ability as a clinician and you may even suggest it to a patient who is openly in denial when you first tell them the news.
6. Explain the prevalence of the condition. This indicates that they are not alone. It can be useful at this point to discuss support groups and local agencies.
7. Discuss the availability of low vision aids and what help they could provide. In this respect, remember the stages of response to vision loss. Patients are unlikely to have the motivation to successfully use low vision aids when depressed. Do not give up on these patients. As and when they overcome the depression and accept their vision loss, low vision aids may usefully be provided.
8. Information leaflets and/or websites are particularly useful in these situations as the patient's shock at the initial news may mean that much of the remainder of your discussion is forgotten.

2.4.5 Prognosis

Explain what is the likely prognosis of the patient's condition(s) and highlight any possible adaptation problems. For example:

1. Explain what symptoms should disappear with the glasses and over what time period.
2. If appropriate (e.g., early myopes and presbyopes), explain that progression is expected and why. Advise young myopes that wearing their glasses will not make their eyes worse, it just gives them clearer vision. Also the patient should know that not wearing their glasses will not make their eyes worse.
3. Explain that a gradual reduction in unaided vision is expected in hyperopia with age. It is not uncommon for hyperopes to conclude that the glasses 'ruined their eyes' when their accommodation gradually declines and they need their glasses more and more often.
4. Be honest: If the condition is likely to get worse, you must inform the patient of this.

2.4.6 The next appointment

1. Finally, indicate to the patient when you would like to see them again.
2. If this is less than a standard time (typically 2 years or 1 year for children and the elderly), explain why.
3. Always inform the patient that if they have any problems with their vision or their eyes before that time, they should make an appointment to see you.

2.4.7 Most common errors

1. Using technical language and jargon to explain diagnoses and treatment plans.
2. Not explaining to myopes, hyperopes and presbyopes the likely progression of their condition.
3. Not explaining to patients when they should wear their glasses.
4. Not warning appropriate patients about possible adaptation problems.

2.5 RECORDING DIAGNOSES AND MANAGEMENT PLANS

It is important to record a summary of your diagnoses and suggestions to the patient. This is useful for several reasons:

1. It is important legally to document all your diagnoses, treatment suggestions, suggestions of referral, etc. Similarly, it provides valuable support when dealing with patients who return with complaints that you didn't provide advice regarding the management of a certain condition.
2. It ensures that you must review the case history and discuss each of the patient's symptoms and review the record card and deal with any significant findings.
3. In subsequent examinations of the same patient, a review of the problem-plan list provides a thorough and complete summary of the examination without having to read the whole record card.

2.5.1 The problem (or diagnosis)-plan list

The problem-plan list appears to be the only formal procedure that has been described to document a patient's diagnoses, treatment suggestions, further investigations necessary, comments made to the patient, etc. The problem-plan list is part of the problem-oriented examination. If a diagnosis cannot be made, then the patient's problems (i.e. symptoms and/or signs) should be listed and a list of the further investigations required to attempt to obtain a diagnosis should be listed in the plan section.

2.5.2 Procedure

1. List each separate diagnosis in a column. Do not list the individual symptoms and signs that allowed the diagnosis. Order diagnoses with the most important first.
2. If a patient has symptoms for which no diagnosis has been made, include the symptoms in the problem list. Similarly, include any abnormal signs or test results for which a diagnosis was not yet possible in the problem list. By this method any problems you do not immediately understand are highlighted and this prompts the consideration of further investigation.
3. For each problem, outline a plan or a series of actions to be taken in an adjoining column. Consider including the following forms of plan:
 - (a) Treatment plans.
 - (b) Further diagnostic procedures required.
 - (c) Counselling provided.

Table 2.2 Two examples of problem-plan lists

No.	Problem	Plan
(a)		
1	First time myope	Rx for b/board, TV, etc. Counselled to read and play $\bar{s}$ Rx. Coun. Re: Typical progression and future changes in myopia. Given leaflet.
2	Moderate protan	Coun. Re: Colour vision problems and effects on career choices. Given leaflet.
(b)		
1	Hyperope & presbyope	Rx PALs (used previously). Coun. Re: Typical progression of presbyopia. Given leaflet.
2	High IOP & large CD ratio	Appt. made for full threshold VFs and gonios. Coun. Re: Reason for extra tests.

Counselling is a fundamental element in patient management. Effective counselling requires that all diagnostic and therapeutic plans be clearly stated to the patient in terminology that they can easily understand.

2.5.3 Recording

Examples of problem-plan lists are provided in [Table 2.2](#).

2.5.4 Most common errors

1. Listing signs and symptoms rather than diagnoses, when diagnoses are possible.
2. Ignoring and not listing an unexplained symptom.
3. Not providing a complete plan list for a given problem. For example, the treatment may be identified but not the counselling or vice versa.

2.6 PATIENT INFORMATION PROVISION

Information regarding the eye examination, diagnoses and management plans should be available, ideally by a variety of mediums, most commonly leaflets and websites. They are viewed by patients as valuable additional information to that provided verbally and information that can be referred to at a future time and for discussion with family members.⁴⁰ They are seen to be particularly valuable given that patients are aware of the time limitations of clinical appointments. DVDs, e-mail and texts will likely become other ways that useful information can be provided to patients and may aid compliance of treatment and contact lens care.^{31,32,41}

2.6.1 Leaflet and website content

- (a) In addition to standard leaflets regarding myopia, hyperopia, astigmatism, presbyopia and the common eye diseases, patients would prefer more information on eye examination procedures and an explanation of prescriptions.⁴⁰
- (b) Patients do not want educational material, which is common in current leaflets and websites. They would prefer practical problem-solving information about how *they* could help to look after their eyesight.⁴⁰
- (c) Contact lens instruction leaflets that provide a rationale for various procedures and links with adverse outcomes may help compliance.^{31,33}

2.6.2 Leaflet and website style

- (a) Less jargon: Research has indicated that patients find the information in currently available information leaflets and websites to contain too much jargon, with a poor layout of diagrams and text and inadequate or irrelevant explanations.⁴⁰ Patients reported that leaflets and websites often included unexplained terms, such as 'accommodation' and 'macula', that were confusing, and that they relied on an excessively high level of previous knowledge.
- (b) Lay terms: Information provided should be interesting, concise and with simple explanations written in lay terms.^{31,40}
- (c) Sections: Different topics should be organised into clearly labelled sections so that patients can identify particular sections that they are interested in.

- (d) Diagrams: Diagrams should be provided in colour. Patients have reported that diagrams in currently available leaflets can be too small with difficult to read labels.⁴⁰ Patients appear to prefer a brief explanation of the function of different structures if included, rather than just labelling them.⁴⁰

2.7 REFERRAL LETTER OR REPORT

Letters of referral to medical personnel or specialist clinicians are required to provide information regarding the reason and urgency of referral. Reports may be required to a referring colleague, teacher, general physician, etc. The categories of patients that require a report may be covered by legal or contractual obligations.

2.7.1 Comparison of letter types

Structured referral sheets have a standardised format and various boxes to fill in. Structured referral sheets can save time and if well designed may reduce the possibility of the omission of pertinent information. Indeed, when combined with dissemination of guidelines from secondary care, they appear to improve the quality of referrals from primary care.⁴² However, non-specific optometry referral forms, such as the UK GOS18 form, can lead to the inclusion of irrelevant information and a lack of required details.⁴³ Referral forms specifically designed for commonly referred conditions, such as cataract and suspect open-angle glaucoma, particularly when supported by referral guidelines for such conditions, are likely to improve referral quality.⁴³ Structured referral sheets can lead to vital information being left off the referral, such as the optometrist's name and even the practice address.⁴⁴ Well-written referral letters are important to help develop a good relationship with secondary eye care personnel and increase the likelihood of feedback being obtained regarding referrals. A lack of feedback appears to be a significant problem in some areas,¹¹ and without it the optometrist cannot learn from the process and improve the quality and appropriateness of referrals.

2.7.2 Procedure for producing a personalised referral letter

As completing a structured referral sheet is somewhat self-explanatory, the procedure for producing an effective personalised referral letter is described.

1. Indicate to the patient that you will be sending a referral letter/report to another person or office. You should inform them of the reason for the referral or report.
2. Write the letter on headed notepaper that includes your practice address and contact information. The letter should ideally not be hand written, as this will make it less legible.
3. Include the date and the recipient's name and address at the top of the letter.
4. Begin the letter with the patient's name, address, date of birth (you may need to distinguish between several people with the same name and even between two people with the same name and address), appointment date and file number (if applicable).
5. Remember that the person you are writing to is likely to be very busy, so they want to read only essential information. Do not include information that is irrelevant to the referral as this could result in your letter not being read or being skim-read and misinterpreted.
6. A likely outline of a referral letter would be:
 - (a) Provide a diagnosis or tentative diagnosis if possible.
 - (b) Indicate the relevant symptoms and signs (if any)
 - (c) Indicate if there is any urgency in the referral.
 - (d) If appropriate, you might indicate what further investigations or treatment you believe to be necessary.
 - (e) Request a reply regarding the outcome of the referral. This may require the patient's written consent.
 - (f) Indicate if you have copied the letter elsewhere (typically to the patient's general physician).
7. If referring a patient because of cataract (the most common referral letter, see [Box 2.2](#)) also include:
 - (a) The effect of reduced vision on the patient's lifestyle.
 - (b) Their willingness to undertake surgery.
8. A likely outline of a report would be:
 - (a) Thank the referring person (if applicable).
 - (b) Indicate the relevant symptoms and signs.
 - (c) Provide a diagnosis or tentative diagnosis if possible.
 - (d) If a diagnosis is not possible, indicate which tests were performed and any pertinent results.

Box 2.2 Example of a referral letter

21 April 2013

Dr John Smith
Bradford Health Centre
Ilkely Road
Bradford

Re: Mrs Mary Patient, 20 Anyold Street,
Somewhere, Bradford. DOB 21-9-35.
File No. 1234. Appointment date: 20 April 2013.

Dear Dr Smith

Mrs Patient complains of great difficulty reading and sewing and is unable to see well when outdoors on a sunny day. She has nuclear and posterior subcapsular cataracts in both eyes with visual acuities of 6/9 in each eye. However, her visual acuities in glare conditions are 6/18 in both eyes and her Pelli-Robson log contrast sensitivity scores are right eye 1.05 and left eye 1.10 and these latter clinical assessments represent a fairer reflection of her functional vision. Both eyes, and particularly both maculae, otherwise appear healthy. I have explained the situation to Mrs Patient and the options open to her and she wishes to be considered for cataract surgery.

Yours sincerely

David B. Elliott PhD MCOptom FAAO

- (e) Indicate any management plan and the time of your intended follow-up appointment.
9. Make sure your spelling is accurate and grammar correct. Spelling and grammar checkers are available on all modern word processing packages.
10. Present the information at a level suitable to the recipient's knowledge. However, do not automatically assume that lay terms are appropriate in a letter to a non-medical person. It may be best to use the correct term with the lay term in brackets to avoid offence. For example, in a letter to a teacher, you may include a statement that 'David has myopia (short-sightedness) ...'
11. Sign the letter with your preferred title and qualifications.
12. Keep a copy of the letter for the patient's file. If the letter or report was not to the patient's GP/physician, you may be required to send them a copy. If it is not a requirement, it is usually good practice to do so.

Box 2.3 Example of a report

21 April 2013
 Ms Joan Smith
 Bradford Primary School
 Ilkely Road
 Bradford

Re: John Young, 20 Anyold Avenue, Somewhere,
 Bradford. DOB 27-8-93. File No. 4321.
 Appointment date: 20 April 2013.

Dear Ms Smith
 I saw John for his first eye examination today. He had no symptoms and his visual acuity was normal at 6/5 in both eyes. However, I found a problem with his colour vision in that John has deuteranopia (red-green colour deficiency) and will have difficulty differentiating between colours such as red, orange, yellow, brown and green. There are no effective treatments for this hereditary condition. I have discussed the restrictions that this will have on his future career with his family and have informed his GP as well as yourself. If you require any further information, please do not hesitate to contact me.

Yours sincerely
 David B. Elliott PhD MCOptom FFAO

2.7.3 Recording

The style and content of referral letters and reports is likely to vary widely in different countries and areas within a country and because of a variety of other factors. Given this proviso, examples of a referral letter and report are given in Boxes 2.2 and 2.3.

2.7.4 Most common errors

1. In a referral of a patient with cataract, failing to include information regarding the effect on a patient's lifestyle and their willingness to undertake surgery.^{43,44}
2. Not including the patient's written consent for release of medical information back to you.⁴⁴

REFERENCES

1. Dawn AG, Lee PP. Patient expectations for medical and surgical care: A review of the literature and applications to ophthalmology. *Surv Ophthalmol* 2004;49:513–24.
2. Dawn AG, Santiago-Turla C, Lee PP. Patient expectations regarding eye care: focus group results. *Arch Ophthalmol* 2004;121:762–8.
3. Court H, Greenland K, Margrain TH. Evaluating the association between anxiety and satisfaction. *Optom Vision Sci* 2009;86:216–21.
4. Fylan F, Grunfeld EA. Visual illusions? Beliefs and behaviours of presbyope clients in optometric practice. *Patient Educ Couns* 2005;56:291–5.
5. Court H, Greenland K, Margrain TH. Predicting state anxiety in optometric practice. *Optom Vision Sci* 2009;86:1295–302.
6. Pesudovs K, Garamendi E, Elliott DB. The Quality of Life Impact of Refractive Correction (QIRC) Questionnaire: development and validation. *Optom Vision Sci* 2004;81:769–77.
7. Ettinger ER. *Professional communications in eye care*. Boston: Butterworth-Heinemann; 1994.
8. Pesudovs K, Garamendi E, Elliott DB. A quality of life comparison of people wearing spectacles or contact lenses or having undergone refractive surgery. *J Refract Surg* 2006;22:19–27.
9. Sjoling M, Nordahl G, Olofsson N, Asplund K. The impact of preoperative information on state anxiety, postoperative pain and satisfaction with pain management. *Patient Educ Couns* 2003;51:169–76.
10. Rehman SU, Nietert PJ, Cope DW, Kilpatrick AO. What to wear today? Effect of doctor's attire on the trust and confidence of patients. *Am J Med* 2005;118:1279–86.
11. Steele CF, Rubin G, Fraser S. Error classification in community optometric practice – a pilot study. *Ophthalmic Physiol Opt* 2006;26:106–10.
12. Weed LL. Medical records that guide and teach. *New Engl J Med* 1968;278:652–7.
13. Moss SE, Klein R, Klein BEK. The 14-year incidence of visual loss in a diabetic population. *Ophthalmology* 1998;105:998–1003.
14. Shamoon H, Duffy H, Fleischer N, et al. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes-mellitus. *New Eng J Med* 1993;329:977–86.
15. Stearne MR, Palmer SL, Hammersley MS, et al. Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 38. *Br Med J* 1998;317:703–13.
16. Tabuchi N, Watanabe T, Hattori M, et al. Adsorption of actives in ophthalmological drugs for over-the-counter on soft contact lens surfaces. *J Oleo Sci* 2009;58:43–52.

17. Elliott DB. Falls and vision impairment: guidance for the optometrist. *Optom in Pract* 2012;13: 65–76.
18. Black A, Wood J. Vision and falls. *Clin Exp Optom* 2005;88:212–22.
19. Cockburn DM. Is it any of our business if our patients smoke? *Clin Exp Optom* 2005;88:2–4.
20. Kennedy RD, Spafford MM, Schultz ASH, et al. Smoking Cessation Referrals in Optometric Practice: A Canadian Pilot Study. *Optom Vis Sci* 2011;88: 766–71.
21. Kennedy RD, Spafford MM, Behm I, et al. Positive impact of Australian ‘blindness’ tobacco warning labels: findings from the ITC four country survey. *Clin Exp Optom* 2012;95:590–8.
22. Sheck LH, Field AP, McRobbie H, Wilson GA. Helping patients to quit smoking in the busy optometric practice. *Clin Exp Optom* 2009;92:75–7.
23. Amos JF. The problem-solving approach to patient care. In: *Diagnosis and Management in Vision Care* (JF Amos, ed.). Boston: Butterworths; 1987. pp. 1–8.
24. Elliott DB. The problem-oriented examination’s case history. In: Zadnik K, editor. *The Ocular Examination: Measurements and Findings*. Philadelphia: WB Saunders; 1997.
25. Blume AJ. Reassurance therapy. In: *Diagnosis and Management in Vision Care* (JF Amos, ed.). Boston: Butterworths, 1987. pp. 715–8.
26. Lim SA, Siatkowski RM, Farris BK. Functional visual loss in adults and children patient characteristics, management, and outcomes. *Ophthalmology* 2005;112:1821–8.
27. Muñoz-Hernández AM, Santos-Bueso E, Sáenz-Francés F, et al. Nonorganic visual loss and associated psychopathology in children. *Eur J Ophthalmol* 2012;22:69–73.
28. Wu YT, Tran J, Truong M, et al. Do swimming goggles limit microbial contamination of contact lenses? *Optom Vision Sci* 2011;88: 456–60.
29. American Academy of Pediatrics, Committee on Sports Medicine and Fitness, American Academy of Ophthalmology, Eye Health and Public Information Task Force. Protective eyewear for young athletes. *Ophthalmology* 2004;111:600–3.
30. Eime R, Finch C, Wolfe R, et al. The effectiveness of a squash eyewear promotion strategy. *Br J Sports Med* 2005;39:681–5.
31. McMonnies CW. Improving contact lens compliance by explaining the benefits of compliant procedures. *Cont Lens Ant Eye* 2011;34:249–52.
32. Shukla AN, Daly MK, Legutko P. Informed consent for cataract surgery: patient understanding of verbal, written, and videotaped information. *J Cataract Refract Surg* 2012;38:80–4.
33. Claydon BE, Efron N. Non-compliance in contact lens wear. *Ophthalmic Physiol Opt* 1994;14:356–64.
34. Edmunds B, Francis PJ, Elkington AR. Communication and compliance in eye casualty. *Eye* 1997; 11:345–8.
35. Baile WF, Buckman R, Lenzi R, et al. SPIKES-A six-step protocol for delivering bad news: application to the patient with cancer. *Oncologist* 2000;5:302–11.
36. Hopper SV, Fischbach RL. Patient-physician communication when blindness threatens. *Patient Educ Couns* 1989;14:69–79.
37. Binns AM, Bunce C, Dickinson C, et al. How effective is low vision service provision? A systematic review. *Surv Ophthalmol* 2012;57:34–65.
38. Neuner B, Komm A, Wellmann J, et al. Smoking history and the incidence of age-related macular degeneration – results from the Muenster Aging and Retina Study (MARS) cohort and systematic review and meta-analysis of observational longitudinal studies. *Addict Behav* 2009;34:938–47.
39. Evans JR, Lawrenson JG. Antioxidant vitamin and mineral supplements for preventing age-related macular degeneration. *Cochrane Database Syst Rev* 2012;6:CD000253.
40. Fylan F, Grunfeld EA. Information within optometric practice: comprehension, preferences and implications. *Ophthalmic Physiol Opt* 2002;22:333–40.
41. Armstrong AW, Watson AJ, Makredes M, et al. Text-message reminders to improve sunscreen use: a randomized, controlled trial using electronic monitoring. *Arch Dermatol* 2009;145:1230–6.
42. Akbari A, Mayhew A, Al-Alawi MA, et al. Interventions to improve outpatient referrals from primary care to secondary care. *Cochrane Database Syst Rev* 2008;4:CD005471.
43. Davey CJ, Green C, Elliott DB. Assessment of referrals to the hospital eye service by optometrists and GPs in Bradford and Airedale. *Ophthalmic Physiol Opt* 2011;31:23–8.
44. Lash SC. Assessment of information included on the GOS 18 referral form used by optometrists. *Ophthalmic Physiol Opt* 2003;23:21–3.

ASSESSMENT OF VISUAL FUNCTION

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3.1 DIFFERENTIAL DIAGNOSIS INFORMATION FROM OTHER ASSESSMENTS

During a problem-oriented examination, a list of tentative diagnoses is made during the case history and this is used to determine which particular tests are likely to be useful to help differential diagnosis. The tentative diagnosis list is then updated after consideration of the results from each test of the eye examination. A brief introduction to some of the relevant information to the assessment of visual function provided in the case history and assessments of other systems is provided.

3.1.1 Symptoms

Symptoms of blurred vision or an inability to see well enough for certain tasks (reading the whiteboard, schoolbooks or a newspaper, watching TV, driving, etc.) all suggest reduced vision due to ametropia or ocular disease. These symptoms should be explained

by reductions in visual acuity and/or contrast sensitivity. If a patient has symptoms of poor vision, but the visual acuity is normal, contrast sensitivity and visual fields should be measured. Symptoms including unexplained headaches, unexplained visual acuity or contrast sensitivity loss, positive or scintillating scotoma, bumping into things on one side and symptoms consistent with neurological disease, such as cluster headache, acquired migraine, dizziness, tingling of limbs all suggest the need for visual field testing. Obviously if a patient complains of colour vision changes, their colour vision should be assessed.

3.1.2 Ocular, family and medical history

The ocular history may indicate an ocular condition that requires monitoring using visual acuity, contrast sensitivity, colour vision and/or visual fields, such as cataract or glaucoma. The family history may indicate a hereditary condition, such as open-angle glaucoma, that should be carefully checked using visual field assessment. The medical history could indicate a systemic condition that requires particular assessment, such as diabetes, or systemic medication that could affect some aspect of vision, such as chloroquine.

3.2 DISTANCE VISUAL ACUITY

3.2.1 When should distance visual acuity be measured?

Visual acuity (VA) is a measure of the patient's ability to resolve fine detail. It is the most commonly used measurement of visual function you will make. Distance VA is used to assess the adequacy of spectacle corrections and as a key indicator of ocular health. VA is also used to assess a person's fitness to drive or enter into some professions such as the police force and to enable registration as a partially sighted or blind person. The need to measure VA accurately is obvious.

There are three principal measures of VA:

- Unaided VA, often called vision.
- Habitual VA, with the patient's own spectacles.
- Optimal VA, with the best refractive correction, i.e. after subjective refraction.

VA after objective refraction is also often recorded. Either vision and/or habitual VA should be measured immediately after the case history for legal reasons, to document the VA level prior to your examination. Habitual and optimal distance VA are routine measurements. Measuring distance unaided VA (vision) is optional, and should be measured with patients who:

- do not wear spectacles;
- have lost/broken their spectacles so that you cannot measure habitual VA;
- do not wear spectacles for some distance viewing tasks (this information must therefore be obtained in the case history);
- require the information for a report;
- wear their spectacles all the time for distance and yet you suspect they may not need to (does the young low hyperope need to wear the spectacles for distance tasks?)

3.2.2 LogMAR versus Snellen

LogMAR visual acuity (VA) charts (Figure 3.1) use the design principles suggested by Bailey and Lovie, including 0.1 logMAR progression of letter size from -0.3 to 1.0 logMAR (equivalent to 6/3 to 6/60 or 20/10 to 20/200), five letters per line, letters of similar legibility and per-letter scoring.¹ Snellen charts were devised by the German ophthalmologist Hermann Snellen in 1862 and have been widely used ever since. There is not a standard Snellen chart and the letter size

sequences, number of letters and/or numbers, varieties of letters, etc., vary from manufacturer to manufacturer. They typically contain one letter at a VA level of 6/60 (20/200; 0.1 logMAR) and increasing number of letters at smaller letter sizes with a typical bottom line of about 6/5 or 20/15 (~ -0.1 logMAR).

The majority of Snellen charts have only one 6/60 or 20/200 letter, two 6/36 or 20/125 letters and three 6/24 or 20/80 letters. LogMAR charts typically have five letters on each of these lines and additional lines of letters at 6/30 or 20/100 (0.70 logMAR) and 6/48 or 20/160 (0.90 logMAR). Most logMAR charts have a 'bottom line' of -0.3 logMAR (6/3 or 20/10), whereas many Snellen charts have a bottom line of 6/5 or 20/15 and thus provide truncated data given that the average visual acuity of a young adult is about 6/4 (Table 3.1).²

LogMAR charts are widely recognised as providing the most reliable and discriminative VA measurements and are standard for clinical research or clinical trials of ophthalmic devices or drugs.^{3,4} Visual acuity measurements using a logMAR chart have been shown to be twice as repeatable as those from a Snellen chart and over three times more sensitive to inter-ocular differences in VA and therefore substantially more sensitive to amblyopic changes for example.^{3,5} The Bailey-Lovie or ETDRS charts are the most commonly used logMAR charts for adults and the Glasgow Acuity Cards (commercially available as the Keeler logMAR crowded charts) have been designed specifically for children.^{4,5}

Many Snellen charts do not contain lines of small letters and are truncated to 6/4, 6/4.5, 6/5 or even 6/6. For some patients, this takes the approach of measuring 'distance vision adequacy' (i.e. determining whether distance VA is adequate for a patient's daily needs, similar to the approach used for near VA) rather than distance VA (a threshold measurement). This makes the detection of slightly reduced VA due to eye disease or uncorrected refractive error in patients with good VA impossible. For example, if your chart is truncated to 6/5 or 20/15, you will not be able to detect a VA loss from 6/3 (or 6/4) to 6/5 or from 20/10 to 20/15.

The major disadvantage of logMAR charts is that although they are available in printed, and projector chart form, they are not as widely available as Snellen charts. However, this is slowly changing. In particular, logMAR VA measurements are being promoted on computer-based visual assessment systems. The new generation of flat panel displays appear especially useful as they are light (easy to wall mount), have excellent resolution, luminance and contrast

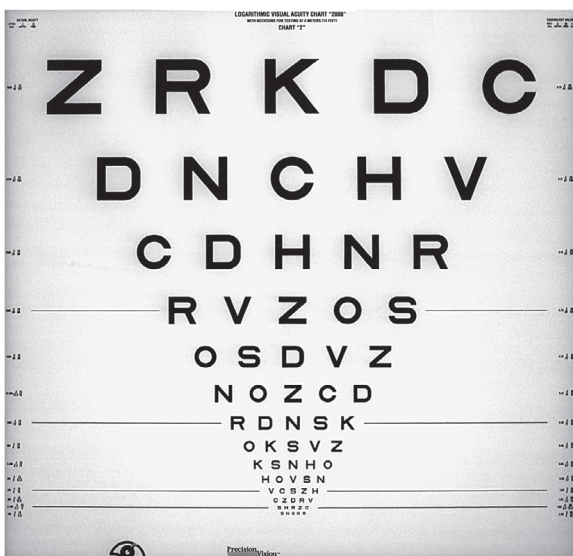


Fig. 3.1 A logMAR visual acuity chart.

Table 3.1 Normal age-matched visual acuity data for various notations. The average is shown with 95% confidence limits in brackets

Age (years)	LogMAR	VAR	Snellen (metric)*	Snellen (imperial)*	Decimal
20–49	–0.14 (–0.02 to –0.26)	107 (101 to 113)	6/4.5 (6/6 to 6/3)	20/15 (20/20 to 20/10)	1.4 (1.0 to 1.8)
50–59	–0.10 (0.00 to –0.20)	105 (100 to 110)	6/5 (6/6 to 6/4)	20/15 (20/20 to 20/12)	1.25 (1.0 to 1.6)
60–69	–0.06 (0.04 to –0.16)	103 (98 to 108)	6/5 ^{–2} (6/6 ^{–2} to 6/4)	20/15 ^{–2} (20/20 ^{–2} to 20/12)	1.15 (0.9 to 1.45)
70+	–0.02 (0.08 to –0.12)	101 (96 to 106)	6/6 (6/7.5 to 6/4.5)	20/20 (20/25 to 20/15)	1.0 (0.8 to 1.3)

**Numbers rounded for simplification.*

and are flicker-free. VA measurements on these systems have the advantage of allowing randomisation of letters, calculation of VA scores and conversion of VA into different notations. One practical disadvantage of printed panel logMAR charts is that patients may not be able to see the 'bottom line' of the chart (–0.3 logMAR, 6/3, 20/10). If they have been used to having their VA measured on a truncated VA chart and being able to see the bottom line, this may upset some patients. You should explain that the new chart includes lines with smaller text than the old one ('this new bottom line is just for superman/superwoman') and indicate, or even highlight, the 6/6 (20/20) line.

Snellen charts have a major advantage at present in that they are widely available and Snellen notation of VA is universally understood. From a practical viewpoint, these charts can generally be produced in a smaller format as considerably fewer large letters are presented and this allows easier display on projector systems and the easy addition of other targets such as a duochrome and spotlight, etc., to wall charts. The charts provide a good target for refraction of patients with good VA as the number of lines between approximately 20/15 to 20/40 (6/5 to 6/12) is similar to logMAR charts and these lines typically have as many, if not more letters than logMAR charts. Although the truncation of Snellen charts (to say 6/5 or 20/15 when some patients can see 6/3 or 20/10) can be a disadvantage, it can speed up the measurement and allows most patients to read your 'bottom line'.

3.2.3 Procedure

See online video 3.1.



1. Ensure the chart is at the appropriate distance and is calibrated correctly.
2. Leave the room lights on and illuminate the chart. The luminance of the chart should be between 80 and 320 cd/m². Seat the patient comfortably with an unobstructed view of the test chart. You should sit in front and to one side of the patient in order to monitor facial expressions and reactions.
3. If you are going to measure both vision and habitual VA, measure vision first to avoid memorisation. To measure vision, ask the patient to remove any spectacles. To measure habitual visual acuity, ask the patient to put their distance vision spectacles on.
4. Measure the visual acuity of the 'poorer' eye first, if a poorer eye is known from previous records or from the case history (to avoid a patient memorising the letters seen with the better eye and giving a false visual acuity with the poorer eye. Note that this can be avoided with computer-based charts by randomising the letters prior to measurement). Otherwise, measure VA in the right eye first.
5. Explain what measurement you are about to take. This can be as simple as 'Now we shall find out what you can see in the distance'.

6. Instruct the patient: 'Please cover up your left/right eye with the palm of your hand/this occluder'. If using the patient's hand, make sure that the palm is being used as otherwise the patient may be able to peek through their fingers. Some clinicians prefer to hold the occluder over the patient's eye themselves to ensure it is properly occluded.
7. Ask the patient: 'Please read the smallest line that you can see on the chart' or similar.
8. Continually monitor the patient's facial expressions and head position. Do not permit the patient to screw their eyes up or look around the occluder or through their fingers.
9. Once the patient has reached what they believe are the smallest letters they can see, they should be pushed to determine whether they can see any more. Use prompts such as 'Can you see any letters on the next line?' or 'Have a guess. It doesn't matter if you get any wrong'. Some patients are more cautious than others and only indicate those letters that they can see easily and clearly. Unless you push patients to guess, you could obtain different VA results depending on how cautious your patient is. Ideally, you should stop pushing patients to read more if they make four or more mistakes on a line of five letters.⁶
10. If the patient cannot see the largest letters on the chart, ask them to move closer to the letter until two or three lines can be seen (or use a printed panel chart at a reduced distance). The distance at which this occurs should be noted. This is a more accurate assessment than determining the position that the patient can 'count fingers'.⁷ If the patient cannot see the letters even at the closest test distance, use the following test sequence. Stop at the level at which the patient can accurately respond.
 - (a) Hand movements (HM) @ Y cm: The patient can see a hand moving from a certain distance. Some computerised VA tests can provide accurate measurements down to the hand movements level and these should be used when available.⁷
 - (b) Light projection (Lproj.): The patient can report which direction light is coming from when you hold a penlight about 50 cm away. Ask the patient to point to the light and note the areas of the field in which the patient has light perception.
 - (c) Light perception (LP): The patient can see the light but not where it is coming from. If



Fig. 3.2 Visual acuity charts designed for use with children.

they cannot see light, the vision is recorded as no light perception or NLP.

11. Record vision/VA.
12. Repeat measurements for the other eye and binocularly.

3.2.4 Alternative procedures to assess VA in children

Amblyopia can be missed if single letters are used rather than a letter chart because of the lack of contour interaction. Ideally logMAR-based charts with contour bars at the end of lines, such as the logMAR crowded charts, should be used when measuring VA in children (Figure 3.2).⁸ The logMAR crowded charts have been shown to be over three times more sensitive to interocular differences in VA than single letter Snellen charts and therefore substantially more sensitive to amblyopic changes.⁵ Crowded and standard and logMAR charts can even be used in children who do not know their letters by providing them with a key card that includes a selection of the letters from the chart. You then point to a letter on the chart and ask the child to identify the letter on their key card. For children that are unable to use a key card, charts are now available in logMAR format that include pictures rather than letters (Figure 3.2), such as the Kay crowded picture test, which has been shown to provide comparable results to the logMAR crowded charts.⁹

3.2.5 Adaptation of VA measurement with older patients

A hyperopic shift is common in older patients and some varifocal wearers adapt to this change by

habitually raising their chin to improve distance vision by viewing through the additional plus power in the intermediate section of the lens. This can be seen when assessing habitual VA as these varifocal wearers will raise their chin during measurements to improve VA. VAs should be measured through the distance portion of the lens. You should make a mental note that these patients will likely require additional plus (or less minus) power in their distance correction.

3.2.6 Recording for logMAR and Snellen charts

VA measurements can be scored in logMAR notation, using the visual acuity rating (VAR) score or converting scores to an equivalent Snellen value.

Computer-based systems will typically convert VA values for you. LogMAR or VAR could be used on your own record cards. However, equivalent Snellen values should generally be provided when writing referral letters and reports, as Snellen notation is universally understood, whereas logMAR is not at present. In all cases, it is preferable to score using a by-letter system rather than measuring the lowest line at which the majority of letters were correctly read as it provides more repeatable and discriminative measurements.¹⁰ Comparisons of various logMAR scores with Snellen and other recording notations are shown in Table 3.2.

The fact that logMAR VAs better than 6/6 or 20/20 are negative is counterintuitive. The VAR score provides a simpler method for scoring logMAR charts.

Table 3.2 Distance visual acuity conversion table

MAR*	LogMAR	VAR	Snellen (metric)	Snellen (imperial)	Decimal*
0.50	-0.30	115	6/3	20/10	2.0
0.63	-0.20	110	6/3.8	20/12.5	1.60
0.80	-0.10	105	6/4.8	20/16	1.25
1.00	0.00	100	6/6	20/20	1.00
1.25	0.10	95	6/7.5	20/25	0.80
1.60	0.20	90	6/9.5	20/32	0.63
2.0	0.30	85	6/12	20/40	0.50
2.5	0.40	80	6/15	20/50	0.40
3.2	0.50	75	6/19	20/63	0.32
4.0	0.60	70	6/24	20/80	0.25
5.0	0.70	65	6/30	20/100	0.20
6.3	0.80	60	6/38	20/125	0.16
8.0	0.90	55	6/48	20/160	0.125
10.0	1.00	50	6/60	20/200	0.10
20	1.30	35	6/120	20/400	0.05
40	1.60	20	6/240	20/800	0.025
100	2.00	0	6/600	20/2000	0.01

*Numbers rounded to simplify sequences.
MAR, minimum angle of resolution; VAR, visual acuity rating.

VAR = 100 – 50 logMAR. Therefore 0.00 logMAR = 100 VAR and each letter has a score of 1. For example if a patient reads all the letters down to the 100 row and gets one letter wrong on this row, their score is 99, two letters wrong 98, etc. If they read all of the letters on the 100 row and one letter on the row below, their score is 101, two letters on the line below 102, etc. A disadvantage of the VAR score is that it suggests that 100 (6/6) is normal VA, which is far from true for many patients with healthy eyes.²

The Snellen fraction is defined as:

Test Distance/Distance at which the letters subtend 5 min of arc.

Test distance can be provided in metres (typical 6m) or feet (typically 20 feet).

Snellen VA can be labelled in either decimal or conventional Snellen notation (see Table 3.2 for comparison).

Vision or visual acuity is recorded as the smallest line in which the majority of the letters are seen, irrespective of subjective blur. Errors are recorded by appending a minus one, two or three to the Snellen fraction or decimal notation. If additional letters are seen on the following line, the Snellen fraction or decimal notation can be appended by a plus (usually up to no more than 3). If the patient could not see the 6/60 letter at 6 m, but could at 2 m, record 2/60. Similarly if the patient could not see the 20/200 letter at 20 feet, but could see the 20/120 letter at 5 feet, record 5/120.

Vision or 'VA s Rx' or VAsc or Vsc all mean visual acuity measured without a correction.

VA c Rx or VAcc or Vcc all mean visual acuity measured with a correction and generally refer to the VA with the patient's spectacles. VA measured with the patient's contact lenses would typically be recorded as VA c CLs or similar.

VAs are recorded for the right eye (RE or OD), left eye (LE or OS) and binocular (BE or OU).

Examples (logMAR charts):

Vision.	RE: 0.78	LE: 1.20		(logMAR)
VA sc.	OD: 24	OS: 36		(VAR)
VA c Rx.	RE: -0.18 (6/4)	LE: -0.22 (6/4 ²)	BE: -0.26 (6/3 ²)	
VAcc.	RE: 118	LE: 114	BE: 122	(VAR)
Vcc.	OD: -0.20	OS: -0.18	OU: -0.24	(logMAR)

Examples (Snellen charts):

Vision.	RE: 6/36 ⁻¹	LE: 2/60	
VA sc.	OD: 20/80 ⁻¹	OS: 5/200	
VA c Rx.	RE: 6/5 ⁻²	LE: 6/5	BE: 6/5
Vcc.	OD: 20/15 ⁻¹	OS: 20/20 ⁻²	OU: 20/15
VAcc.	RE: 1.25 ⁻¹	LE: 1.00 ⁻³	BE: 1.25

This last example is given in decimal format, which is commonly used in parts of Europe. It should not be confused with logMAR.

3.2.7 Interpretation

Any deviation from normal age-matched results, as shown in Table 3.1, should be noted. Note that the average VA for patients less than 50 is about -0.14 logMAR (6/4.5, 20/15) and that 6/6 or 20/20 represents reduced VA for the vast majority of patients. 6/6 or 20/20 only becomes the average VA for patients over 70 years of age with healthy eyes. You must also check whether there has been any change in VA from the previous examination. In patients with normal or near normal VA, a significant change in VA is more than 0.1 logMAR or one line.^{5,11} Also note any interocular asymmetry of a line or more, or a binocular result that is worse than the monocular response.⁵

By comparing vision and optimal VA or habitual and optimal VA and using the one line of VA is equivalent to -0.25DS rule, an estimate of the mean spherical correction can be gained (section 4.1.5). If this estimate is widely different from the actual subjective refraction result, an error may be suspected and the subjective (and/or spectacle power) rechecked.

3.2.8 Most common errors

1. Allowing cautious patients to decide their acuity (i.e. not pushing them to guess).
2. Permitting the patient to screw their eyes up and improve their VA.
3. Permitting the patient to look around the occluder or through their fingers and view binocularly when measuring monocular VA.
4. Not recording the result immediately and guessing the result at the end of the examination.
5. Forgetting that patients could have VA better than your bottom line (of typically 6/5 or 20/15 with some Snellen charts).

3.3 NEAR VISUAL ACUITY (AND NEAR VISION ADEQUACY)

There are three principal measures of near visual acuity: unaided near VA or near vision; habitual near VA, with the patient's own spectacles and optimal near VA, with the best refractive correction. Habitual and optimal near VA are routine measurements in presbyopes and on all patients who complain of near vision problems. Measuring unaided near VA is optional, and should be measured with presbyopic patients who do not wear spectacles for all or certain near viewing tasks (this information must therefore be obtained in the case history) or if it is required for a

report. A reading distance should always accompany a near VA as N8 (1.0 M) at 40 cm (2.5 MAR, equivalent to 6/15, 20/50) is a totally different near VA to N8 (1.0 M) at 10 cm (10 MAR, 6/60, 20/200).

3.3.1 Comparison of different near vision charts

Near vision cards typically present sentences or paragraphs of words rather than isolated letters and can incorporate examples of near vision tasks such as sheet music, technical drawings and telephone directories (Figure 3.3). They are also now available on e-tablet and e-phones. There are five main types of notations used to measure near VA: logMAR, N-point, M-scale, equivalent Snellen, and Jaeger. LogMAR near charts (section 3.2.2) and should be used whenever an accurate, non-truncated measurement of near VA is needed and particularly when distance VA and near VA may differ, such as with multifocal implants/contact lenses

and patients with subcapsular cataract. Some near logMAR charts use isolated letters rather than words, but word charts are preferred, particularly in patients with conditions such as age-related macular degeneration as it relates better to reading performance and is typically worse than near letter VA.¹² N-point uses the Times New Roman font and is the standard test in the UK and Australia. It is based on the 'point size' used by printers and word processing packages on modern computers, in which 1 point = 1/72 inch (~0.353 mm). This can be a useful aid when indicating to a patient the level of vision that would be provided for computer use by new lenses. N8 is approximately equal to 1.0 M and this eight times conversion holds for all print sizes. M-units are widely used in North America and indicate the distance in metres at which the height of a lower case 'x' subtends 5 minutes of arc. A 1.0 M letter 'x' is therefore 1.45 mm high. Equivalent Snellen notation is a confusing notation, especially when near VAs are not measured at the standard 16': What does 20/20 near VA at 8' mean? In addition, near vision adequacy should indicate what patients can see at their own near working distance, not an arbitrary standard of 16' (working distances for reading in patients with normal vision range from 10' to 20'¹³). Cards using Jaeger notation should not be used as there is no standardisation of what J1 or J5, etc., means and different charts can give totally different sizes of print with the same J-value.

Many non-logMAR based reading charts are truncated as the smallest print sizes often provided are N5 (at 40 cm equivalent to ~6/9 distance VA) and 0.4 M (at 40 cm equivalent to ~20/20 distance VA) so that many patients could read sentences of text smaller than this if given the chance and a threshold is not measured. Thus 'near vision adequacy' is a more appropriate description of the measurements than near visual acuity. Near vision adequacy measurements have the added advantage that the measurement is quicker than a threshold measurement and most patients will be able to see the 'bottom line' of text. It is left to distance VA measurements, with its many advantages in this regard (fixed measurement distance, same letter format, letters of similar legibility, etc.) to provide an accurate measurement of a patient's resolution.

3.3.2 Procedure: logMAR near VA and M or N-notation near vision adequacy

See online video 3.2.

1. Sit in front and to one side of the patient in order to monitor facial expressions and reactions.

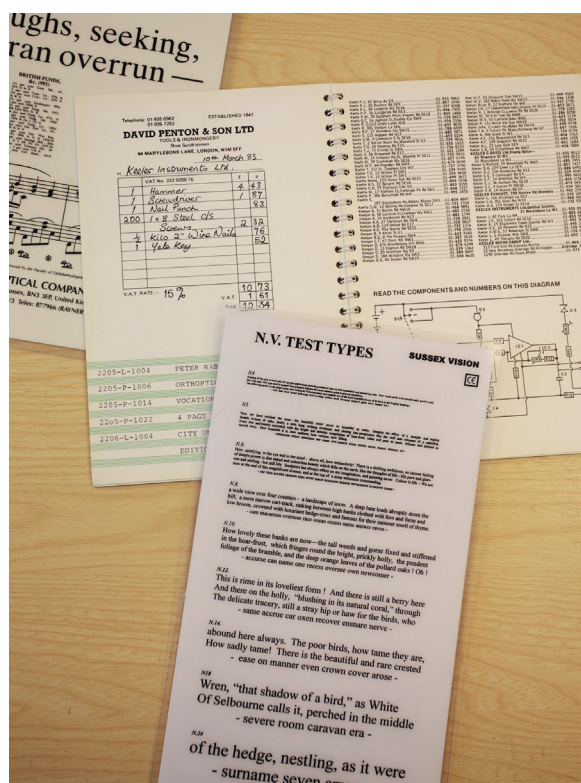


Fig. 3.3 A selection of near visual acuity charts.

2. Measurements should be made in similar lighting conditions to those the patient uses at home. Ask if the patient uses an anglepoise or goose-neck light at home, and if they do, use additional light for your near VA measurements.
3. Instruct the patient to place the near vision card (or e-tablet, e-phone or e-book reader) at their normal near working distance. Measure and record this distance.
4. Measure the near VA of the 'poorer' eye first, if a poorer eye is known from previous records or from the case history. Otherwise, measure the right eye first. Use an occluder or the patient's palm of their hand to cover the other eye. If using the patient's hand, make sure that the palm is being used as otherwise the patient may be able to peek through their fingers.
5. Explain to the patient what measurement you are about to take. This may be a simple: 'Now we shall find out what you can see at close distances'.
6. Instruct the patient to read the smallest paragraph they can.
7. Unless the patient can see the smallest print, push them to determine whether they can see anymore. Prompts such as 'Try and make out some of the words in the smaller paragraph' may be useful. Some patients are more cautious than others and only indicate those letters that they can see easily and clearly. Unless you push patients to guess, you could therefore obtain different near VA results depending on how cautious your patient is.
8. Repeat measurements for the left eye and binocularly.

3.3.3 Adaptation for older patients

You should have asked the patient whether they use additional lighting, such as an anglepoise or goose-neck light, to read in their home. If they do not and you subsequently find they cannot easily read N5 (or 0.4 M) at the end of the reading addition part of the refraction, they should be encouraged to obtain additional light for near tasks in their home. It is very useful to demonstrate how helpful such additional light can be. The main objective of people with vision impairment is to be able to read and a majority can be successfully helped in primary eye care using high reading additions, simple magnifiers and additional lighting.¹⁴ Note that although near VA levels can be associated with a range of near tasks (Table 3.3), the poorer near VAs are

threshold measurements (measurements of N5, 0.4 M and 20/20 may be truncated and not thresholds as discussed earlier) so that patients would not be able to read print of that size comfortably for any length of time. For example, to allow somebody to read newspaper print comfortably requires a near VA better than N8 or 1.0 M which is the typical size of newspaper print (Table 3.3) as a 'reading reserve' of 2:1 is needed and a near VA of N4 or 0.5 M.¹⁵

3.3.4 Recording

Note the working distance and then record the smallest paragraph size seen by the right and left eyes and binocularly. For approximate equivalents to other notations see Table 3.3. Some clinicians do not note the working distance unless it is different from the 'norm'. However, even patients with good vision present a wide range of normal working distances (22 cm to 50 cm for reading,¹³ and further away for computer use), and as stated earlier a reading acuity is meaningless without a working distance. It can also be useful to record the working distance(s) used to determine near VA with the patient's own spectacles to allow a comparison with the one used to determine the reading add. This can also be useful for comparison if patients return to your practice dissatisfied with the near vision in any new spectacles. These cases are often due to problems with working distance determination rather than an incorrect refraction.

Near vision or 'NVA s Rx' or NVAsc or NVsc all mean near visual acuity measured without a correction. NVA c Rx or NVAcc or NVcc all mean near visual acuity measured with a correction and generally refer to the VA with the patient's spectacles. Near VA measured with the patient's contact lenses would typically be recorded as NVA c CLs or similar. Near VAs are recorded for the right eye (RE or OD), left eye (LE or OS) and binocular (BE or OU) and should include the near working distance in cm or inches. If the patient can only read a paragraph slowly or with difficulty, include this information.

Examples:

NVA c Rx.	RE: 0.26	LE: 0.44 (logMAR) @ 40 cm	
Near vision.	RE: N14	LE: N12 (slowly) @ 40 cm	
NVAcc.	RE: 0.4 M	LE: 0.4M	BE: 0.4M @ 38 cm
NVcc.	OD: 20/20 (diff.)	OS: 20/20	OU: 20/15 @ 16'

3.3.5 Interpretation

When determining a reading addition, do not assume you have the correct add just because a patient can see the smallest text on your near chart such as N5, 0.4 M or 20/20. At 40 cm 0.4 M is equivalent to about 20/20

Table 3.3 Near visual acuity conversion table

logMAR	N-scale	M-units	Equivalent Snellen (imperial)	Equivalent Snellen (metric)	Common usage
−0.10	2.5	0.32	20/16	6/5	
0.00	3	0.40	20/20	6/6	Medicine bottle labels
0.10	4	0.50	20/25	6/7.5	Medicine bottle labels
0.20	5	0.60	20/30	6/9	Footnotes, bibles
0.30	6	0.75	20/40	6/12	Telephone directories
0.40	8	1.0	20/50	6/15	Newspaper print
0.50	10	1.2	20/60	6/18	Magazines, books
0.60	12	1.6	20/80	6/24	Books
0.70	16	2.0	20/100	6/30	Children's books
0.80	20	2.5	20/125	6/36	Large print books
0.90	25	3.2	20/160	6/48	Large print books
1.00	32	4.0	20/200	6/60	Sub-headlines
1.10	40	5.0	20/250	6/75	Sub-headlines

Numbers rounded to simplify sequences.

or 6/6 distance VA and N5 is equivalent to 6/9 or 20/30. Therefore, a patient could have reduced distance VA and still read N5, 0.4 M or 20/20 at near. Apart from this truncation effect, near VA can be expected to be similar to distance VA in most cases provided that the eye is accommodating normally or that the reading addition is correct. Notable exceptions include patients with multifocal intra-ocular lenses (IOLs) or wearing multifocal contact lenses or patients with posterior sub-capsular cataract. Patients with some eye disorders, such as amblyopia, age-related macular degeneration (ARMD) and macular oedema, can have significantly worse reading VA than distance VA and isolated-letter near VA.¹²

3.3.6 Most common errors

1. Not measuring or recording the test distance.
2. Not watching the patient to see if they are screwing their eyes up or looking at the chart with both eyes.
3. Measuring near VA with an additional light rather than the light levels typically used by the patient in their home or at work.

3.4 CENTRAL VISUAL FIELD SCREENING

Perimetry enables the assessment of visual function throughout the visual field, the detection and analysis of damage along the visual pathway, and the monitoring of disease progression. Central visual field analysis using standard automated perimetry (SAP) can be a lengthy procedure and quicker and simpler techniques can be used for screening the central visual field. Central visual field screening should *not* be performed on patients with minimal risk factors (such as patients over 40 years of age without other risk factors, high myopes) due to the problems of false positive results when testing healthy patients (section 1.2).¹⁶ For example, the most commonly used screening programme for Frequency Doubling Perimetry is the N-30-5. The −5 in the programme title indicates that there is a 5% chance of a positive test being from a patient with a normal visual field, so that specificity is set at 95%. With a POAG prevalence of about 2%; out of 1000 patients, 20 would have POAG, but 980 would be healthy and 5% of them (49) would have a positive test result (49 false positives, ~72% of those with a

positive result). Central visual field screening can be considered for patients who are asymptomatic with minor risk factors, such as patients with normal looking discs and intra-ocular pressures (IOP) but who have a primary family history of glaucoma, or who over 75 years, or over 30 years of age and black (African Caribbean, African American) where the prevalence of POAG is higher and false positives less of an issue (section 1.2).¹⁶ This is particularly true when positive tests are repeated. For patients exhibiting significant risk factors for glaucoma (abnormal appearing discs, high IOP), neurological disease, certain types of retinal disease or symptomatic patients, it is more appropriate to perform a central visual field analysis rather than use a screening technique.

3.4.1 Comparison of tests

The speed and accuracy of contemporary fast threshold estimation strategies have made several of the traditional screening techniques somewhat redundant. Fast thresholding strategies can produce an estimation of visual field sensitivity in a time (2.5–4 minutes per eye) similar to single stimulus, suprathreshold screeners. All of the fast central field analysis techniques have the advantage over suprathreshold screening techniques in that they are better able to detect early visual field defects, and can give an idea of defect depth and area. They have the disadvantage of taking longer than some suprathreshold techniques. They are similar in sensitivity and specificity for glaucoma as frequency doubling perimetry, but much better at detecting other types of visual field defect.^{17,18} When compared to techniques for full central field analysis they are quicker but less precise and with worse test-retest characteristics.¹⁹ The Humphrey Field Analyser (HFA) II, SITA Fast (Swedish Interactive Thresholding Strategy), Central 24-2 tests 58 locations over the central 25° in a 6° grid pattern that straddles the horizontal and vertical mid-lines, i.e. targets are located 3° either side of the mid-lines. In addition there are targets located on the nasal field between 25° and 30°. The SITA Fast, 24-2 programme rarely takes more than 3.5 minutes in a normal patient, and can be as quick as 2.5 minutes. Most modern perimeters have similar fast thresholding central visual field programmes.

3.4.2 Procedure

1. Explain the test and the reasons for performing the assessment to the patient.
2. When performing visual field screening pupils should be 3 mm or greater, whenever possible.

It is considered acceptable to perform visual field testing whilst a pupil is dilating, provided the pupil is at least 3 mm at the start of the test. Note the position of the upper lid (i.e. possible blepharoptosis or dermatochalasis) and consider taping if it is obstructing the field of view.

3. Reduce ambient illumination and turn on the instrument.
4. For most visual field screeners: Contact lens wearers should perform the visual field test in their lenses. This is particularly useful for aphakes and high ametropes. Full aperture trial case lenses should otherwise always be used. Reduced aperture lenses and masked cylindrical lenses (i.e. those with opaque masks running along the direction of the axis) can result in visual field artefacts. Similarly bifocal and progressive addition glasses and those with small frames should be avoided. Best sphere should be used for any cylinder less than 1.50 D. If the cylinder is greater than 1.50 D then place the appropriate spherical lens in the back cell of the lens holder and the cylindrical lens in the cell immediately in front of the sphere. You should use a translucent occluder if the patient has latent nystagmus.
5. Seat the patient at the instrument and adjust the height of the instrument to ensure patient comfort. Over-extension of the neck and a bent back with hunched shoulders and neck should both be avoided.
6. Select 'Central 24-2' and then subsequently select 'Change Parameters' and 'Test Strategy' to ensure 'SITA Fast' is used.
7. Select the eye to be tested first, and unless otherwise indicated select 'Right'.
8. Enter the patient ID. Let the patient adapt to the bowl luminance while entering the data. This is a very important but frequently overlooked procedure, as it ensures a consistent level of retinal adaptation over the duration of the test. Enter as much patient data as possible but always include patient name using the surname first, date of birth (this is often formatted as month-day-year) and patient file number if appropriate. It is often useful to enter the prescription lenses used and pupil size. It is also possible to enter a diagnostic code, VA, IOP and cup-to-disc ratio.
9. Occlude the left eye and give the patient the response button.

10. Place the patient's head in the headrest. Explain the test to the patient: 'I want you to keep looking at the yellow light in the middle of the bowl. When you see a light flashing off to the side of the yellow light, please press this button. There will be times during the test when you will not be able to see any lights flashing and this is normal. Remember to keep looking at the yellow light in the middle of the bowl all the time'.
11. Align the patient using the video eye monitor.
12. Ensure that the vertex distance of the trial lens is adjusted appropriately and the trial lens is centred in front of the eye.
13. Select 'Demo' for a naïve patient. Repeat until you are happy that the patient understands the procedure.
14. Select 'Start'.
15. Some models will have a Gaze Monitoring feature. Once initialised, select 'Start'.
16. Monitor fixation, check that the patient's forehead has remained touching the rest and encourage the patient throughout the test. Use phrases such as 'you are doing well', 'over half way now', 'keep looking straight ahead...that's good' or 'you've nearly finished'. Do not leave the patient unattended.
17. When the test is completed, store the result on disk then select 'Test Other Eye'. Occlude the patient's right eye and align the left eye with the appropriate correction having been placed in the lens holder.
18. When the left eye is completed, store the results on disk and print the results if required.

3.4.3 Recording

If no test locations are highlighted on the Total and Pattern Deviation probability plots then record 'SITA-Fast: WNL (within normal limits) R and L'. If there is a field defect, repeat the test, print and store both fields of both eyes and attach to the record card. SITA-Standard (or equivalent) could be used instead of SITA-Fast for the repeated field. The single field analysis of the repeated field should accompany any referral to the secondary eye care system. The single field analysis printout illustrates the data as an interpolated greyscale, raw data in decibels, and Total and Pattern deviation plots. It also summarises the field using the Glaucoma Hemifield Test, Global Indices, Reliability Indices, and Gaze Tracking plots (section 3.5.4).

3.4.4 Interpretation

These are interpreted in exactly the same way as the strategies for full central field analysis (section 3.5.4). It is important to be aware of the possible causes of artefact in cases where it would appear that a new defect has been detected, particularly in a patient with no previous experience of visual field screening or no history of field loss. A new defect is *not* a defect until it is repeated, 'if in doubt always repeat'. The effect of learning and fatigue can be dramatic.²⁰ Note that when the Glaucoma Hemifield Test classifies the field as having a 'general reduction of sensitivity', the Mean Defect/Deviation is abnormal and/or the Total Deviation probability plot shows a majority of test locations as being outside of normal limits, care should be taken when interpreting the results. There is usually an obvious clinical reason, with the most likely association being with cataracts or small pupils.

3.4.5 Most common errors

1. Using an inappropriate spectacle or lens type.
2. Poorly aligning the patient.
3. Providing poor patient instruction: It is worth investing time to ensure that the naïve patient understands what is expected of them. If necessary, repeat the test until you are satisfied that the patient has performed adequately.
4. Failing to encourage and communicate with the patient.
5. Examining the right eye with a left eye programme.

3.5 CENTRAL VISUAL FIELD ANALYSIS

The most commonly used perimeter and programmes for central visual field analysis is the Humphrey Field Analyser (HFA) SAP programmes 30-2 and 24-2. The 30-2 programme tests 76 locations over the central 30° in a 6° grid pattern that straddles the horizontal and vertical mid-lines, i.e. targets are located 3° either side of the mid-lines.²¹ Equivalent programmes can be found on most perimeters. The 24-2 programme examines the central 25°, with the addition of more peripheral targets in the nasal step region, and consequently testing time is reduced by up to 20% compared to the 30-2 strategy. It is often used in follow-up assessments and to lessen the likelihood of any fatigue effect. Analysis of the central visual field should be performed on all patients with:

- Significant risk factors for glaucoma (compare with [section 3.4](#)) including, but not limited to, combinations of IOP >21 mmHg, old age, family history, narrow angles, vertical elongation of the optic nerve head, notching of the neural rim tissue of the optic nerve head, disc haemorrhage, nerve fibre layer defect, exfoliative syndrome, pigment dispersion, optic nerve head asymmetry.
- Abnormal screening test (e.g. positive screening test, confrontation or Amsler).
- Symptoms consistent with neurological disease (for example, headache including migraine, dizziness, tingling of limbs) or neuro-ophthalmic disease.
- Symptoms consistent with central field loss, e.g. non-refractive reduced vision, positive scotoma, scintillating scotoma.

In addition threshold fields are always required when monitoring a known defect, and they should always be included in protocols for the management of glaucoma.

3.5.1 Comparison of tests

The instrument should be capable of monitoring fixation, providing full threshold fields in less than 8 minutes, providing reliability indices and analysing the results. A rapid threshold estimation algorithm, such as the HFA's SITASstandard or the Octopus Dynamic Strategy is recommended. These strategies take approximately 7 to 9 minutes per eye, without compromising the accuracy or repeatability of the result.^{22,23} The use of faster, less repeatable, thresholding strategies (e.g. HFA SITAFast and Octopus TOPs; [section 3.4](#)) may be considered as an alternative for some patients with a demonstrated history of fatigue. There has been discussion that SITA should not be used in patients suspected of conditions other than glaucoma as they are optimised specifically for glaucoma. However, clinically the advantage of the reduced test time makes such a compromise worthy of consideration, and no evidence has been presented that suggests a reduction in diagnostic capability for non-glaucomatous defects.

3.5.2 Procedure

The procedure for central visual field analysis is the same as that for central visual field screening ([section 3.4.2](#)) except that:

- At the 'Main Menu' select 'Central 30-2' (or 'Central 24-2').
- Select 'Change Parameters', followed by 'Test Strategy' and ensure 'SITASstandard' is selected. If a full threshold strategy is considered appropriate, select 'Full Threshold'.
- If false negative catch trials are noted, advise the patient to rest by keeping the response button pressed down which will pause the test.
- If false positive catch trials are noted, pause the test by keeping the response button pressed down and re-instruct the patient.

3.5.3 Recording

If no test locations are highlighted on the Total and Pattern Deviation probability plots then record 'SITASstandard (30-2): WNL (Within Normal Limits) R and L'. Print the fields for both eyes and attach to the record card. If a new defect has been detected, particularly in a patient with no previous experience of perimetry or no history of field loss, then repeat the field measurement. Confirmation of visual field abnormalities is essential for distinguishing reproducible visual field loss from long-term variability ([section 1.2](#)). The single field analysis printout illustrates the data as an interpolated greyscale, raw data in decibels, and Total and Pattern deviation plots ([Figure 3.4](#)). It also summarises the field using the Glaucoma Hemifield Test, Global Indices, Reliability Indices, and Gaze Tracking plots. When monitoring glaucoma, the Guided Progression Analysis (GPA), which is based upon the Early Manifest Glaucoma Trial, is designed to identify true glaucoma progression.²⁴

3.5.4 Interpretation

See online figures 3.4i to 3.4viii, with interpretation. Visual fields should be interpreted with respect to their reliability, as a single field and with respect to change over time.

Reliability indices

The reliability indices consist of the following (for a review see [Lalle](#))²⁵:

Fixation losses

These are assessed by presenting suprathreshold targets in the blind spot (Heijl-Krakau technique). They are flagged if more than 20% occur, however this has been found to be too stringent and 30% is a more appropriate cut-off.²⁶ If fixation losses are flagged, only discard the field if you feel that the patient was struggling to fixate, or if false negatives are also flagged.

The HFAII also employs gaze-tracking throughout the test, displayed as a bar chart on the monitor

Fixation Monitor: Gaze Track

Fixation Target: Central

Fixation Losses: 0/0

False POS Errors: 0 %

False NEG Errors: 0 %

Test Duration: 05:46

Fovea: 30 dB ■

Stimulus: III, White

Background: 31.5 ASB

Strategy: SITA-Standard

Pupil Diameter: 5.0 mm

Visual Acuity:

RX: +4.75 DS DC X

Date: 06-10-98

Time: 11:46 AM

Age: 66

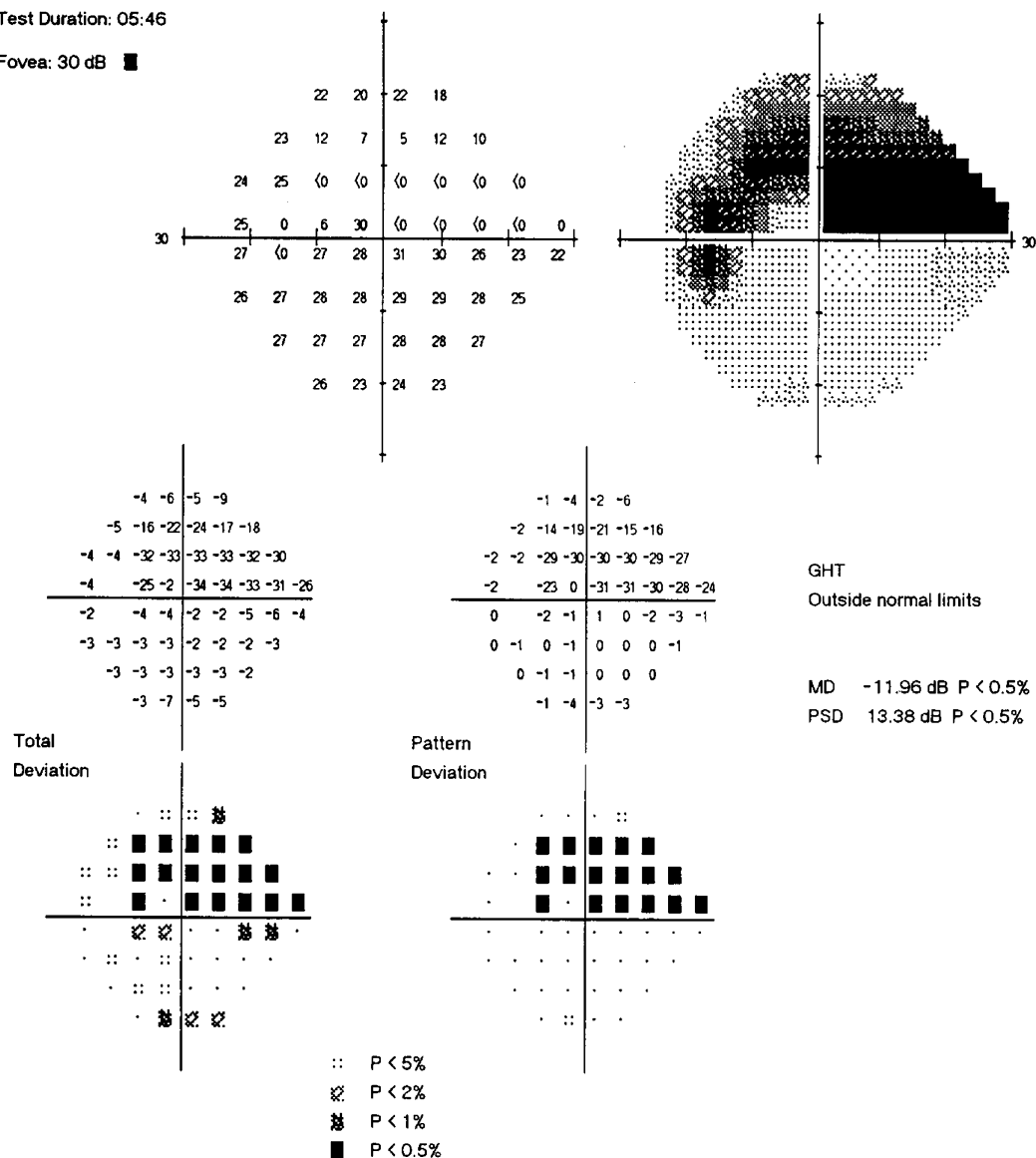


Fig. 3.4 The printout includes the sensitivity level for each point in decibels; an interpolated grey scale display; the total deviation in decibels and probability of each point being normal in a non-interpolated grey scale; the pattern deviation in decibels and probability of each point being normal in a non-interpolated grey scale; the glaucoma hemifield test; the gaze track plot; and global indices.

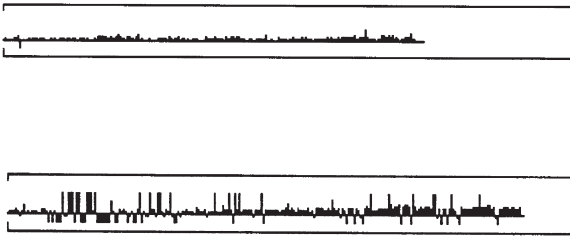


Fig. 3.5 Example of gaze tracking plots. Upward deflections indicate fixation losses and downward deflections are recorded when the position of the eye cannot be determined or there is a blink. The upper plot indicates good fixation, the lower plot indicates poor fixation.

and the printout (Figure 3.5). Upward deflections indicate eye movements and downward deflections are recorded when the position of the eye cannot be determined or there is a blink.

False positives

These errors indicate a 'trigger happy' patient who is responding to the sound of the perimeter when no target is presented. They should be less than 20%. Intervene immediately if false positives start to appear during the test and re-instruct the patient. If false positives are greater than 20%, the result should be discarded and the field repeated. For a repeat field, the test speed could be reduced.

False negatives

These errors accumulate when a patient fails to respond to a suprathreshold target at a given location; these are associated with fatigue and/or inattention. They should also be less than 20%. If you notice false negatives accumulating, particularly toward the end of an examination, give the patient a rest. This will often ensure that the false negative score does not reach significance. If the false negative rate does not improve, despite a rest, it can be better to continue on another day.

For strategies other than SITA there will also be an estimate of the intra-test variance called the short-term fluctuation, which should be within normal limits (not have a reported p-value).

Single field analysis

The single field analysis (Figure 3.4) includes: the sensitivity level for each point in decibels; an interpolated grey scale display; the total deviation in decibels and probability of each point being normal in a

non-interpolated grey scale; the pattern deviation in decibels and probability of each point being normal in a non-interpolated grey-scale and the glaucoma hemifield analysis. The Octopus and Oculus perimeters also include a defect curve.

- Total deviation (TD) compares the result to an age-matched normal population and states the probability of each point being abnormal on a point-by-point basis.
- Pattern deviation (PD) compares the result to an age-matched normal population corrected for the overall level of sensitivity for the individual. The probability of any point varying from this level is stated on a point-by-point basis. This enhances the ability to observe mappable scotomata within a generalised depression, which may be induced by small pupils or poor media.
- If there are no abnormal points on the TD and PD plots, then the patient can be considered as having a normal field.
- A generalised depression will be most easily appreciated by looking for a majority of abnormal points on the TD probability chart. Clusters of two or more non-edge points together on the PD chart ($p < 0.05$) should be considered suspicious. An isolated point within the central 10° ($p < 0.05$) should also be considered suspicious. If a cluster of abnormal points exists it should be interpreted with respect to its underlying anatomical correlate and subsequent clinical significance. Many artefacts show large jumps in sensitivity, from -1 to -28 dB for example.
- The glaucoma hemifield test analyses the relative symmetry of five pre-defined areas in the superior and inferior field, as well as judging the overall level of sensitivity compared to age-matched normal values. The visual field is then classified as being 'within normal limits', 'outside normal limits', 'borderline', 'abnormally high sensitivity', or to have a 'general reduction of sensitivity'. Note that some other visual defects are not picked up by the glaucoma hemifield test, so it should not be relied upon to interpret all visual field losses. The defect curve ranks the test locations from most to least sensitive and plots relative to the 5% and 95% confidence interval for normal visual fields.

The global indices

The global indices are data reduction statistics designed to describe specific characteristics of the glaucomatous visual field.²⁷ In summary:

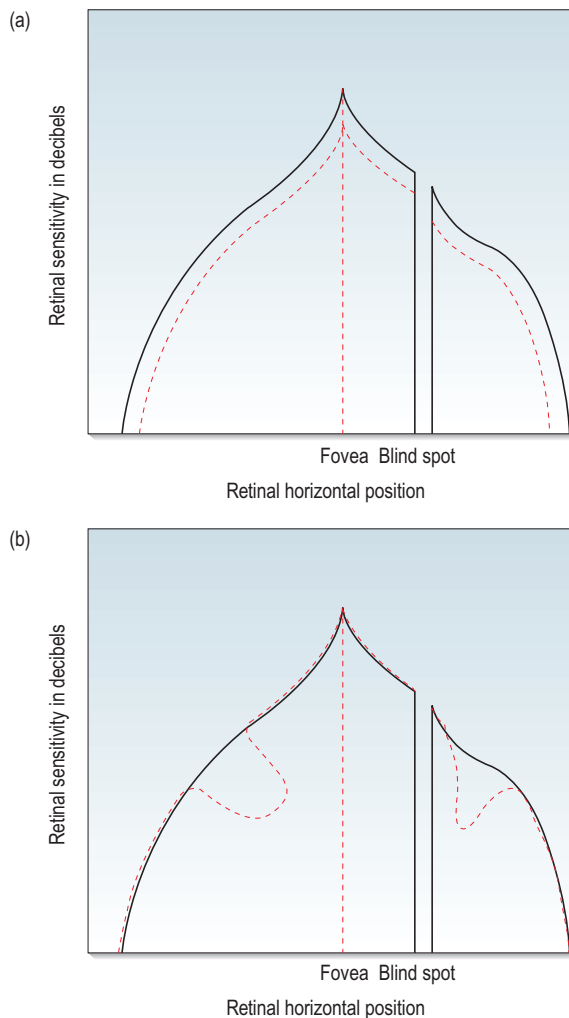


Fig. 3.6 The hill of vision, showing changes that would produce (a) a significant mean defect (MD) and (b) a significant pattern standard deviation (PSD).

- Mean deviation (MD) is the mean difference in decibels between the 'normal' expected hill of vision and the patient's hill of vision. If the deviation is significantly outside the norms, a p-value will be given. It is useful to monitor the overall change in the visual field (Figure 3.6a).
- Pattern standard deviation (PSD) is a measure of the degree to which the shape of the patient's field deviates from age-matched normal. A low PSD indicates a smooth hill of vision, while a high PSD indicates an irregular hill. PSD

characterises localised changes in the visual field (Figure 3.6b). The value is expressed in decibels and any value of 2dB or greater will have a p-value next to it indicating the significance of the deviation. Note that it gets better as the field defect advances to more severe stages, as the field becomes more uniform once again.

- Short-term fluctuation (SF) is a measure of the intra-test variance. It has proven to be of little clinical value.
- Corrected pattern standard deviation (CPSD) is PSD corrected for the SF. These latter two indices are no longer provided on SITA fields.

The probability of the global indices being normal is stated on the printout.

Visual field progression

Change in the visual field of a single patient over time is best appreciated using the Overview printout. Caution is recommended when considering change in the visual field due to the high level of inter-test variability, particularly when a defect is present.²⁸ The mantra should be 'if in doubt always repeat'. If a glaucomatous defect is being followed, the Guided Progression Analysis (GPA) can be considered (see online figure 3.4vi). This is a refinement of the original Glaucoma Change Probability analysis and was developed for the Early Manifest Glaucoma Trial. GPA uses the pattern deviation database rather than the total deviation database, and is therefore more robust to the effects of cataract and reduced pupil size. The analysis uses estimates of the inherent variability within glaucomatous visual fields. This is combined with the Early Manifest Glaucoma Trial criterion of three significantly deteriorating points repeated over three examinations. A minimum of two baseline and one follow-up examination are required. Each exam is then compared to baseline and to the two prior visual fields. Abnormal points are highlighted, as are those that progress on two or three consecutive examinations.

It is also possible, but not recommended, in the Change Analysis printout, to monitor change in the global indices by linear regression analysis and overall change by means of a box-plot chart. Recently the Visual Field Index has been introduced to evaluate the rate of progression, and predict future defect, should progression remain at a constant rate.

3.5.5 Most common errors

See section 3.4.5.

3.6 PERIPHERAL SUPRATHRESHOLD VISUAL FIELD SCREENING

Peripheral testing should be considered in some neurological cases, occasional retinal (particular retinitis pigmentosa) and glaucoma cases, when patients report symptoms of poor peripheral vision and when assessing vision standards.

3.6.1 Comparison of tests

The recommended approach to peripheral field testing is to first record a fast threshold central test (see [section 3.4](#)) followed by a peripheral suprathereshold screening programme that tests between 30 and 60 degrees. Similar programmes can be found on most modern bowl perimeters. Alternate methods would include a full field suprathereshold screening programme or combining a fast threshold central test with a fast threshold peripheral test. It should be noted that there has been no comparison of these different approaches.

Virtually all visual field defects, including those due to chiasmal or post-chiasmal lesions, are reflected within the central 30° visual field.²⁹ This is simply due to the anatomy of the visual pathway. There is a systematic bias towards representation of the central visual field, with over 80% of the visual pathway dedicated to processing the central 30° of vision.³⁰

3.6.2 Procedure

The example used is the Humphrey Field Analyser, Three-zone, Peripheral 60.

1. Following completion of the 30-2 programme select 'Screening' test type from the 'Main Menu'.
2. Select 'Peripheral 60'.
3. Select 'Right'.
4. Select 'Change Parameters'.
5. Select 'Three Zone' test strategy.
6. Select 'Age Reference Level' test mode.
7. Follow steps 7 to 18 of [Section 3.4.2](#).
8. Print results as a merged file with the central 30 degree threshold result, if possible.

3.6.3 Recording

If all test locations are labelled as being 'within normal limits' on the printout then record 'Peripheral 60, 3-zone: WNL (within normal limits) R and L'. If there is a defect evident then print the fields for both eyes,

attach to the record card and consider a confirmatory field. The printout illustrates the data with symbols that designate the location as 'within normal limits', 'relative defect' and 'absolute defect'. There is usually some indication of patient reliability, e.g. test time, catch trials and fixation losses. The combined printout will show the threshold 30-2 result as a greyscale, surrounded by the Peripheral 60 symbols.

3.6.4 Interpretation

Identify any clusters of relative or absolute defect. Repeatable clusters of three or more relative defects should be noted. Look for continuity of defect from the central to peripheral field. As with all visual field analysis the position and shape of a defect, along with additional clinical findings, will dictate the management of the patient.

3.6.5 Most common errors

See [section 3.4.5](#).

3.7 CENTRAL 10 DEGREE VISUAL FIELD ANALYSIS

The most common assessment of central visual function is visual acuity measurement. However, this provides just one assessment of central vision and offers little help in differential diagnosis. In addition, some ocular abnormalities can produce little or no reduction in visual acuity, but can produce other changes to central vision, such as centrocaecal scotomas, metamorphopsia (distorted vision) and changes in colour vision. Although central visual field should be assessed in patients with suspect age related maculopathy, those taking certain medications such as hydroxy-chloroquine that are known to occasionally cause maculopathy and similar conditions, structural measures such as SD-OCT ([section 7.11](#)) can provide earlier diagnoses.³¹

3.7.1 Comparison of tests

Standard automated perimetry has been shown to be much more sensitive, specific, reliable and valid for detecting central visual field changes than Amsler charts.^{32,33} Standard Amsler charts are high contrast and even threshold adaptations of the chart (using cross-polarising filters) are poor at detecting scotomas smaller than 6°. ³² Schuchard also found that more than half of the distortion reported in Amsler grids was at retinal locations that corresponded to the location of

scotoma. Amsler charts rely heavily on subjective interpretation and may also be compromised by the 'completion phenomena', which perceptually fills small gaps in line stimuli.³³

The Amsler Grid is an alternative to 10° central visual field analysis if a quick assessment of macular function is required and it is particularly useful in cases with metamorphopsia or visual distortion. Amsler charts have the advantage that they are portable, so can be used for home visits. The recording sheets can be used for home monitoring, although compliance has been shown to be poor and it is likely that the white-on-black Amsler charts are more sensitive to macular changes than the black-on-white recording sheets.^{34,35}

3.7.2 Procedure for the Humphrey Field Analyser 10-2 programme

The same as central visual field analysis but replace programme 30-2 with programme 10-2 (Section 3.5.2).

3.7.3 Procedure for Amsler charts

1. Seat the patient comfortably in the examining chair with the appropriate near correction. As the working distance for the test is 30 cm, ideally a 3.25 D near add should be used for absolute presbyopes. However, the patient's own spectacles are usually satisfactory given sufficient depth of focus. Use single vision glasses or trial lenses, but avoid multifocal lenses.
2. Position yourself so as to be able to occlude the non-viewing eye and measure the working distance. Get the patient to hold the chart at 30 cm.
3. Keep the room lights on. The method is qualitative and critical light levels are not essential; however, it is useful to be able to reproduce approximate ambient luminance levels.
4. Select the chart for testing:
 - (a) Chart 1: the standard chart used in every case. Consists of a 5 mm square, white grid with each square subtending approximately 1° from 30 cm, on a black background with a central, white fixation target.
 - (b) Chart 2: similar to chart 1 but with two diagonal white lines to assist steady fixation in patients with a central scotoma.
 - (c) Chart 3: similar to Chart 1 but with a red grid. It has been reported to be useful in the toxic amblyopias and optic neuritis, but is also capable of testing the malingeringer when used in conjunction with red and green filters.
 - (d) Chart 4: consists of scattered white dots with a central, white fixation target. It appears no more sensitive than the standard chart for relative scotomas and cannot detect metamorphopsia.
 - (e) Chart 5: consists of white parallel lines only and a central, white fixation point. The chart can be rotated to change the orientation of the lines and is used to investigate metamorphopsia along specific meridians.
 - (f) Chart 6: similar to chart 5 but has black lines on a white card with additional lines at 0.5° above and below fixation.
 - (g) Chart 7: similar to chart 1 but with additional 0.5° squares in the central 8°. This chart is used for detection of subtle macular disease.
5. Instruct the patient to view chart 1 monocularly.
6. Ask the patient if they can see the central white dot. This is intended to determine whether the patient has a central relative (the dot looks blurred) or absolute scotoma. However, many patients with a central scotoma fixate eccentrically.
7. Ask the patient to keep looking at the central dot for the remainder of the test. They should be aware of the rest of the grid out of 'the corner of their eyes'.
8. Ask the patient if they can see all four sides and all four corners of the large square. This is intended to determine large scotomas, such as that produced by glaucoma.
9. Ask the patient if any of the small squares within the grid are missing or blurred.
10. Ask the patient if any of the lines that make up the grid appear wavy or distorted. This step is very important as it detects any metamorphopsia, which is usually caused by macular oedema.
11. Repeat steps 6 to 10 with any additional chart as deemed appropriate.
12. Record any defects or disturbances on an Amsler recording sheet (see online figure 7.36). It is sometimes useful to have the patient draw the defects on a recording chart.

3.7.4 Recording

- **10-2:** If no test locations are highlighted on the Total and Pattern Deviation probability plots then record 'SITA-Standard 10-2: WNL (within normal limits) R and L'. Print the fields for both eyes and attach to the record card. If a defect is evident then consider a confirmatory field. The single field analysis printout illustrates the data as an interpolated greyscale, raw data in decibels, and Total and Pattern deviation plots. It also summarises the field using Global Indices, Reliability Indices, and Gaze Tracking plots.
- **Amsler:** Record defects or disturbances on an Amsler recording sheet. Always record the eye tested, the date of examination and the patient's name. Ensure that if no defects are detected, this is recorded clearly in the patient's file, e.g. Amsler charts: central fields full R and L (OD and OS).

3.7.5 Interpretation

- **10-2:** 10° central visual field programmes provide higher spatial resolution in the central 10° than the standard 25-30° visual field programmes. Their interpretation is as discussed for 30-2 programmes (Section 3.5.4).
- **Amsler:** Metamorphopsia may indicate macular oedema. Although this can be advantageous clinically, great care must be taken when choosing the suitability of a patient for home monitoring with the test, as it can point out otherwise unnoticed problems that subsequently greatly annoy patients. For other patients, compliance can be poor.³⁴ The step in the Amsler chart manual that suggests that you ask the patient to look for movement of lines, shining, or colours (entoptic phenomena) has been omitted as it can produce many artefacts.

3.7.6 Most common errors

1. Using an incorrect working distance.
2. Using an inappropriate near correction.
3. Using the patient's bifocals with a small reading area.
4. Performing the test binocularly.

3.8 VISUAL FIELD ASSESSMENT FOR DRIVERS

The Esterman test was developed for use with Goldmann perimetry as a way of assessing visual

disability.³⁶ It expresses the visual field as a percentage of seen targets, presented at a suprathreshold level of 10 dB (III3e equivalent). The monocular Esterman test uses 100 locations and the binocular test uses 120. The stimulus pattern favours the inferior visual field.

3.8.1 Advantages and disadvantages

The binocular Esterman grid is now available on several of the automated perimeters, including the Humphrey Field Analyser, and gives an automated score. As such it has gained in popularity for the evaluation of visual impairment and visual disability.²¹ It has not been validated for use with standard automated perimetry, but has become a standard of measurement in many circumstances, including the driving standard in several countries.

3.8.2 Procedure

The example used is the Humphrey Field Analyser binocular Esterman test. Other perimeters have similar testing procedures.

Standard visual field set-up applies, but in addition:

- At the 'Main Menu' select 'Specialty Test' and select 'Esterman Binocular'.
- Move the chin rest to the extreme right position and position the patient's chin on the left chin rest.
- Give the patient the response button. Use the habitual prescription used for driving, and do not attempt to use trial case lenses.
- If false positive catch trials appear, it can be useful to pause the screening and re-educate the patient before completing the test. If false positive catch trials get too high, the field screening will have to be repeated (see interpretation).

3.8.3 Recording

The printout uses a non-interpolated grey scale to illustrate those grid locations that were seen (open circle) at the 10 dB screening level, and those that were missed (black box). The number of seen and missed points are also stated as a proportion of the total 120 grid locations and an efficiency score is expressed as the percentage seen. The efficiency score is then used to judge the patient's disability. At the end of the test print the result and record the efficiency score as a percentage.

3.8.4 Interpretation

The results are interpreted as a percentage of visual function, giving an indication of visual disability. For driving standards it is often necessary to assess the extent of the horizontal binocular visual field. Several jurisdictions consider 120° or more of continuous horizontal field to be the required standard. The percentage rate of false positives is an important check of the reliability of the test, as some patients can try to improve their chances of 'passing' this driving standard test by pressing the response button when a light was not seen. Typically, a false positive score above 20% means that the visual fields are unreliable and not acceptable to a driving standards agency, so that the test must be repeated.

3.8.5 Most common errors

These are the same as for visual field screening (section 3.4.5).

3.9 GROSS VISUAL FIELD SCREENING

A variety of very simple visual field tests are available and include confrontation fields, kinetic boundary testing, colour comparison fields and oculo-kinetic perimetry (OKP). The confrontation test can be used in primary eye care patients with very gross field defects to provide an assessment of their functional visual field.

3.9.1 Comparison of tests

The prime use of simple visual field tests is during home (domiciliary) visits. Their only advantages are that they are portable and inexpensive compared to automated perimeters. The most sensitive method appears to be examination of the central visual field with a red target(s).³⁷⁻³⁹ From a visual field screening point of view, all of these tests have been shown to be insensitive to all but gross field defects such as homonymous hemianopias when compared to automated perimetry.^{38,39} It is advisable for general medical practitioners who suspect a patient may have a visual field defect to refer such patients for automated field testing rather than relying on the results of a confrontation test.

3.9.2 Procedure: for red card test³⁷

1. Explain to the patients that you are going to measure the area over which they can

see rather than how well they can see detail.

2. Keep the room lights on and hold the test card at 30 cm from the patient's eye.
3. Ask the patient to cover their left eye and look at the black cross in the centre of the card. The card includes four red squares surrounding a fixation target. The squares are positioned about 10 degrees from fixation, two above fixation and two below.
4. Ask the patient how many squares they see, whether any of the four squares are missing and whether all squares look equally red.

3.9.3 Recording

Record whether any of the squares or parts of them were missed or looked a paler red than the others. A normal result could be recorded as 'Fields grossly full to red card test'.

3.9.4 Interpretation

The red card test is useful in the detection and monitoring of large absolute defects (e.g. hemianopsia) as a simple, portable, 'bedside' test and appears superior to confrontation tests.^{37,39}

3.10 CONGENITAL COLOUR VISION

Congenital colour deficiency is found in both eyes equally and does not change over time. It is virtually always a red-green deficiency and is far more common in males than females as it is an X-linked disorder. Approximately 8% (1 in 12) of the male and 0.5% of the female population are red-green deficient. Dichromats, with only two of the three cone photopigments have the most severe type of colour vision anomaly. Deuteranopes (1%) lack the 'green-catching' chlorolabe and protanopes (1%) lack the 'red-catching' erythrolabe and both confuse all colours from red, through orange and yellow to green. Anomalous trichromats have all three photopigments, but either the red or green photopigments provide less discriminative colour vision than normal. The level of colour vision anomaly can range from near normal to near dichromat levels. Protanomalous trichromats (1%) and deuteranomalous trichromats (5%) confuse colours such as red and brown, green and brown, yellow and orange, pink and grey, purple-red and grey. These colours are more likely to be confused if they are pale or dull or made in dim lighting. In addition, all protans are relatively insensitive to red light. These confusions

of colour create difficulties in a variety of everyday problems, including⁴⁰:

- Matching coloured objects such as clothes, paints and materials used in crafts and hobbies.
- Differentiating differently coloured objects such as ripe and unripe fruit, school workbooks, features on maps.
- Judging when meat is cooked.
- Recognising skin rashes and sunburn.

Patients with colour deficiency will also have difficulty with road traffic signals and protans, because of their relative insensitivity to red light, have difficulty seeing low intensity red lights such as car and bicycle retro-reflectors. Colour vision defects also lessen the chances of being accepted for certain jobs within the armed forces, police force, fire brigade, aviation and railway industry, etc. For example, at the present time in the UK, a patient with a colour deficiency who fails the Ishihara test cannot become a pilot, air traffic control officer, flight engineer or flight navigator in the armed forces or with the civil aviation authority and is unable to become a firefighter, train driver or railway

signaller. In addition to these occupations, the presence of a colour deficiency results in greater difficulty at pursuing a career that stresses the ability to discriminate colour. Such careers include histology, photography, the paint and textiles industries, interior decorating and electronics. Medical practitioners have been shown to have difficulties in identifying the presence and extent of coloured clinical signs (e.g., body colour changes, skin rashes, blood in urine, faeces, sputum and vomit, test strips for blood and urine, etc.⁴⁰) and should be aware of their colour deficiency and its effects. Optometrists with colour deficiency report difficulties identifying disc pallor, the redness of inflamed eyes and skin rashes and differentiating retinal pigment and haemorrhage.⁴⁰

Due to the increased use of colour as a teaching aid in schools, it is important to test the colour vision of children soon after the commencement of school. For any moderate to severe colour deficiencies, it can also be useful to inform the child's school of the condition and its implications (e.g., [Box 3.1](#)).

All hereditary colour defectives should be reassured about their condition: that it is not a disease and the

Box 3.1 Information that could be conveyed to teachers of children with colour vision deficiencies (see colorvisiontesting.com)

Re: John Jones

John has protanopia, a relatively severe form of congenital colour vision deficiency. He sees colours, but sees them differently to other children and will confuse some colours, particularly reds, greens and browns, but also purples, oranges and yellows. These colours are more likely to be confused if they are pale or dull or viewed in dim lighting. Here are some suggestions that may help John and other pupils with colour vision problems:

- Colour deficient children may confuse coloured workbooks or colour-coded reading schemes and make errors when making or reading colour-coded bar charts and pie charts, etc.
- Crayons, coloured pencils, and pens can more easily be identified if labelled with the name of the colour. A colour deficient child may prefer to use their own set of labelled coloured pencils.
- Coloured chalk can be very difficult for a colour deficient child to see, particularly on green chalkboards. White chalk is much easier to see.

- Colour deficient students may appreciate help from a classmate when assignments require colour recognition, such as colour coding different countries on a world map or making colour-coded pie charts, etc.

Particularly for young children:

- Colour deficient children will have difficulty with colour-matching activities.
- Most colour deficient children can identify pure primary colours and it is typically just different shades that give them problems. It can help them to be taught 'all' the colours.
- Label a picture with words or symbols when the response requires colour recognition.
- Make sure a child's colour vision has been tested before they have to learn their colours or colour-enhanced instructional materials are used.
- If they cannot learn certain colours, let them know you understand some colours look the same to them and it is 'OK'.

condition will always remain but will not get worse. Young colour defectives and their parents should be counselled regarding the effects of the modified colour vision on their everyday life and on future career restrictions (see online video 2.2).

3.10.1 Comparison of tests

The Ishihara test (Figure 3.7) is a very efficient screening test for red–green colour deficiency and provides quick and simple measurements.⁴¹ It is by far the most commonly used colour vision test and is a required entrance test for several professions throughout the world, including the armed forces, aviation and railway industries. Disadvantages include that the Ishihara plates do not assess tritan colour problems. In addition, it is designed as a screening test around the normal/abnormal boundary and is therefore less useful for grading the severity of a defect or for monitoring an acquired colour deficiency. To grade the severity of a congenital or acquired colour deficiency, for monitoring acquired colour defects, and detecting blue–yellow defects, either the City University or Farnsworth D-15 tests or similar tests are recommended. After several years, note that the colours on the Ishihara plates can fade and the test loses its validity. Tests similar to the Ishihara are often provided on computer-based eye examination systems, although their validity has yet to be confirmed.

3.10.2 Procedure: Ishihara test

See online video 3.3. The Ishihara test is made up of several plates that present various numbers made up of coloured dots of varying size embedded in a background of different coloured dots (Figure 3.7). The colours of the number and background dots are chosen so that they are confused by patients with red–green colour defects (i.e. they appear isochromatic to those with colour defects) but discriminated by patients with normal colour vision. Plate 1 is a demonstration plate that should be read by all literate patients and can be used to indicate malingerers. Different designs of pseudoisochromatic plates follow, and include transformation (plates 2–9), vanishing (10–17) and hidden digit (18–21) plates. Normal trichromats can see numbers on all but the hidden digit plates. Patients with red–green colour deficiency do not see a number on the vanishing plates, see a different number than normals on the transformation plates (Figure 3.7) and *can* see a number on the hidden digit plates. Classification plates, which attempt to differentiate protans and deuterans, are found on plates 22–25. Two numbers are shown on each plate. The right hand number (blue–purple) is not seen or seen less well by deuterans, and the left hand number (red–purple) is not seen or less well seen by protans (Figure 3.8). The rest of the plates contain pseudoisochromatic pathways and are used for patients who cannot read letters, such as young



Fig. 3.7 Two Ishihara transformation plates.



Fig. 3.8 An Ishihara classification plate.

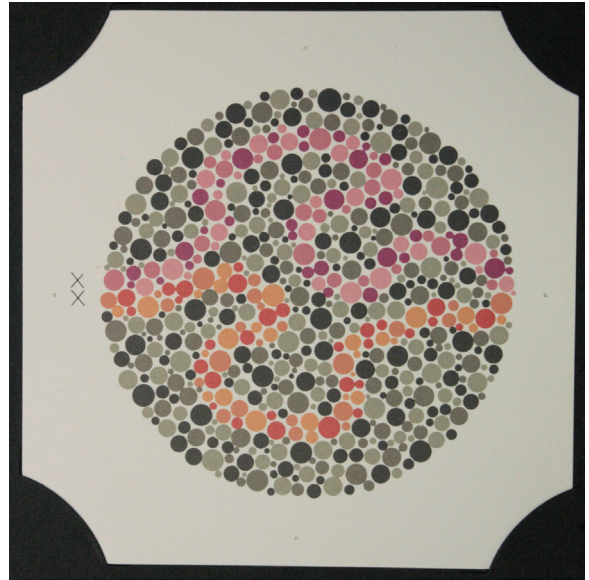


Fig. 3.9 An Ishihara pseudoisochromatic pathway plate.

children. The patient's task is to trace the pathway (Figure 3.9).

1. You must use the proper quantity and quality of illumination, as the colour temperature of the illuminant will affect the colours of the test. Colour vision testing is normally performed under a standard source, such as one of the Gretag Macbeth Sol-Source daylight desk lamps. This simulates natural daylight conditions provided by direct sunlight and a clear sky. As these desk lamps are expensive, alternative sources are also used. For example, you can use high colour rendering fluorescent lights (>5000 K) or a Kodak Wratten #78AA filter (found in camera shops) placed in front of the patient's eye in conjunction with a 100 watt incandescent light source. Natural daylight is not recommended due to its variability in both the quality and quantity of light, although even this is preferable to tungsten lighting.
2. The Ishihara test (unlike other pseudoisochromatic tests) is insensitive to changes in working distance, duration and blur, so that deviations from the manufacturer's recommended viewing distance (75 cm) and viewing time (≤ 3 seconds) do not make a significant difference to errors.⁴²
3. Explain to the patient that you are going to test their colour vision.
4. If screening for a congenital defect, measure colour vision binocularly. If screening for an acquired defect, measure colour vision monocularly.
5. Ask the patient to use their near vision correction and hold the booklet at ~75 cm. Tinted spectacle or contact lenses should be avoided.
6. Ask the patient to read the numbers, starting at plate one. The patient should only be allowed about 3 seconds to view each plate.
7. Use the results sheet to keep a count of any errors. Allow patients another attempt if they make mistakes that are NOT the specific mistakes that red-green colour defectives make.
8. If a patient makes three or more errors, use the classification plates and attempt to categorise the colour defect. Two numbers are shown on each plate and if the patient only reads one number or one number is less visible than the other, the patient can be categorised as deutan (blue-purple letter is not seen or is less visible)

or protan (red–purple letter is not seen or is less visible).

9. Any patient who is diagnosed as colour defective should be counselled regarding the effects of the modified colour vision on their everyday life and on future career restrictions.

3.10.3 Recording

Record the number of plates correctly determined from the number of plates attempted. Patients with normal colour vision will make few, if any, errors. If a patient fails the test, attempt to categorise the defect using the result from the classification plates. You should also record any advice given to the patient and their family.

Examples:

Ishihara 15/16 correct. Normal colour vision.

Ishihara 8/16 correct. ? Deutan. Patient advised re. effect and future career restrictions.

Ishihara 2/16 correct. Protan. Patient advised re. effect and future career restrictions.

3.10.4 Interpretation

Patients with red–green colour defects will make specific errors as indicated in Table 3.4. Generally, three or more errors constitutes a fail, although entrance requirements for some professions allow no errors.^{41,43} Some clinicians do not present the hidden-digit plates, which are not very sensitive to colour deficiency, and just present transformation and vanishing plates.⁴¹ Mistakes that are NOT the specific mistakes that red–green colour defectives make should be viewed with caution, as they are much less likely to indicate red–green colour deficiency.⁴³

3.10.5 Most common errors

1. Using an inappropriate light source.
2. Attempting to assess an acquired colour deficiency using only the Ishihara test.

3.10.6 Alternative procedure: Standard Pseudoisochromatic Plates Part 2

The SPP-2 is another very efficient screening test for red–green colour deficiency and has the advantage over the Ishihara in that it can also be used to screen for blue–yellow defects.^{44,45} Its major disadvantage is that it is not used as a standard entrance requirement for certain professions like the Ishihara test and therefore

Table 3.4 The Ishihara 24-plates edition scoring sheet

Plate	Normal	Person with red–green deficiency		Person with total colour blindness	
1	12	12		12	
2	8	3		X	
3	29	70		X	
4	5	2		X	
5	3	5		X	
6	15	17		X	
7	74	21		X	
8	6	X		X	
9	45	X		X	
10	5	X		X	
11	7	X		X	
12	16	X		X	
13	73	X		X	
14	X	5		X	
15	X	45		X	
		Protan		Deutan	
		Strong	Mild	Strong	Mild
16	26	6	(2)6	2	2(6)
17	42	2	(4)2	4	4(2)
X means that the plate cannot be read. Numbers in parentheses mean that the plate can be read but not as easily as the other numbers.					

is less commonly used. Table 3.5 is a modified score sheet for the SPP-2. Place an 'X' through the figures on each plate that were missed and record the total number of blue–yellow, red–green and scotopic errors. Asking the patient to identify which number is more distinct when two figures are seen on each page may only be helpful when testing for subtle differences between the two eyes. If the only BY error was on plate 4, then repeat the plate to rule out the error being caused by the patient's expectation of seeing only one figure.

Table 3.5 The SPP-2 scoring sheet

Plate	Right eye or binocular		Left eye or binocular repeat	
3	2 BY	4 BY	2 BY	4 BY
4	6 BY	7 BY	6 BY	7 BY
5	3 BY	2 RG	3 BY	2 RG
6	6 BY	3	6 BY	3
7	5 BY	9 S	5 BY	9 S
8	9 BY	8 RG	9 BY	8 RG
9	5 BY	2 RG	5 BY	2 RG
10	2 BY	6 RG	2 BY	6 RG
11	3 BY	5 RG	3 BY	5 RG
12	4 RG/BY	3 S	4 RG/BY	3 S
Number of BY errors ____. Number of RG errors ____. Number of scotopic errors _____.				

When totalling the errors, ignore any mistakes of '2' on plate 3 and '3' on plate 6. The '2' is very difficult to discern and almost everyone misses it. The '3' is a reference that can be used to compare the visibility of the two numbers on the page. A patient over 60 years of age fails the test if they make two or more errors, a patient less than 20 years of age fails the blue-yellow part of the test with two or more errors. The failure criteria for all other patients is one or more errors. Classifying an error based on a fail on plate 12 can be confusing because the figure can be missed by individuals with either a protan or tritan defect. In this case, errors on other plates should be considered. With other red-green errors, but not blue-yellow, classify the patient as a protan. With no other red-green errors, then the error should be classified as blue-yellow. With acquired

defects, both red-green and blue-yellow errors can occur along with failing plate 12 and additional testing should be carried out with either the Farnsworth-Munsell D-15 or the City University (TCU) test.

3.11 ACQUIRED COLOUR VISION

Acquired colour defects are normally monocular or unequal in the two eyes, found about equally in males and females, can progress (or regress) and most often involve a loss of blue sensitivity leading to blue-green and yellow-violet discrimination loss accompanied by decreased vision. Acquired defects may be due to the presence of an anomaly involving the ocular media, retina or the visual pathways. The causes of the anomalies can be due to ocular or systemic diseases and disorders, drugs, or toxic substances. In patients with acquired colour deficiencies, their colour problems can get ignored because other aspects of vision, such as visual acuity, contrast sensitivity or visual fields, are reduced and take precedent. Although these latter tests may be more routinely measured in patients with ocular abnormality and may be more important from a diagnostic perspective, colour vision is an important part of the assessment of a patient's real world vision. Depending on the prognosis for the condition, young patients with an acquired colour defect should be counselled that their condition lessens their chances of joining certain occupations as discussed in [section 3.10](#). Relatively common causes of acquired colour defects in the working population include diabetes and glaucoma. Note that diabetes can cause blue-yellow defects even prior to the appearance of ophthalmoscopically visible retinopathy.⁴⁶ Patients who acquire a colour vision problem who have already started a career that requires good colour vision should be warned of possible problems. For example, general medical practitioners should be warned of the difficulties in identifying the presence and extent of various coloured clinical signs such as body colour changes, skin rashes, blood in urine, faeces, sputum and vomit and test strips for blood and urine.⁴⁰ A tritan-type defect occurs with increasing age due to the yellowing of the lens and receptor changes and cataract (particularly nuclear cataract) and age-related maculopathy in particular can lead to more severe colour defects in the elderly population. Hobbies that may be affected by colour defects include art, photography, interior decorating and electronics. The famous impressionist artist, Claude Monet (1840–1926) had great trouble with acquired colour defects due to cataract in his later life.⁴⁷ Finally, elderly individuals

with colour defects should be warned of differentiating tablets based purely on their colour.

3.11.1 Comparison of tests

Because the Ishihara test is relatively poor at grading the severity of congenital and acquired colour defects and monitoring acquired colour defects, and cannot detect blue–yellow defects, an additional colour vision test is required. The Farnsworth-Munsell D-15 test consists of 16 caps that each contains a paper of a different colour (Figure 3.10). The differences between the colours are relatively large and the test was designed to separate patients into those with a mild colour defect who pass the test and those with a moderate to severe defect that fail the test. It can grade the severity of colour vision problems and can test for blue–yellow and red–green defects so that it can be used to detect and monitor all patients with acquired colour deficiency. It is more sensitive to protan loss than the City University test.⁴⁸

The City University test contains ten plates that each displays a central coloured dot surrounded by four coloured dots derived from the Farnsworth-Munsell D-15 test.⁴⁹ The patient's task is to select the peripheral coloured dot that looks most similar in colour to the central dot. Three of the peripheral colours are chosen as typical isochromatic confusion colours for patients with a protan, deutan or tritan deficiency respectively. The fourth colour is very similar to the central coloured dot and is the one chosen by patients with normal colour vision. The 2nd edition of the TCU is preferred to the 3rd edition, which has not been independently evaluated and is substantially different from the 2nd edition.⁴⁹ It can grade the severity of colour vision problems and can test for blue–yellow and red–green



Fig. 3.10 The Farnsworth D-15 colour vision test.

defects so that it can be used to detect and monitor all patients with acquired colour deficiency.

However, the D-15 and TCU are not as sensitive to subtle colour vision defects as the Ishihara test and patients with a mild red–green defect could pass the D-15 and/or TCU and yet fail the Ishihara. Therefore the D-15 and TCU must never be used as a screening test, particularly given that passing the more stringent Ishihara test is a common requirement for some professions. The usefulness of any colour vision test is influenced by whether it is used as part of the entrance requirements to certain professions in the region you are working.

3.11.2 Procedure: The Farnsworth-Munsell D-15

See online video 3.4.



1. You must use the proper quantity and quality of illumination as described in 3.10.2, step 1.
2. If grading the severity of a congenital colour vision defect detected using the Ishihara test, measure colour vision binocularly. Explain to the patient that you are going to assess the extent of their colour vision difficulty.
3. If screening for an acquired defect, measure colour vision monocularly. Explain to the patient that you are going to test their colour vision.
4. Ask the patient to use their near vision correction and avoid tinted spectacles or contact lenses.
5. Arrange the loose colour caps in a random order in front of the patient near to the box that contains the pilot colour cap.
6. Ask the patient to place the test cap that most closely resembles the colour of the pilot cap next to it in the box. This then becomes the reference cap for the next test cap, and so on (Figure 3.10) until all caps are in place. Allow the patient time to review the ordering and make any necessary adjustments.
7. Close the box, turn it over and open it again to determine the order that the caps have been arranged.
8. If the caps have been arranged in the correct order, or with just one or two transpositions of adjacent caps, record the result as normal.
9. If mistakes have been made in the arrangement of the caps, record the arrangement order on the D-15 score sheet (Figure 3.11). Draw lines from the numbers on the score sheet according to the

FARNSWORTH DICHOTOMOUS TEST for colour blindness—Panel D-15

Name Age Date File No

Department Tester

Dichotomous analysis			
Type	Axis of confusion		
PROTAN	(RED–bluegreen)	☐	OS PASS ☒
DEUTAN	(GREEN–redpurple)	☐	
TRITAN	(VIOLET–greenishyellow)	☒	OD FAIL ☒

Test OD

Subject's order 1 4 3 2 5 6 7 15 14 8 9 13 12 10 11

Test OS

Subject's order 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

OD

OS

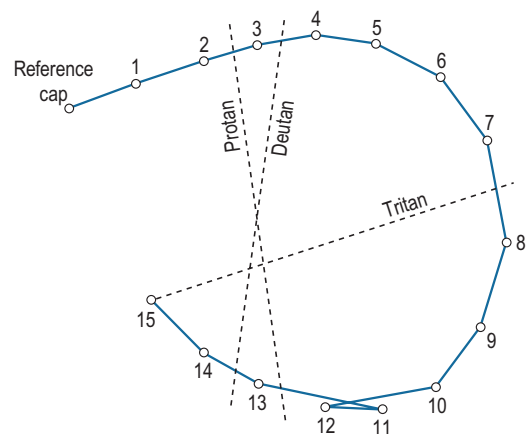
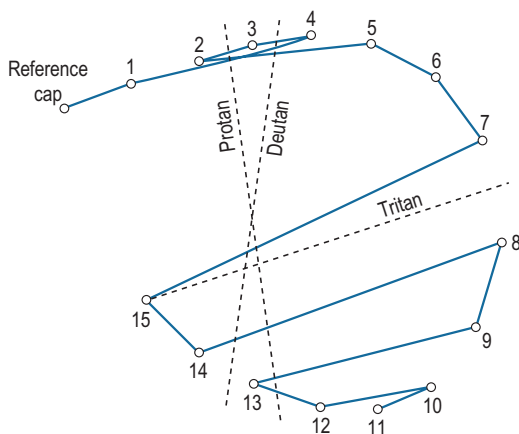


Fig. 3.11 A D-15 scoring sheet showing a tritan defect in the right eye and a passed test in the left eye.

patient's arrangement of the caps. Repeat the test and plot your retest results on a different score sheet (indicate which score relates to which test).

- Any patients who are diagnosed as colour defective, should be counselled regarding the effects of the modified colour vision on (as appropriate) jobs, hobbies and future career restrictions.

3.11.3 Procedure: The City University (TCU) test

- You must use the proper quantity and quality of illumination as described in 3.10.2, step 1.
- If grading the severity of a congenital colour vision defect detected using the Ishihara test, measure colour vision binocularly. Explain to the patient that you are going to assess the extent of their colour vision difficulty.
- If screening for an acquired defect, measure colour vision monocularly. Explain to the patient that you are going to test their colour vision.
- Ask the patient to use their near vision correction and avoid tinted spectacles or contact lenses.
- Hold the test in your hand or place it on the table in front of the patient, about 35 cm away with the pages at right angles to the patient's line of sight. The cap colours can become soiled with time and some practitioners use white cotton gloves (photographer's) for themselves and/or the patient.
- Show the demonstration plate A to the patient and describe the test: 'Here are four coloured

spots surrounding one in the middle. Please tell me which of the four spots is nearest in colour to the one in the middle. Either point or tell me whether it is the top, bottom, left or right, but please don't touch the pages.'

7. Show the test plates 1 to 10 in turn. Allow about 3 seconds per page, with a slightly longer time for the first few pages while the patient becomes familiar with the task.
8. Record the patient's choices in the appropriate column on the record card (either right, left or both eyes).
9. Any patients who are diagnosed as colour defective, should be counselled regarding the effects of the modified colour vision on (as appropriate) jobs, hobbies and future career restrictions.

3.11.4 Recording

1. Patients with normal colour vision should make no errors and this can be recorded.
2. The D-15 score sheet should be plotted and retained for patients who make errors. It is also important to record any advice given to the patient and their family.
3. The TCU record form (Figure 3.12) indicates the most likely of the four spots which will be called as most similar to the middle by colour normals, protans, deutans and tritans. This can be used to categorise a colour defect in a patient who makes some mistakes. Score the patient's responses out of 10. The number of mistakes in the normal column indicates the severity of the colour defect. Record if the patient was unusually slow and record any advice given to the patient and their family.

Examples:

Ishihara failed; D-15 no errors: Mild R/G defect.
Patient advised re. effect and future career restrictions.

Ishihara failed; D-15 failed/see attached: mod./severe R/G defect. Patient advised re. effect and future career restrictions.

See attached sheet (Figure 3.11): D-15. OD: Acquired tritan defect. OS: No errors. Fail: patient advised re. possible effect on job as interior decorator.

See attached sheet: TCU. RE: no errors, but slow; OS: 8/10 tritan: Severe acquired tritan defect. Patient advised re. possible effect on job as interior decorator.

3.11.5 Interpretation

Patients with normal colour vision should make no errors.

- **D-15:** Patients with mild colour vision defects may make minor errors, such as reversals of adjacent caps or one crossing of the D-15 score sheet. These errors still constitute a pass for this test. A failure, as specified by Farnsworth, is two or more crossings of the D-15 score sheet (Figure 3.11). These crossings should parallel one of the protan, deutan or tritan axes marked on the score sheets.
- **TCU:** A patient 'fails' the test if they make more than two mistakes. A patient who makes one or two mistakes is 'borderline' and may require retesting or testing with a more extensive battery of tests. The TCU grades the severity and classifies the colour deficiency.⁴⁹ Patients who fail the Ishihara and then pass the TCU have a mild red-green defect, and are unlikely to have trouble with most occupations.

3.11.6 Most common errors

1. Using an inappropriate light source.
2. Believing that a pass on the D-15 or TCU tests means that the patient has normal colour vision.

3.12 CONTRAST SENSITIVITY

Numerous studies have shown that contrast sensitivity (CS) provides useful information about functional or real-world vision that is not provided by visual acuity, including the likelihood of falling, control of balance, driving, motor vehicle crash involvement, reading, activities of daily living and perceived visual disability.⁵⁰ It is clear that CS should be included with visual acuity and visual fields in definitions of visual impairment and visual disability and for legal definitions of blindness.⁵¹ Thus, using CS in combination with visual acuity (and visual field assessment, when necessary) gives you a better idea of how well a patient actually functions visually. In addition, CS can provide more sensitive measurements of subtle vision loss than visual acuity. There are many clinical situations in which CS can be reduced while VA remains at normal levels, including after refractive surgery, with minimal capsular opacification, with oxidative damage due to heavy smoking, in patients with optic neuritis and

City University colour vision test

Address Patient

Examiner Male/Female Date / /200

Spectacles worn? Yes/No RE/LE/BE

Illumination ('Daylight') Type Level

FORMULA: Here are four colour spots surrounding one in the centre. Tell me which spot looks most near in colour to the one in the centre. Use the words 'TOP', 'BOTTOM', 'RIGHT' or 'LEFT'. Please do not touch the pages.

	Page (A is for demonstration)	Subject's choice of match			Normal	Diagnosis		
		R	L	Both		Protan	Deutan	Tritan
'Chroma four'	1				B	R	L	T
	2				R	B	L	T
	3				L	R	T	B
	4				R	L	B	T
	5				L	T	B	R
	6				B	L	T	R
'Chroma two'	7				L	T	R	B
	8				R	L	B	T
	9				B	L	T	R
	10				T	B	L	R
SCORE		At chroma four			/6	/6	/6	/6
		At chroma two			/4	/4	/4	/4
		Overall			/10	/10	/10	/10
Probable type of Daltonism					P; PA, EPA mixed D, DA, EDA Tritan			

Fig. 3.12 The TCU record form. (Reproduced with the permission of Keeler Ltd.)

multiple sclerosis and in diabetics with little or no background retinopathy.⁵⁰ For these reasons, CS measurements have become standard for most clinical trials of ophthalmic interventions, and they have been widely used in the assessment of refractive surgery, new intraocular implants, anticataract drug trials and potential treatments for age-related macular degeneration and optic neuritis. CS can therefore be used to help screen for visual pathway disorders and to explain symptoms of poor vision in a patient with good visual acuity. Patients with reduced visual acuity could have normal or reduced CS at low frequencies. Patients with reduced CS will have a poorer quality of vision than those with normal CS, despite the same acuity. When used in combination with visual acuity

in this way, CS can be used to help explain symptoms of poor or deteriorating vision and to help justify referral of a cataract patient with reasonable visual acuity. Reduced CS can also explain a poor response to an optical aid by a low vision patient and suggest the need for a contrast enhancing CCTV. Binocular CS that is better than best monocular, can also suggest the desirability of a binocular low vision aid over a monocular one.⁵⁰

3.12.1 Comparison of tests

Pelli-Robson CS is quickly and simply measured and provides a reliable measurement of low spatial frequency CS (0.5–1 cycles/degree) when measured at

the standard 1 m. It provides significantly more repeatable measures than sine-wave grating charts such as the Vistech⁵², FACT⁵³ or CSV-1000 charts.⁵⁴ Other 'large letter' contrast sensitivity charts such as the MARS test are similarly repeatable, but those provided on electronic test charts may not be due to issues with liquid crystal display screens at low contrast.⁵⁵ If high contrast visual acuity is used to assess the high spatial frequency end of the CS curve, then a combination of Pelli-Robson CS and standard VA provides an indication of the whole CS curve. For example, a patient with low frequency CS loss only would have reduced Pelli-Robson CS and normal VA; a patient with high frequency CS loss only would have normal Pelli-Robson CS and reduced VA and a patient with CS loss at all frequencies would have reduced Pelli-Robson CS and reduced VA.⁵⁰ The Pelli-Robson chart is ideal when determining functional vision loss in patients with low vision and moderate and dense cataract, when screening for low spatial frequency loss in patients with optic neuritis, multiple sclerosis or visual pathway lesions and when examining diabetics with little or no background retinopathy and patients with Parkinson's or Alzheimer's disease. The Pelli-Robson chart can be used at longer working distances such as 3 m, so that higher spatial frequencies are assessed and it becomes more sensitive to conditions such as early cataract. One disadvantage of the chart is that a variable endpoint can be gained depending on how long the patient is left to stare at the letters near threshold.⁵⁰

3.12.2 Procedure

1. Illuminate the chart (Figure 3.13) to between 60 and 120 cd/m². If room lighting is inadequate, ensure the additional lighting provides a uniform luminance over the chart, and avoids specular reflections from the surface.
2. Sit/stand the patient 1m from the chart, with the middle of the chart at eye level. Longer distances can be used if required.
3. Patients can wear their own distance spectacles as measurements are relatively immune to moderate dioptric blur.
4. Occlude one eye.
5. Ask the patient to read the lowest letters that they can see, and encourage the patient to guess. Once the patient states that they cannot see any further, indicate where the next lower contrast triplet is on the chart and ask the patient to keep looking at this point for at least 20 seconds. Generally, if given sufficient time, at

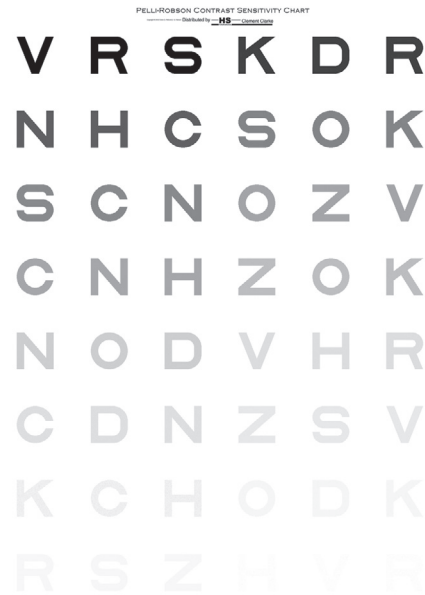


Fig. 3.13 The Pelli-Robson letter contrast sensitivity chart. (Reproduced with permission from Pelli DG, Robson JG and Wilkins AJ. The design of a new letter chart for measuring contrast sensitivity. *Clinical Vision Sciences* 1988;2:187–99.)

least one more triplet of letters will become visible in this manner.

6. Count the reading of the letter C as an O as a correct response to further balance the legibility of the letters.⁵⁰
7. Score 0.05 log CS for every letter read correctly (the first triplet should be ignored as it has a log CS value of 0.00). This 'by-letter' scoring provides a more repeatable and sensitive measurement than the manufacturer's recommended scoring of the lowest line at which the patient can read two of the three letters.⁵⁰
8. Repeat the measurements in the other eye and binocularly as required.

3.12.3 Recording

Record the CS score in log units.

Examples:

Pelli-Robson. RE: 1.70 log CS, LE: 1.75 log CS, BE: 1.85 log CS.

Pelli-Robson. OD: 1.70 log CS, OS: 1.25 log CS, OU: 1.65 log CS.

3.12.4 Interpretation

For patients between 20 and 50 years old, monocular CS should be 1.80 log units and above; for patients less than 20 years old and older than 50 years, monocular CS should be 1.65 log units and above. It is best to obtain your own norm values. If the monocular scores are equal, the binocular score should be 0.15 log units higher (binocular summation). With increasingly unequal monocular CS, the binocular summation will reduce and in some patients, the best monocular score can be better than the binocular (binocular inhibition).

3.12.5 Most common errors

1. Not allowing the patient at least 20 seconds for the letters to become visible when the patient is near threshold.
2. Not pushing the patient to guess.
3. Inappropriate use of the occluder so that the patient can see the chart binocularly when monocular measurements are being made.
4. Inappropriate illumination (generally too low or not uniform).

3.12.6 Useful additional techniques: Small letter CS and low contrast VA

Small-letter CS is more sensitive than traditional VA to several clinical conditions, such as early cataract and contact lens oedema and should be ideal when attempting to measure subtle losses of vision such as after refractive surgery.⁵⁶ CS of very small letters, such as 20/30, correlates very highly with VA and the ideal size for a small-letter test may be about 20/50.⁵⁷ The measurement procedure is very similar to that for the Pelli-Robson chart.

Low-contrast VA charts measure the smallest letter that can be resolved at a fixed contrast and do not measure CS. It is difficult to state which spatial frequencies the low-contrast letter charts are measuring, because this depends on the VA threshold. If only the large letters at the top of the chart can be seen, the score gives an indication of CS at intermediate spatial frequencies. If a patient can see the small letters at the bottom of the chart, the score gives an indication of higher spatial frequencies. Low-contrast VA scores are believed to indicate the slope of the high-frequency end of the CSF. It has been suggested that they can be used to indicate the CSF when used in combination with a low-frequency or peak CS

measure such as the Pelli-Robson chart and a high-contrast VA measurement. The lower the contrast of the acuity charts, the more sensitive they become to subtle vision loss. For example, for detecting subtle vision losses in aviators or subtle changes after refractive surgery, 5–10% charts should be used. For greater losses in vision, such as cataract, even the large letters on these very low contrast charts cannot be seen by some patients, and a higher-contrast chart at about 25% is necessary. As with high contrast VA measurements, charts that follow the Bailey-Lovie (logMAR) design principles should be used and the measurement procedure is the same as for high contrast visual acuity (section 3.2).

3.13 DISABILITY GLARE

Disability glare tests measure the reduction in a patient's vision due to a peripheral glare source. Light from the glare source is scattered within the patient's eye and forward light scatter produces a veiling luminance on the retina that reduces the contrast of the retinal image. In the following clinical conditions in which disability glare can be a problem, the site of increase in light scatter is indicated: corneal oedema (corneal epithelium especially) and opacity, post-refractive surgery (corneal epithelium), cataract (particularly posterior subcapsular cataract), post-cataract surgery (capsular remnants) and retinitis pigmentosa and other retinal disorders leaving a large reflective area on the retina.⁵⁰ Light scatter within the retina may also be increased in conditions such as macular oedema.

3.13.1 Comparison of tests

For routine optometric practice, disability glare is mainly used to help determine functional vision loss in patients with cataract. In these situations, the amount of intraocular light scatter is large and disability glare is probably best determined by remeasuring visual acuity while directing a glare source, such as a penlight or ophthalmoscope, into the eye. The disadvantage of this technique is the lack of standardisation of the amount of glare light reaching the eye.⁵⁰ This can be remedied by using a standardised glare source such as the Brightness Acuity Tester (BAT), although this is a relatively expensive instrument for what it provides.⁵² For more specialised practices, more sensitive measures of disability glare can be obtained using a low contrast VA chart or letter contrast sensitivity chart with a BAT or using a straylight meter.^{52,58} The latter is sensitive to relatively minor changes in

intraocular light scatter, such as in contact lens wearers and pre- and post-refractive surgery.^{58,59}

3.13.2 Procedure: Simple penlight glare test

1. Take the measurements with the patient wearing their own distance vision spectacles or contact lenses. It is difficult to measure disability glare with a trial frame/phoropter because the reduced aperture stops some of the glare light getting into the eye. You should check whether the spectacles or contact lenses are badly scratched as this could cause some disability glare.
2. Perform the test without dilating the pupils, so that the normal pupillary constriction from bright light will occur.
3. Occlude the eye not being tested.
4. Direct the penlight into the patient's eye from about 30 cm and at an angle of 30° from the eye. Alternatively, the slit-lamp illumination system can be used if it is in an appropriate position relative to the visual acuity chart. This helps to standardise the glare angle and distance of the glare source from the eye.
5. Re-measure visual acuity under these glare conditions.

3.13.3 Recording

Record as visual acuity with glare. For example:

VA with glare. RE: 6/24, LE: 6/18.

VA with glare. OD: 20/80, LE: 20/60.

3.13.4 Interpretation

The amount of glare loss will differ depending on the test conditions such as the glare illumination and glare angle (disability glare is inversely proportional to the glare angle) and you should attempt to keep these constant and develop your own mean data for healthy eyes. Typically, most patients will show no change in visual acuity. A decrease in visual acuity of one line or less is normal. Some cataract patients can lose four lines of visual acuity and more. This test gives the patient's visual acuity under bright light conditions, which can be reduced with media opacification: corneal scars, post-refractive surgery, cataracts, posterior capsular opacification or central vitreous floaters. A poor visual acuity in glare conditions can provide justification for early referral of patients with cataract or posterior capsular

opacification who have good visual acuity in normal light conditions.

3.13.5 Most common errors

1. Lack of standardisation of the glare source and its distance and angle from the eye.
2. Not directing the glare light into the eye.
3. As for visual acuity testing.

3.14 POTENTIAL VISION ASSESSMENT

Potential vision assessments predict the visual function of the neural system behind cataracts or other media opacities and thus predict the potential vision after cataract or other media opacity surgery. The most common cause of poor visual outcome after cataract surgery is ocular comorbidity and, particularly, age-related macular degeneration. This has led to many patients with cataract and macular degeneration not being offered surgery and there are many low vision patients that have cataract as a secondary diagnosis.¹⁴ Whether cataract surgery would be beneficial for these patients is unclear, and depends on whether cataract surgery increases the risk of macular degeneration in the years following surgery or not.⁶⁰⁻⁶² Potential vision testing can contribute to the decision of whether surgical intervention is appropriate. Potential vision testing can also be used in the decision of which eye should be operated on with a patient with bilateral cataract and to provide valuable prognostic information to the patient about the likely outcome of surgery.

3.14.1 Comparison of tests

Although fundus biomicroscopy provides a much clearer view of the retina behind media opacity than direct ophthalmoscopy, subtle maculopathies can still provide inconclusive fundusoscopic findings. Schein et al. reported that 63% of patients who were predicted by an ophthalmic examination to have visual acuity of 6/12 (20/40, 0.5) or worse after surgery (the level at which cataract surgery is typically deemed 'unsuccessful') actually attained a visual acuity of 6/9 or better.⁶³ This suggests that potential vision tests are required in addition to standard clinical tests such as case history information, dilated fundus examination and the swinging flashlight test. Unfortunately, the most commonly used tests, the potential acuity meter (PAM) and the various interferometers, cannot penetrate

dense or even moderate cataracts and suggest that potential vision is poor in these cases regardless of the state of the neural system.⁶⁴ In addition, the interferometers in particular can predict good post-operative vision in patients with certain retinal diseases that is not obtainable.⁶⁵ The 'super' pinhole test is a very simple potential vision test that has provided encouragingly accurate results, superior to the previous standard tests of the PAM and interferometers in moderate cataract.^{64,66,67} This is simply a pinhole visual acuity test that incorporates adaptations to overcome the loss of light when a VA chart is viewed through a pinhole and cataract.

3.14.2 Procedure: Super pinhole test

1. Measure the potential visual acuity of the 'poorer' eye first to avoid a patient memorising the letters seen with the better eye and giving a false visual acuity with the poorer eye. Otherwise, measure VA in the right eye first.
2. Ensure that the patient is wearing their near correction.
3. Explain what measurement you are about to take. For example, 'this test will help us to estimate the vision you are likely to obtain after cataract surgery'.
4. Instruct the patient: 'Please cover up your left/right eye with the palm of your hand/this occluder'. If using the patient's hand, make sure that the palm is being used as otherwise the patient may be able to peek through their fingers. Some clinicians prefer to hold the occluder over the patient's eye themselves to ensure it is properly occluded.
5. Hold a near VA card at an appropriate distance from the patient and illuminate it with a transilluminator or other bright light source (the Retinal Acuity Meter is a commercially available version of the super pinhole test and provides a brightly transilluminated near card with a multiple pinhole occluder).
6. Give the patient a multiple-pinhole occluder and ask them to move it around until they obtain the best view possible of the near card through one of the pinholes.
7. Ask the patient to read the smallest line (or paragraph) that you can see on the chart.
8. Move the transilluminator to illuminate the text that the patient is reading or attempting to read.
9. Once the patient has reached what they believe is the smallest letters they can see, they should be pushed to determine whether they can see anymore. Use prompts such as 'Can you see any letters on the next line?' or 'Have a guess. It doesn't matter if you get any wrong'. Also allow the patient to move the multiple pinhole occluder around to see if they can see further down the chart with the pinhole in a different position.
10. Repeat measurements for the other eye.

3.14.3 Recording

Record the near VA obtained with the super pinhole test:

Super PH:	RE: N14	LE: N12
Super PH:	OD: 0.4M	OS: 0.4M
Super PH:	OD: 20/20	OS: 20/30

3.14.4 Interpretation

The near VA obtained with the super pinhole VA gives an indication of the possible near VA after uncomplicated cataract surgery. The test cannot bypass dense cataracts so that in such cases the super pinhole result is likely to be worse than the post-operative VA and just represents the minimum VA that is likely to be obtained after surgery.⁶⁴ Other results and assessments should be taken into account when considering the likely visual outcome after cataract surgery and these include the patient's age, indications from the case history and results from a dilated fundus examination and swinging flashlight test. Visual acuity in the pseudophakic eye is another useful indicator for patients undergoing second eye surgery.

3.14.5 Most common error

Not allowing the patient an opportunity to move the multiple pinhole occluder around to get the best possible potential visual acuity reading.

3.15 ASSESSMENT OF MACULAR FUNCTION

It can be useful to try to differentiate between vision loss due to macular disease and vision loss caused by abnormalities in other parts of the visual pathway, particularly when diagnosis of the cause of vision loss is difficult: Is the vision loss caused by subtle macular

changes or is there an underlying optic nerve or other visual pathway problem or amblyopia?

3.15.1 Photostress recovery time

Long lasting after-images (longer than 15 seconds) produced by relatively brief flashes of light are due to photochemical changes in the receptors. Light absorption by rhodopsin (it is assumed that cone photopigments work in a similar fashion, although slightly faster) leads to the separation of the retinal chromophore from opsin. This process is called bleaching as it results in the loss of rhodopsin's purple colour. While the photopigment is being regenerated, the patient will see an after-image. Photostress recovery time (PSRT) determines the speed at which the photopigment regenerates. Recovery time is solely dependent on the speed of regeneration of the photopigment and is therefore a test of retinal function. It should be independent of other disease within the visual pathway and to some extent will be independent of mild cataract as long as sufficient bleaching light can reach the retina. Only macular disease will cause a prolonged photostress recovery time. The main disadvantage of the test is that there is no standardisation of the procedure. Recovery times are primarily dependent on the brightness of the light and the length of time used, and it is best to obtain your own normal values with your own particular technique and instrumentation.⁶⁸

3.15.2 Procedure

1. Measure distance visual acuity of both eyes (section 3.2).
2. Ask the patient to remove their spectacles, but keep them in their lap so that they can be quickly put back on again.
3. Occlude the 'bad' eye. Hold your direct ophthalmoscope or other bright light source about 2–3 cm away from the patient's 'good' eye. Turn on the light and ask the patient to look directly at the light for exactly 10 sec.
4. After 10 sec, remove the ophthalmoscope, ask the patient to put his or her glasses back on and point to the letters one line larger than the patient's original visual acuity. Ask the patient to read those letters as quickly as he or she can after the after-image has disappeared.
5. Time how long it takes after removal of the bleaching light for the patient to read at least two-thirds of the letters on the line indicated.
6. Repeat the measurement for the 'bad' eye.

3.15.3 Recording

Record the time taken in seconds to recover to within one line of pre-bleached visual acuity in seconds.

Examples:

PSRT: RE 35, LE 40.

PSRT: OD 45, OS 105.

3.15.4 Interpretation

When used with patients with unilateral visual acuity loss, the results are compared between the 'good' and the 'bad' eye. If the recovery times are similar in the two eyes, then the cause of the poor visual acuity in the 'bad' eye is likely to be an optic nerve lesion. If the PSRT is much longer in the bad eye compared to the fellow eye, then the cause of the poor visual acuity is likely retinal. It is generally suggested that any PSRT longer than 50 sec is abnormal, and suggests a macular disease rather than optic nerve abnormality. Of course, recovery times are primarily dependent on the brightness of the light and the length of time used, and it is best to obtain your own normal values with your own particular technique and instrumentation.⁶⁸

3.15.5 Most common errors

1. Allowing the patient to lose fixation of the bleaching light.
2. Using a direct ophthalmoscope with batteries that are not fully charged.
3. Having the patient wait until the letters are clearly visible rather than just visible.
4. Timing inaccurately.

REFERENCES

1. Bailey IL, Lovie JE. New design principles for visual acuity letter charts. *Am J Optom Physiol Opt* 1976;53:740–5.
2. Elliott DB, Yang KC, Whitaker D. Visual acuity changes throughout adulthood in normal, healthy eyes: seeing beyond 6/6. *Optom Vision Sci* 1995; 72:186–91.
3. Lovie-Kitchin JE. Validity and reliability of visual acuity measurements. *Ophthalmic Physiol Opt* 1988;8:363–70.
4. Ferris FL, Bailey I. Standardizing the measurement of visual acuity for clinical research studies: Guidelines from the Eye Care Technology Forum. *Ophthalmology* 1996;103:181–2.
5. McGraw PV, Winn B, Gray LS, Elliott DB. Improving the reliability of visual acuity measures in

- young children. *Ophthalmic Physiol Opt* 2000;20: 173–84.
6. Carkeet A. Modeling logMAR visual acuity scores: effects of termination rules and alternative forced-choice options. *Optom Vision Sci* 2001;78: 529–38.
 7. Schulze-Bonsel K, Feltgen N, Burau H, et al. Visual acuities ‘hand motion’ and ‘counting fingers’ can be quantified with the Freiburg visual acuity test. *Invest Ophthalmol Vis Sci* 2006;47:1236–40.
 8. McGraw PV, Winn B. Glasgow Acuity Cards: a new test for the measurement of letter acuity in children. *Ophthalmic Physiol Opt* 1993;13: 400–4.
 9. Jones D, Westall C, Averbeck K, Adolell M. Visual acuity assessment: a comparison of two tests for measuring children’s vision. *Ophthalmic Physiol Opt* 2003;23:541–6.
 10. Bailey IL, Bullimore MA, Raasch TW, Taylor HR. Clinical grading and the effects of scaling. *Invest Ophthalmol Vis Sci* 1991;32:422–32.
 11. Bailey IL. Visual acuity. In: *Borish’s Clinical refraction*. (WJ Benjamin, ed.). 2nd ed. Philadelphia: WB Saunders; 2006.
 12. Cacho I, Dickinson CM, Smith HJ, Harper RA. Clinical impairment measures and reading performance in a large age-related macular degeneration group. *Optom Vision Sci* 2010;87:344–9.
 13. Millodot M, Millodot S. Presbyopia correction and the accommodation in reserve. *Ophthalmic Physiol Opt* 1989;9:126–32.
 14. Elliott DB, Trukolo-Ilic M, Strong JG, et al. Demographic characteristics of the vision-disabled elderly. *Invest Ophthalmol Vis Sci* 1997;38: 2566–75.
 15. Latham K, Tabrett DR. Guidelines for predicting performance with low vision aids. *Optom Vision Sci* 2012;89:1316–26.
 16. Burr JM, Mowatt G, Hernández R, et al. The clinical effectiveness and cost-effectiveness of screening for open angle glaucoma: a systematic review and economic evaluation. *Health Technol Assess* 2007;11:1–190.
 17. Liu S, Lam S, Weinreb RN, et al. Comparison of standard automated perimetry, frequency-doubling technology perimetry, and short-wavelength automated perimetry for detection of glaucoma. *Invest Ophthalmol Vis Sci* 2011;52: 7325–31.
 18. Noval S, Contreras I, Rebolleda G, et al. A comparison between Humphrey and frequency doubling perimetry for chiasmal visual field defects. *Eur J Ophthalmol* 2005;15:739–45.
 19. Artes PH, Iwase A, Ohno Y, et al. Properties of perimetric threshold estimates from full threshold, SITA standard, and SITA fast strategies. *Invest Ophthalmol Vis Sci* 2002;43:2654–9.
 20. Hudson C, Wild JM, O’Neill EC. Fatigue effects during a single session of automated static threshold perimetry. *Invest Ophthalmol Vis Sci* 1994;35: 268–80.
 21. Anderson DR, Patella VM. *Automated static perimetry*. CV Mosby: St. Louis; 1999.
 22. Wild JM, Pacey IE, O’Neill EC, Cunliffe IA. The SITA perimetric threshold algorithms in glaucoma. *Invest Ophthalmol Vis Sci* 1999;40: 1998–2009.
 23. Budenz DL, Rhee P, Feuer WJ, et al. Sensitivity and specificity of the Swedish interactive threshold algorithm for glaucomatous visual field defects. *Ophthalmology* 2002;109:1052–8.
 24. Leskea MC, Heijl A, Hyman L, et al. Factors for progression and glaucoma treatment: the Early Manifest Glaucoma Trial. *Curr Opin Ophthalmol* 2004;15:102–6.
 25. Lalle P. The Humphrey visual field analyzer. In: *Primary Care of the Glaucomas* (M Fingeret, T Lewis, eds). 2nd ed. New York: McGraw-Hill; 2001. pp. 213–53.
 26. Katz J, Sommer A. Reliability indices of automated perimetric tests. *Arch Ophthalmol* 1988; 106:1252–4.
 27. Heijl A, Lindgren G, Olsson J. A package for the statistical analysis of visual fields. *Doc Ophthalmol Proc Ser* 1987;49:153–68.
 28. Heijl A, Lindgren A, Lindgren G. Test re-test variability in glaucomatous visual fields. *Am J Ophthalmol* 1989;108:130–5.
 29. Wellings PC. Detection and recognition of visual field defects resulting from lesions involving the visual pathways. *Aust NZ J Ophthalmol* 1989;17: 331–5.
 30. Drasdo N, Peaston WC. Sampling systems for visual field assessment and computerised perimetry. *Br J Ophthalmol* 1980;64:705–12.
 31. Marmor MF, Kellner U, Lai TY, et al. Revised recommendations on screening for chloroquine and hydroxychloroquine retinopathy. *Ophthalmology* 2011;118:415–22.
 32. Schuchard RA. Validity and interpretation of Amsler grid reports. *Arch Ophthalmol* 1993;111: 776–80.
 33. Achard OA, Safran AB, Duret FC, Ragama E. Role of the completion phenomenon in the evaluation of Amsler grid results. *Am J Ophthalmol* 1995;120: 322–9.

34. Fine AM, Elman MJ, Ebert JE, et al. Earliest symptoms caused by neovascular membranes in the macula. *Arch Ophthalmol* 1986;104:513–4.
35. Roper-Hall MJ. The usefulness of the Amsler chart. *Eye* 2006;20:508.
36. Esterman B. Functional scoring of the binocular field. *Ophthalmology* 1982;89:1226–34.
37. Mandahl A. Red square test for visual field screening. A sensitive and simple bedside test. *Acta Ophthalmol* 1994;72:683–7.
38. Elliott DB, North I, Flanagan J. Confrontation visual field tests. *Ophthalmic Physiol Opt* 1997;17: S17–24.
39. Pandit RJ, Gales K, Griffiths PG. Effectiveness of testing visual fields by confrontation. *Lancet* 2001;358(9295):1820.
40. Cole BL. The handicap of abnormal colour vision. *Clin Exp Optom* 2004;87:258–75.
41. Birch J. Efficiency of the Ishihara test for identifying red–green colour deficiency. *Ophthalmic Physiol Opt* 1997;17:403–8.
42. Long GM, Lyman BJ, Tuck JP. Distance, duration and blur effects on the perception of pseudoisochromatic stimuli. *Ophthalmic Physiol Opt* 1985;5: 185–94.
43. Miyahara E. Errors reading the Ishihara pseudoisochromatic plates made by observers with normal colour vision. *Clin Exp Optom* 2008;91: 161–5.
44. Hovis JK, Cawker CL, Cranton D. Comparison of the standard pseudoisochromatic plates—Parts 1 and 2—as screening tests for congenital red-green color vision deficiencies. *J Am Optom Assoc* 1996;67:320–6.
45. Vu BL, Easterbrook M, Hovis JK. Detection of color vision defects in chloroquine retinopathy. *Ophthalmology* 1999;106:1799–803.
46. Ismail GM, Whitaker D. Early detection of changes in visual function in diabetes mellitus. *Ophthalmic Physiol Opt* 1998;18:3–12.
47. Elliott DB, Skaff A. Vision of the famous: the artist's eye. *Ophthalmic Physiol Opt* 1993;13:82–90.
48. Oliphant D, Hovis JK. Comparison of the D-15 and City University (second) color vision tests. *Vision Res* 1998;38:3461–5.
49. Birch J. Clinical use of the City University Test (2nd edition). *Ophthalmic Physiol Opt* 1997;17:466–72.
50. Elliott DB. Contrast sensitivity and glare testing. In: *Borish's Clinical Refraction* (WJ Benjamin, ed.). 2nd ed. Philadelphia: WB Saunders; 2006.
51. Leat SJ, Legge GE, Bullimore MA. What is low vision? A re-evaluation of definitions. *Optom Vision Sci* 1999;76:198–211.
52. Elliott DB, Bullimore MA. Assessing the reliability, discriminative ability, and validity of disability glare tests. *Invest Ophthalmol Vis Sci* 1993;34: 108–19.
53. Pesudovs K, Hazel CA, Doran RM, Elliott DB. The usefulness of Vistech and FACT contrast sensitivity charts for cataract and refractive surgery outcomes research. *Br J Ophthalmol* 2004;88:11–6.
54. Kelly SA, Pang Y, Klemencic S. Reliability of the CSV-1000 in adults and children. *Optom Vision Sci* 2012;89:1172–81.
55. Thayaparan K, Crossland MD, Rubin GS. Clinical assessment of two new contrast sensitivity charts. *Br J Ophthalmol* 2007;91:749–52.
56. Rabin J, Wicks J. Measuring resolution in the contrast domain—the small letter contrast test. *Optom Vision Sci* 1996;73:398–403.
57. Elliott DB, Situ P. Visual acuity versus letter contrast sensitivity in early cataract. *Vision Res* 1998;38:2047–2052.
58. van der Meulen IJ, Engelbrecht LA, van Vliet JM, et al. Straylight measurements in contact lens wear. *Cornea* 2010;29:516–22.
59. Rozema JJ, Coeckelbergh T, van den Berg TJ, et al. Straylight before and after LASEK in myopia: changes in retinal straylight. *Invest Ophthalmol Vis Sci* 2010;51:2800–4.
60. Casparis H, Lindsley K, Kuo IC, et al. Surgery for cataracts in people with age-related macular degeneration. *Cochrane Database Syst Rev* 2012;6: CD006757.
61. Chakravarthy U, Wong TY, Fletcher A, et al. Clinical risk factors for age-related macular degeneration: a systematic review and meta-analysis. *BMC Ophthalmol* 2010;10:31.
62. Wang JJ, Fong CS, Rochtchina E, et al. Risk of age-related macular degeneration 3 years after cataract surgery: paired eye comparisons. *Ophthalmology* 2012;119:2298–303.
63. Schein OD, Steinberg EP, Javitt JC, et al. Variation in cataract surgery practice and clinical outcomes. *Ophthalmology* 1994;101:1142–52.
64. Vianya-Estopa M, Douthwaite WA, Funnell CL, Elliott DB. Clinician versus potential acuity test predictions of visual outcome after cataract surgery. *Optometry* 2009;80:447–53.
65. AHCPR report: Cataract Management Guideline Panel. *Cataract in Adults: Management of Real World Impairment*. Clinical Practice Guideline, Number 4. Rockville, MD. U.S. Department of Health and Human Services, Public Health Service, Agency for Health Care Policy and Research. AHCPR Pub. No. 93-0542. Feb. 1993.

66. Hofeldt AJ, Weiss MJ. Illuminated near card assessment of potential acuity in eyes with cataract. *Ophthalmology* 1998;105:1531–6.
67. Melki SA, Safar A, Martin J, et al. Potential acuity pinhole—A simple method to measure potential visual acuity in patients with cataracts, comparison to potential acuity meter. *Ophthalmology* 1999;106:1262–7.
68. Margrain TH, Thomson D. Sources of variability in the clinical photostress test. *Ophthalmic Physiol Opt* 2002;22:61–7.

4

REFRACTION AND PRESCRIBING

DAVID B. ELLIOTT

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4.1 DIFFERENTIAL DIAGNOSIS INFORMATION FROM OTHER ASSESSMENTS

During a problem-oriented examination, a list(s) of tentative diagnoses is made during the case history and this is used to determine which particular tests are likely to be useful to help differential diagnosis. The tentative diagnosis list is then updated after consideration of the results from each test of the eye examination. A very brief introduction to some of the relevant information to the measurement of refractive error provided in the case history and assessments of other systems is provided here.

4.1.1 Symptoms

Distance vision blur or difficulties with certain distance tasks such as reading from the whiteboard, watching TV or driving, but with good near vision suggests myopia. Near vision blur and/or reading difficulties with good distance vision suggests hyperopia or presbyopia depending on the patient's age. Significant astigmatism in combination with myopia or hyperopia

can cause blur at all distances. Headaches and asthenopia can accompany uncorrected hyperopia and presbyopia. Myopes who squint to see can develop frontal headaches and uncorrected astigmatism can often lead to complaints of asthenopia. If these symptoms are due to ametropia, they usually have a gradual onset.

4.1.2 The patient's ocular history

The natural progression of the type of ametropia given the patient's age can indicate what change in refractive correction to suspect. For example, a childhood-onset myope who obtained their first spectacles at age 12 and is now 16 is likely to attend an examination complaining of increased myopia given the typical progression of myopia. Any mention of cataracts in the case history should lead to a careful investigation for increased myopia (nuclear cataract) or astigmatic change (cortical cataract).¹

4.1.3 Family ocular history

When examining children who do not wear spectacles, it is useful to ask whether any of the patient's family wear glasses or contact lenses. Mutti and colleagues reported that juvenile onset myopia was evident in 33% of the offspring of two myopic parents, compared with only 6% of the children of two non-myopic parents.² A family history of hyperopia highlights possible amblyopia.

4.1.4 General health

Diabetes, either undiagnosed or poorly controlled, can lead to wide fluctuations in refractive error, with either hyperopic or myopic shifts. In addition, a variety of systemic medications can lead to refractive error shifts.³

4.1.5 Distance vision and habitual VA

For low myopic refractive errors and hyperopic changes in absolute presbyopes, a degradation of one line of vision (on a logMAR chart) corresponds to approximately -0.25 D of refractive error (although very approximate and dependent on pupil size and patient blur tolerance).⁴ For example:

1. Vision of 20/40 (6/12) in a young adult patient suggests a four-line loss in VA and an equivalent spherical correction of approximately -1.00 DS.
2. Astigmatism in adults changes with age from with-the-rule in young adults to against-the-rule in older patients.⁵ However, these changes in astigmatism are often minimal over the typical 1–3 year period between eye examinations, so that habitual distance VA reductions in spectacle wearing myopic astigmats and older hyperopic astigmats tend to indicate the change in spherical power required. Therefore, a myope of $-1.00/-0.50 \times 180$ with a habitual VA of 6/12 or 20/40 is likely to need a change in refractive correction of -1.00 DS and an updated prescription to approximately $-2.00/-0.50 \times 180$.

4.1.6 Far point estimation

An estimate of myopia can be determined from the patient's far point. Ask the patient to remove any spectacles, occlude one eye and bring in the near VA card until they can just see it. The far point provides an estimate of the mean sphere refractive correction. For example, patients with far points of 33 cm, 25 cm and 20 cm have mean sphere refractive corrections of approximately -3.00 DS, -4.00 DS, and -5.00 DS respectively.

4.2 FOCIMETRY

These devices are also referred to by trade names in some countries, including lensometer or lensmeter (America) and vertometer (Australia). Automatic focimeters are available that measure the lens characteristics mentioned above once the lens has been appropriately positioned and provide a printout of the results. These are very simple to use and the measurement procedure will not be explained. Their main disadvantage is that they break down more often than non-automated focimeters.⁶

4.2.1 Spectacle lens identification

Focimeters measure the vertex power, axis direction, prism and optical centres of ophthalmic lenses. They do not provide information about all the important features of spectacle lenses, however, and it is important to consider that changes in other spectacle characteristics could cause patients problems and need to be checked. These include base curve and lens form, segment style, height, size and inset, centre or edge thickness, optical and surface quality and the presence

of a lens tint and/or surface coating (antireflection, anti-scratch).

4.2.2 Procedure

See online video 4.1.



1. Explain the test to the patient: 'I am going to measure the power of your spectacles.'
2. Set the power of the focimeter to zero and focus the eyepiece (turn it as far anti-clockwise as possible, then slowly turn it clockwise until the target and graticule first come into sharp focus).
3. Measure the back vertex power (BVP) by placing the spectacles on the focimeter with the back (ocular) surface away from you. Position the middle of the right lens against the lens stop.
4. Look into the focimeter and adjust the lens position vertically (using the lens table) and horizontally until the illuminated target is placed in the middle of the reticule. If the lens is high powered, you may need to turn the power wheel to bring the target into focus before it can be centred.
5. Fix the lens into position using the lens retainer.
6. To obtain the power of the sphere, turn the power wheel to bring the target into focus.
 - (a) If the entire target is focused at the same time (Figure 4.1), the lens is a sphere and there is no cylindrical component. Record the sphere power for the right eye from the power wheel or the internal scale and go to step 8.
 - (b) If parts of the target are in focus at different powers and to record in the standard negative cylinder format, turn the power wheel until the meridian with the most plus power (or least minus power) is brought into focus.
 - (c) With focimeters using line targets, rotate the axis wheel until the sphere line (Figure 4.1a) is in focus and the line is continuous without breaks. You may need to use the power wheel to gain best focus.
 - (d) Record the sphere power from the power wheel or internal scale.
7. To obtain the power and axis of the cylinder:
 - (a) Focus the image in the meridian at 90° from the first meridian by turning the power wheel towards the most minus (or least plus) power.
 - (b) Read off the power when this meridian is in focus. With focimeters using line targets, the cylinder lines will be in focus.

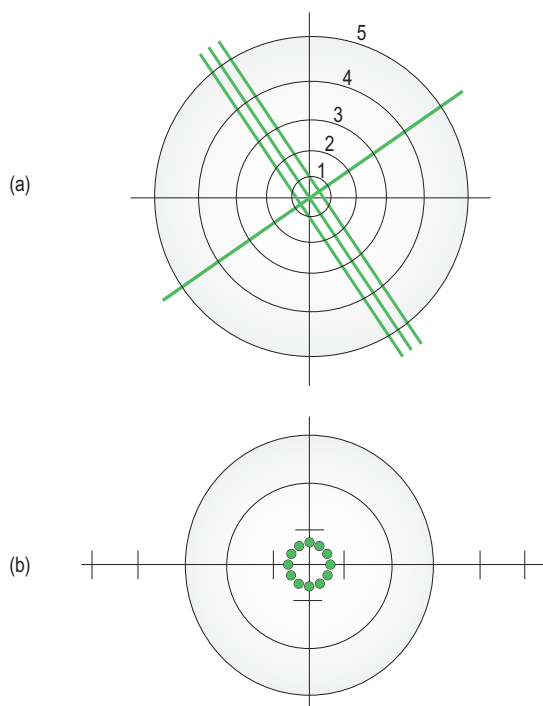


Fig. 4.1 The entire focimeter target is in focus at the same time, indicating a spherical lens. The graticule scale allows measurement of prism. (a) A focimeter that uses a cylindrical (3-line) and spherical (1-line) target. The graticule scale is numbered 1 to 5. (b) A focimeter that uses a circle of dots target. The graticule scale is indicated by the intersecting lines and runs from 1–5 horizontally and 1–3 vertically in both directions from the centre. With an astigmatic lens, the dots become lines orientated along the two principal meridians.

- (c) Record the difference between the sphere power from step 6d and the new meridian power as the cylinder power.
 - (d) Record the orientation of the second meridian from the eyepiece protractor or the axis wheel as the cylinder axis. With focimeters using line targets, this will be the orientation of the cylinder lines (Figure 4.1a).
8. Make sure the target is centred in the graticule and dot the right lens using the focimeter's marking device. This could be just one spot (the lens optical centre) or three dots (the middle is the lens optical centre, the other two indicate the horizontal line).
9. Release the lens retainer and repeat steps 5 to 8 for the left eye. Do not change the vertical position of the lenses between measurements of the right and left lenses as you need to determine if any vertical prism is incorporated in the spectacles.
10. Move the lens horizontally until the target is in the same vertical plane as the centre of the graticule and dot the left lens using the focimeter's marking device.
11. If the target is above or below the centre of the graticule, vertical prism is present and should be recorded to the nearest 0.5^{Δ} using the graticule scale (Figure 4.1).
12. Remove the spectacles from the focimeter and measure the distance between the right and left optical centres to calculate the distance between centres (DBC). Record the DBC in mm.
13. For front-surface solid multifocal lenses, the reading add must be measured using front vertex power (FVP). Turn the lens around so that the ocular surface faces you and reposition the spectacles in the focimeter. Measure the FVP along one meridian in the distance portion of the spectacles. Measure the FVP along the same meridian in the near portion of the spectacles. The difference between these powers is the reading addition. Repeat the measurement in the left lens. For low-powered lenses, the FVP approximately equals the BVP, and the BVP add can be measured.
14. For progressive addition lenses (PALs), the appropriate position on each lens to measure the distance and near prescription, optical centres and any prism must first be found (Figure 4.2). A faint mark is etched into both the nasal and temporal sides of each lens, and this must be found and marked with a non-permanent marker. The mark may also indicate the PAL manufacturer and the power of the addition. Use the manufacturer's marking up card, to find the appropriate distance and near centres and measure the sphero-cylindrical power as previously described. Use the card to determine where to mark the optical centres and where to check for any prism (Figure 4.2).
15. Compare the distance DBC and the patient's interpupillary distance (PD). If these distances are different, calculate the induced horizontal prism using Prentice's rule (induced prism = Fc , where F is the power of the lens along the horizontal meridian and c is the difference

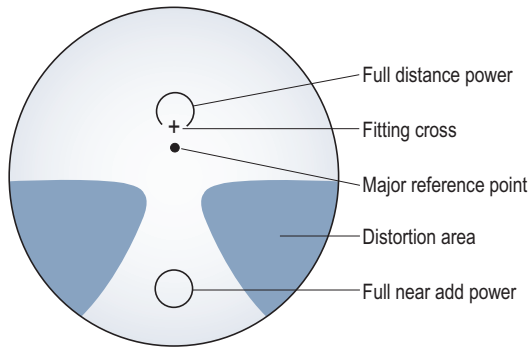


Fig. 4.2 An example of the important points and areas of a progressive addition lens.

between the DBC and PD in cm). The direction of the prism also needs to be deduced.

4.2.3 Recording

Record the sphero-cylinder correction in minus cylinder form for both eyes and the reading addition power if a multifocal. Also record any prism, the type of lens, any tints or coatings, etc. Use 'x' rather than the word 'axis'. Record the spherical and cylindrical power to the nearest 0.25 D, and the cylinder axis to the nearest 2.5°. The axis should be between 2.5° and 180°. Use 180 rather than 0 degrees.

For example:

D28 segment bifocal, CR39, MAR coat.

RE: -2.00 / -1.00 × 35 LE: -2.25 DS

Add +2.00 DS

NV spectacles, CR39.

OD: +2.25 / -0.75 × 80 OS: +2.50 / -0.50 × 105.

4.2.4 Interpretation

One of the most common errors in focimetry is an axis reading incorrect by 90°. Given that the cylindrical axes in the two eyes are often mirror images of each other (for example, both axes 90° or both axes 180°; right axis 175°, left 5°; right 20°, left 160°; right 45°, left 135° etc.), if axes are 90° different to this (for example, 180° and 90°; 175° and 95°; 20° and 50°; both axes 45°; both axes 135°) then recheck the two cylindrical axes.^{5,7} Reading additions are typically the same in both eyes, so that if they are read as different, they should be rechecked.

4.2.5 Most common errors

- Reading one or both of the cylindrical axes incorrectly by 90°.⁶
- Not focusing the focimeter eyepiece. This can lead to inaccuracies for high-powered lenses.
- Not measuring the reading addition using FVP measurements for front-surface solid multifocals.
- Ignoring the relative vertical position of the target between the right and left lens, thereby missing vertical prism.
- Changing the vertical position of the lenses between measurements of the right and left lenses, thereby incorrectly reading vertical prism.

4.3 INTERPUPILLARY DISTANCE (PD)

The PD is the distance between the centres of the pupils of the eyes. It is measured for two reasons:

- To place the optical centre of the phoropter/trial frame lenses in front of the patient's visual axes to control prism and avoid aberrations.
- So that the optical centre of spectacle lenses can be placed in front of the patient's visual axis to avoid unwanted prism and aberrations or deliberately placed elsewhere to produce desired prism.

4.3.1 Anatomical PD

Anatomical PD measurement is quick and convenient to use during an eye examination and it requires no instrumentation other than a simple millimetre ruler. The repeatability of anatomical binocular PD measurements is similar to that for a pupillometer.^{8,9} A pupillometer could be considered when refracting or dispensing a patient with a large amount of ametropia, where slight discrepancies in PD could lead to induced prism, and for monocular measurements when dispensing progressive addition lenses.

4.3.2 Procedure

- Keep the room lights on.
- Explain the test to the patient: 'I am going to measure the distance between your eyes so that I can put your lenses in the correct position for your eyes.'
- Face the patient directly at the distance desired for the near PD (usually about 40 cm).

- Rest the PD ruler on the bridge of the patient's nose or on the forehead so that the millimetre scale is within the spectacle plane. Steady your hand with your fingers on the patient's temple to ensure that the ruler is held firmly in place.

Distance PD

- Close your right eye and ask the patient to look at your left eye. (It is usually easiest to indicate with your finger the eye that you want the patient to fixate.) To allow a patient with unilateral strabismus to fixate, you may need to cover the fellow eye.
- Choose a point of reference on the patient's right eye. The temporal pupil margin is usually most convenient, although the centre of the pupil or the temporal limbus margin may also be used and the latter may be essential with patients with dark irides. Align the zero point on the ruler with this reference point.
- Close your left eye, open your right and ask the patient to change fixation to your open right eye. Take care not to move the ruler or your head position. By sighting again to the appropriate reference point on the patient's left eye, you will obtain a reading for the distance PD (Figure 4.3). This would be the left nasal pupil margin if you used the temporal pupil margin of the right eye.

Near PD

- Move laterally to place your dominant eye opposite the patient's nose.

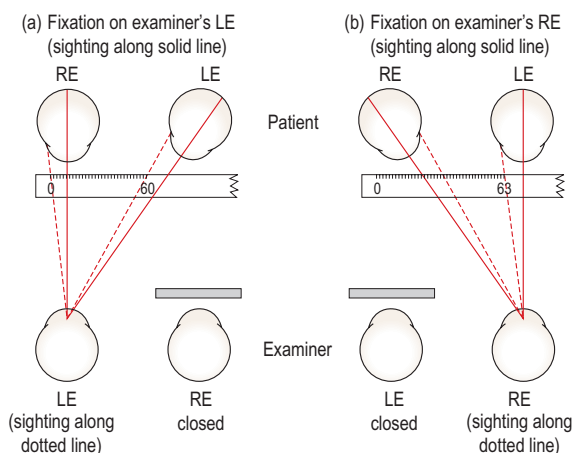


Fig. 4.3 (a) Measurement of near PD. (a and b) Measurement of distance PD.

- Ensure that you are still at a distance from the patient equal to their near working distance. Normally this is done at 40 cm but, if desired, the near PD can be measured for a closer or farther working distance.
- Using your dominant eye only, choose a point of reference on the patient's right eye and align the zero point on the ruler with this reference point.
- Look over to the patient's left eye and note the reading on the ruler that aligns with the corresponding reference point on the left eye (Figure 4.3a).

4.3.3 Recording

The values are normally recorded as distance PD/near PD (in mm). For example, PD: 63/60.

4.3.4 Interpretation

For women the distance PD is most commonly in the range of 55 to 65 mm, and for men, 60 to 70 mm.¹⁰ Young children may have PDs as low as 45 mm. The distance PD value is usually 3 or 4 mm greater than the near PD at 40 cm.¹⁰ Inaccuracies in anatomical PD can occur due to parallax error when there is a large difference between your PD and patient's PD. However, the error is slight, with an 8 mm difference in the examiner and patient's PDs leading to a 0.5 mm error in the measured patient PD.¹¹ The repeatability of anatomical PDs taken by an experienced practitioner is approximately ± 1 –2 mm.^{8,9} Repeatability between practitioners is slightly poorer at about ± 1.5 –2 mm.⁹

4.3.5 Most common errors

- Moving the ruler during the measurement. Make sure it is held firmly and steadily in position. After taking the distance PD reading, it is a good idea to re-open your left eye, have the patient switch fixation back to it and check that the zero mark on the ruler is still aligned with the original reference point on the patient's right eye.
- Using an inaccurate near test distance. Most commonly, unwittingly drifting in closer than 40 cm so the near PD turns out to be lower than it should be. The test distance should not affect the distance PD measurement.
- Using a PD ruler that is not accurately calibrated, such as some give-away rulers provided by optical companies.

4.3.6 Alternative procedure: Corneal reflection pupillometer

Pupillometers allow monocular PDs to be measured more accurately than an anatomical measurement.⁹ This is beneficial when ordering spectacles for high refractive errors or for progressive addition lenses where precise centration of each lens along the patient's visual axes is necessary. In addition, the procedure is quick and simple and could be performed by a clinical assistant and the examiner does not need to be binocular. The PD measured with a corneal reflection pupillometer will typically be 0.5–1 mm smaller than the anatomical PD.^{8,9} This is because pupillometers measure the 'physiological PD', the distance between the two principle corneal reflexes, and locate the visual axes, whereas the anatomical PD locates the lines of sight or optical axes. Note that many pupillometers use a correction for the parallax error mentioned in the anatomical PD section.¹¹ Inaccuracies can occur if the pupillometer sits higher or (usually) lower on the bridge than the intended spectacle frame and the nose is not straight, so that the monocular PDs can be shifted to one side.

4.4 PHOROPTER OR TRIAL FRAME?

A phoropter is a unit that is placed in front of the patient's head and contains all the equipment

necessary to measure a patient's ametropia, heterophoria and accommodation. It can also be called a refractor, refractor head or refracting unit. A trial frame is an adjustable spectacle frame that includes cells into which all the various lenses required to measure a patient's ametropia, heterophoria and accommodation can be placed.

4.4.1 Advantages of a phoropter

See online video 4.2.



The use of a phoropter (Figure 4.4) is the preferred technique for distance vision refraction of the majority of patients. The main advantages of phoropters are:

- A quicker refraction: As the lenses are all contained within the phoropter, it is much quicker to change lens powers for both retinoscopy and subjective refraction than with a trial frame. This may also provide less back strain for the examiner.
- Comfort: The trial frame containing several lenses can become uncomfortably heavy, particularly for older patients.
- Jackson cross-cylinder alignment: On all modern phoropters, the Jackson cross-cylinder (JCC) is automatically aligned with the cylinder axis in the phoropter.
- No lens smear: Trial case lenses can become covered with fingerprints, and require regular

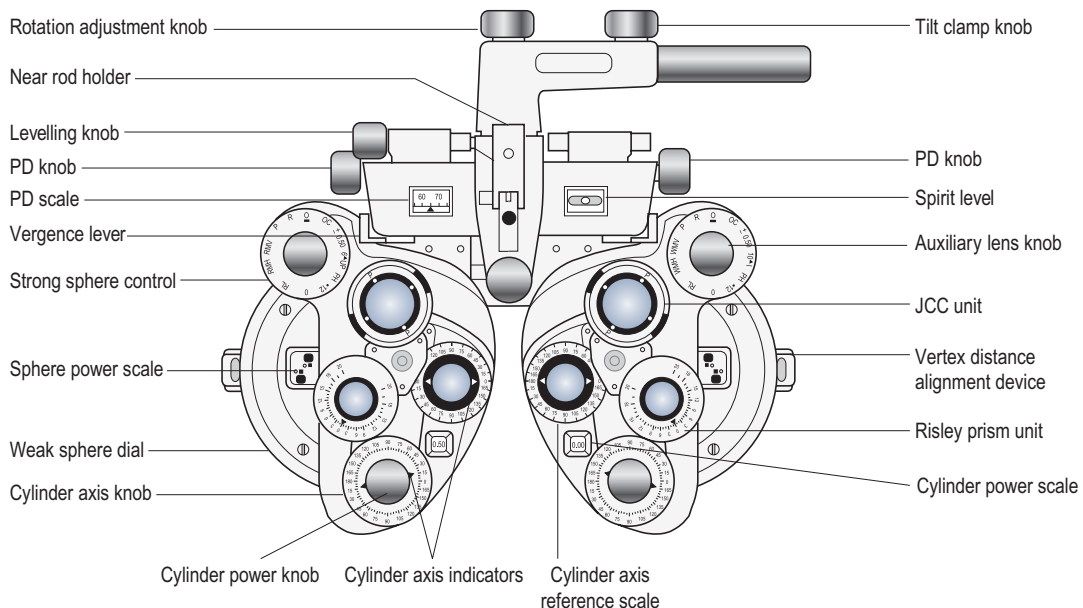


Fig. 4.4 Diagram of a phoropter.

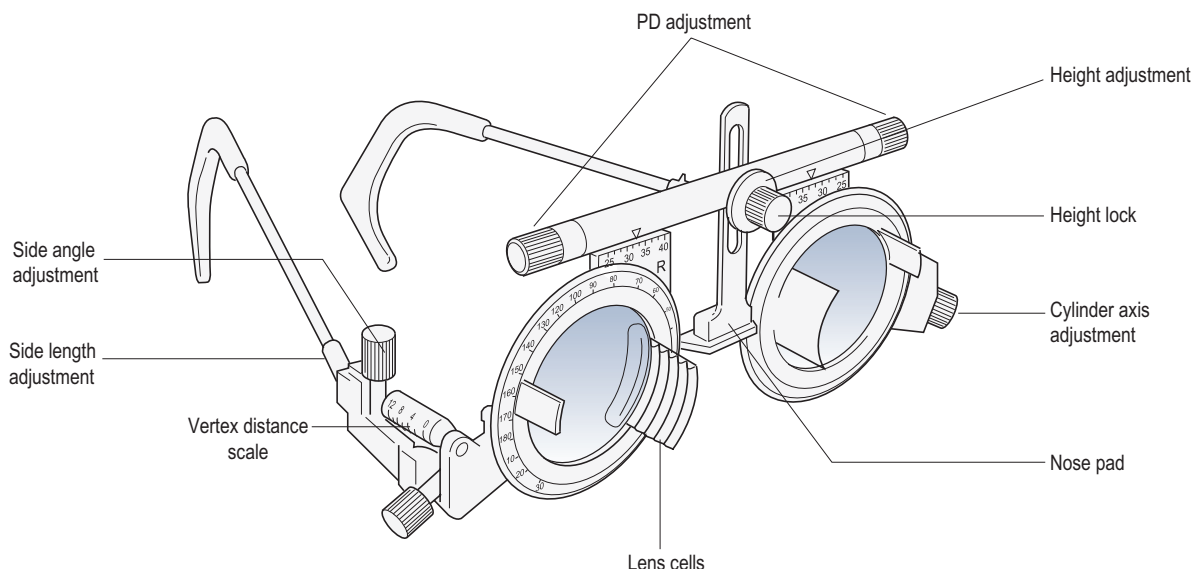


Fig. 4.5 Diagram of a trial frame.

cleaning. The trial frame should also be regularly cleaned.

- **Risley prisms:** These are standard on phoropters and make measurements of subjective heterophoria and fusional reserves faster and easier and allow for easy use of the binocular prism dissociated accommodative balance technique.
- **Computerisation:** Computerised phoropters are available and can include data links to an automated focimeter (lensmeter) and/or autorefractor.
- **High-tech:** Some patients may prefer high-tech phoropters rather than the ancient-looking trial frame.

4.4.2 Advantages of a trial frame

▶ See online video 4.3.

In the routine refraction of presbyopic patients, the trial frame (Figure 4.5) is preferred for the final determination of the near addition, as the test can be performed at the patient's preferred working distance and position, and the range of clear vision can be easily measured and compared to the near vision requirements of the patient. A trial frame is also useful to illustrate the improvement in distance vision in the 'real world' that a pair of spectacles could provide. For example, the new refractive correction can be placed into the trial frame and the patient shown the improvement of their vision while looking through the window

of the practice. This can be particularly useful when partially prescribing (section 4.15).

A trial frame is required for refractions during home (domiciliary) visits and is preferred when refracting:

- **Patients with binocular vision problems and children:** The trial frame can stimulate less proximal accommodation than a phoropter and it provides more repeatable results of oculomotor status.¹² In addition, it is possible to perform the cover test with large aperture lenses in a trial frame, but not with a phoropter. Children can also more easily see their parent/guardian.
- **Patients with visual impairment:** Large dioptric changes in sphere and a high-powered Jackson cross-cylinder (± 0.75 or ± 1.00 D) are required in the subjective refraction of these patients to enable them to appreciate a difference in vision. These can be used very easily during a trial frame refraction. In addition, the trial frame can provide larger aperture lenses and allow unusual head and eye positions that may be necessary for visually impaired patients using eccentric fixation.
- **Patients with hearing problems:** The phoropter obscures the patient's view of the examiner and therefore prevents communication with sign language or simple hand signals.
- **When over-refracting patients being fitted with multifocal contact lenses:** helps to keep the visual environment, binocularity and pupil size as close to normal as possible (section 5.11).

- Patients who provide poor subjective responses: Some patients, despite normal or near normal visual acuity, provide poor subjective responses and cannot seem to discriminate between the view provided with and without a 0.25 DS lens or a ± 0.25 Jackson cross-cylinder (JCC). Using larger dioptric changes in sphere (± 0.50 or ± 0.75 DS) and a higher-powered JCC (± 0.50 or ± 0.75) can sometimes elicit better subjective responses, and these changes are more easily made with a trial frame than with a phoropter.
- Patients with high refractive error: The back vertex power (BVP) of a combination of lenses in the trial frame or phoropter is not necessarily the algebraic sum. It depends on the power, thickness, form and position of the lenses used. After refracting a patient with high ametropia in a trial frame, you should measure the BVP using a focimeter. This is not possible with a phoropter. Indeed, for all phoropter lens powers and their combinations, you are placing your trust in the manufacturer. In addition, the pantoscopic angle and vertex distance can be controlled more easily with a trial frame. Any changes in head position could vary these parameters in a phoropter, but do not in a trial frame as it is fitted to the patient's head.
- Patients with large angle strabismus: Retinoscopy can be done on the line of sight with a trial frame without occluding the fellow eye allowing for a more accurate measure of refractive error and particularly astigmatism.

4.5 OBJECTIVE REFRACTION

An objective measurement of refractive error, usually by retinoscopy or autorefraction, is the only assessment available in patients who are unable to co-operate in a subjective refraction, such as young children. It is also heavily relied upon when subjective responses are limited (patients who do not speak the same language as you and those whose subjective responses are poor) or unreliable (malingerers). In more routine patients, it provides an objective first measure of refractive error that can be refined by subjective refraction. It is not often used in contact lens fitting and aftercare, as the spectacle prescription and contact lens power are usually well matched and therefore any over-refraction is likely to be small, although it can be useful as a problem solver when finding a precise end point is proving difficult.

4.5.1 Comparison of tests

Retinoscopy provides a more accurate result of refractive error in a greater array of patients than autorefraction, although autorefraction is a useful and reliable alternative in many 'standard' adult patients and can be particularly accurate at determining astigmatism.¹³⁻¹⁵ Autorefractors should not be used with young children without cycloplegia because of proximal accommodation errors producing significantly more minus results than subjective refraction, particularly in young hyperopes.^{13,16} Retinoscopy also provides a sensitive assessment of the ocular media (e.g. early detection of cataracts, keratoconus), can be used to determine refractive error at distance and near, identify accommodative dysfunction, and is portable, less expensive and less likely to break down.⁶

Retinoscopy's major disadvantage is that it requires several years of training to become proficient at using it. When a subjective refraction is not possible, limited or unreliable, it is preferable to have more than one assessment of objective refractive correction.

There appears to be no research literature that compares the accuracy of streak or spot retinoscopes or refractions using negative or positive cylinders. The procedure will be described for streak retinoscopy, but spot retinoscopy appears an acceptable alternative. Positive cylinders have the advantage of making retinoscopy easier to learn, as 'with' movement is typically easier to see than 'against' movement. However, negative cylinders are preferred as they are standard in phoropters. In addition, there is the possibility of stimulating accommodation during subjective refraction when removing a plus cylinder from a trial frame to replace it with one of another power. For these reasons the procedure will be described using negative cylinders.

4.5.2 Procedure: Retinoscopy (Summary in Box 4.1)

See online videos 4.4 to 4.7.

1. Prior to the retinoscopy procedure, it can be useful to estimate the refractive correction from relevant case history and visual acuity information (section 4.1).
2. Set the patient's distance PD in the phoropter or trial frame, which should be positioned so that it is level with the lenses in the patient's spectacle plane (~12 mm from the cornea).
3. Either:
 - (a) Dial in the +1.50 DS retinoscope lens into the phoropter or place working distance



Box 4.1 Summary of retinoscopy procedure

1. Estimate the refractive correction from relevant case history, VA information and focimetry/lensometry.
2. Position the phoropter or trial frame appropriately and set the PD.
3. Dial in the working distance lenses if appropriate.
4. Switch on the duochrome (bichromatic), spotlight or a similar large target.
5. Explain the test to the patient.
6. Dim the room lights.
7. Set the retinoscope mirror to the plano position and align yourself with the visual axis of the patient's right eye.
8. Look across to the left eye and if 'with' movement is observed, add positive lenses until 'against' movement is obtained.
9. Determine if the refractive error of the right eye is spherical or astigmatic.
10. If the reflex is dim and the movement is relatively slow, use an appropriate lens to get nearer to neutrality, and check again for astigmatism.
11. If astigmatic, determine the principal meridians.
12. Neutralise the most plus/least minus meridian first.
13. Check the neutral point by moving forward and backward slightly from your normal working distance, and check the reflex movement.
14. Along the second meridian, add minus cylinder in a bracketing technique to achieve neutrality.
15. Repeat for the patient's left eye.
16. Remove the working distance lenses or subtract 1.50 or 2.00 D from your final result.
17. Measure the patient's visual acuities with the net retinoscopy result.

lenses in the back cells of the trial frame (+2.00 DS for a 50 cm working distance, +1.50 DS for 67 cm). This technique has the advantage that all 'with' movements indicate hyperopia and all 'against' movements indicate myopia. It also provides a 'fogging' lens to both eyes that

will relax accommodation in a low hyperope.

or

- (b) Do not add a working distance lens. The working distance power (+1.50 D or +2.00 D usually) must later be subtracted from your final retinoscope result. This technique has the advantage that you avoid introducing two reflection surfaces from the working distance lens, which can make retinoscopy easier in some cases.
4. Switch on the duochrome (bichromatic), spotlight or a similar distance fixation target that is easy to see when blurred and does not provide a stimulus to accommodation. Computer-based optometry programmes include cartoon and other images for use with children.
 5. Explain the test to the patient: 'I'm going to shine a light in your eye and get an indication of the power of the glasses you may need. Please look at the target, and let me know if my head blocks your view. Don't worry if the target is blurred.' Ensure that your head does not block the patient's view at any time, otherwise they are likely to accommodate to it.
 6. Dim the room lights to provide a more high contrast, brighter view of the pupillary reflex, while providing enough light to allow easy viewing of the phoropter/trial case. A totally dark room may induce a dark focus response (Mohindra retinoscopy, see [section 4.13.7](#)).
 7. Sit or stand off to the side of the patient so that manipulation of the trial frame/phoropter is easy. Use a comfortable working distance from the patient so that you can change lenses in the spectacle plane easily (a comfortable arms length is often 67 cm or 50 cm). You should be on the patient's right side and use your right hand and right eye to check the patient's right eye and vice versa for the left eye.
 8. Set the retinoscope mirror to the plano position (maximum divergence, with the retinoscope collar at the bottom of its range) and align yourself with the visual axis of the eye you are scoping (their other eye is fixating the distance target; [Figure 4.6a](#)), otherwise you will obtain off-axis errors.¹⁷

If the patient is looking slightly upwards to view the target, which is common if it is above the patient's head and viewed through a mirror,

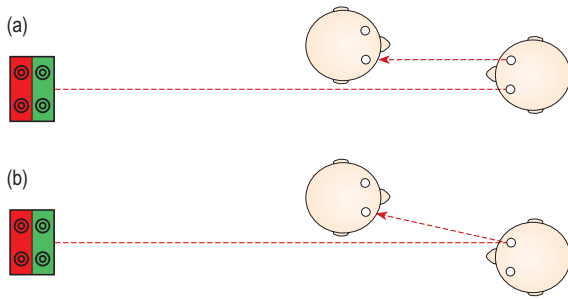


Fig. 4.6 Plan view of the position of the examiner and patient when performing retinoscopy. (a) The examiner is viewing along the visual axis of the patient's right eye, while the patient's left eye fixates the duochrome target. (b) The examiner views off-axis in the 'good' eye of a patient with strabismus. For the strabismic eye, retinoscopy could be performed along the angle of strabismus, or the good eye could be occluded and retinoscopy performed off-axis.

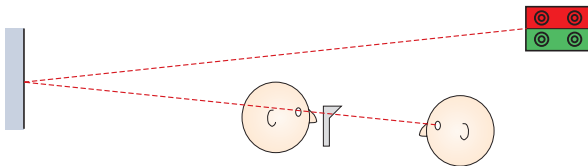


Fig. 4.7 Side view of the position of the patient and examiner when performing retinoscopy when the target is above the patient's head.

to look along their visual axis you will need to be slightly higher than the patient (Figure 4.7).

9. Position the streak so that it is vertical. Look through the aperture of the retinoscope and direct the light at the patient's pupil and you should see the red retinoscope reflex. Sweep the retinoscope streak across the patient's pupil horizontally and compare the movement of the reflex in the pupil with the movement of the retinoscope. If the reflex moves in the same direction as the movement of the retinoscope streak, this is known as 'with' movement. If the reflex moves in the opposite direction to the movement of the retinoscope streak, this is known as 'against' movement.
10. Before you begin retinoscopy on a pre-presbyopic patient, you must try to ensure that they will not accommodate while looking at the target. If you are assessing the right eye first, look across to the left eye and if 'with' movement is observed, add positive lenses until 'against' movement is obtained. This will ensure that the left eye (which is viewing the target) is blurred by at least +1.50 D.
11. Sweep the retinoscope streak across the patient's right pupil and compare the movement of the reflex in the pupil with the movement of the retinoscope. Mentally note the direction of movement with the streak vertical and also observe the reflex's brightness, speed and width. Now rotate the retinoscope streak so that it is horizontal and sweep across the pupil vertically and finally observe the reflex movement when the streak is oriented obliquely (45 and 135). For all four streak positions, mentally note the direction of the reflex movement and the relative brightness, speed and width of the reflex movements.
12. Determine if the refractive error is spherical (the observed reflex has the same direction, speed, brightness and thickness in all meridians) or astigmatic (the reflex differs in different meridians). If the reflex movement is relatively slow and any difference between the reflex speed and thickness is difficult to determine, place an appropriate spherical lens in the trial frame to get nearer to neutrality, and check again for astigmatism.
13. If astigmatic, determine the principal meridians by rotating the streak axis until the angle of the reflex movement coincides with the angle of the streak in two meridians; one perpendicular to the other (Figure 4.8).
14. Determine the spherical component by 'neutralising' (adding plus lenses to 'with'

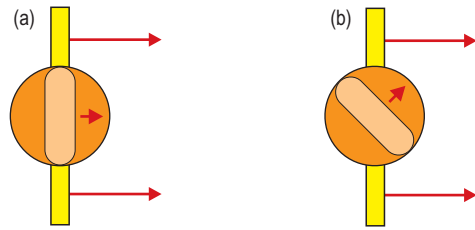


Fig. 4.8 Determining the two astigmatic meridians: (a) If you are scoping on axis, the reflex will move in the same direction as the retinoscopy streak. (b) If you are off axis, the reflex will move in a different direction than the direction of the retinoscopy streak. You should then rotate your streak to align with the reflex.

movement and minus lenses to 'against' movement until the reflex fills the entire pupil and all perceived movement stops) the most plus/least minus meridian first (the meridian with the slowest, duldest 'with' or fastest, brightest 'against' movement). Use a bracketing technique to determine neutrality.

15. Check the neutral point by moving forward slightly and observing the movement of the reflex. A 'with' movement should be seen. If you move backward slightly from your normal working distance, an 'against' movement should be seen.
16. Set the minus cylinder axis parallel with the streak orientation of the least plus/most minus meridian. Move the retinoscope with the streak in this position and you should observe 'against' movement. Add minus cylinder in a bracketing technique to achieve neutrality. As 'with' movement can be easier to see than 'against' movement, you may wish to add minus cylinder until 'with' movement is just seen and then reduce the cylinder by 0.25 D.
17. Briefly, recheck the sphere and cylinder components for neutrality. The axis can be checked using Copeland's 'straddling' technique. This involves comparing the speed of rotation and alignment of the reflex at the cylinder axis $+45^\circ$ with that at the cylinder axis -45° . The cylinder axis should be changed until the reflex at these two positions is the same. In spot retinoscopy, the cylinder axis can be checked and refined by sweeping the beam along the axis of the cylindrical trial lens. If the trial cylinder is oriented at the correct axis, the reflex should be in alignment with the spot of light in the trial frame. The axis of the trial cylinder can be adjusted until this is the case. The power of the cylindrical lens should be rechecked following an adjustment of cylinder axis.
18. Repeat steps 11 to 17 on the patient's left eye.
19. Recheck the right eye. This step may not be necessary if you have ensured that no accommodation has taken place throughout the procedure (see step 10).
20. Remove the +1.50 (or +2.00) working distance lenses (or subtract 1.50 or 2.00 D from your final result).
21. Measure the patient's visual acuities with the net retinoscopy result.

4.5.3 Adaptations to the standard procedure

1. Improving the accuracy of the cylinder axis estimate

After the sphere has been estimated, the position of the cylinder axis can be 'fine tuned' with the retinoscope in the concave mirror position (with the retinoscope collar moved to the top position, this changes all 'against' movements to 'with' movements and vice-versa), in which case slight focusing and rotation of the 'with' reflex allows the reflex and streak to be aligned and the axis to be accurately determined. Remember to return the retinoscope collar to the bottom position before neutralising the now 'against' movement with a minus cylinder.

2. Large pupils

Spherical aberration can provide a more against movement in the periphery of the lens compared to the centre and a common error for inexperienced students is to miss slight 'with' movement in the pupil centre for this reason (see online video 4.6). Concentrate on the central reflex and ignore the reflex at the edges of the pupil.¹⁸



3. 'Scissors' reflex

This reflex moves like the action of a pair of scissors, moving simultaneously in opposite directions from the centre of the pupil, and accurate neutralisation can be very difficult. The reflex can be due to optical aberrations, particularly coma in a normal eye or more rarely due to abnormalities in the media such as keratoconus or corneal scarring. Use lens steps larger than 0.25 DS and try to bracket the neutral point. Increasing the room light level can help as it reduces the patient's pupil size and cuts down the peripheral aberrations.

4. Dim reflex

If the reflex is very dim or hard to interpret, the patient either has media opacities, small pupils or high ametropia. In young patients, it is most likely the latter. If the patient is a high myope, moving increasingly closer to the patient's eye will move the retinoscope closer to the patient's far point and the reflex will become increasingly bright and fast. Alternatively, you could just add a medium to large powered positive or negative lens and repeat retinoscopy at the normal distance.

5. Accommodative fluctuations

During accommodative fluctuations, the pupil will be seen to vary in size and the reflex movement and brightness will rapidly change. This can be seen with young children who change fixation (typically to look at the retinoscope light or their parent/guardian) and the patient needs to be reminded to keep looking at the distance target. If these changes do not appear related to changes in fixation, then accommodative fluctuations that could be due to latent hyperopia or pseudomyopia should be suspected and a cycloplegic refraction (section 4.13) and assessments of accommodation (sections 6.9 to 6.11) should be performed.

6. Patients with strabismus

Retinoscopy is ideally performed along the patient's visual axis. In a patient with strabismus, this can be difficult, particularly when using a phoropter. Retinoscopy on the 'good' eye must be performed slightly off-axis (Figure 4.6b), and this will lead to errors, so minimise the extent as much as possible.¹⁷ For the strabismic eye, it can be easier to change the fixation point for the 'good' eye, so that retinoscopy along the visual axis of the strabismic eye is easier.

7. Examiners with poor vision in one eye (e.g. amblyopic examiners)

If you are unable to obtain accurate retinoscopy results in your poorer eye, you can use your better eye on both sides, but you will have to scope off-axis on one side (Figure 4.6b) which will provide incorrect results.¹⁷ An alternative is Barrett's method in which you perform retinoscopy of both the patient's eyes while the patient fixates the retinoscope and then check the spherical component of this initial result with the patient fixating in the distance using your good eye. For example, if your good eye is the right, scope the patient's right eye using your right eye. The difference in the spherical correction between distance and near fixation should be applied to the other eye. For example, retinoscopy at near gives: OD: $-1.50/-1.00 \times 10$; OS: $-2.00/-0.50 \times 170$. Retinoscopy in the distance for the right eye gives $-2.50/-1.00 \times 10$, an extra -1.00 DS. Apply this difference to the left eye so that the final retinoscopy result is: OD: $-2.50/-1.00 \times 10$; OS: $-3.00/-0.50 \times 170$.

4.5.4 Adaptations for older patients

Older patients will often have small pupils and some will have media opacities/cataract and you will see a dim reflex as a reduced amount of light reaches the retina and even less returns to your retinoscope. Increasing the retinoscope light intensity may just reduce the pupil size further and a medium intensity is usually best. Often an autorefractor result is not possible for these patients,¹³ but retinoscopy might provide a useful result if used with these three adaptations:

- (i) Perform retinoscopy at a closer distance (sometimes called 'radical retinoscopy') such as 25 cm or 33 cm as this can provide a brighter reflex. You will have to subtract a larger value from your retinoscopy result to compensate for the reduced working distance (4.00 or 3.00 D, respectively, for 25 cm or 33 cm). Remember that there is a greater chance of dioptric error when using a close working distance. For example, if you work at 62 cm rather than a correct 67 cm when using a +1.50 DS working distance lens, the error is 0.10 D. The same 5 cm error when assuming a working distance lens of +4.00 D (25 cm) is 1.00 D. There should be no error for astigmatism as long as your working distance remains constant.
- (ii) Use the least number of lenses in the trial frame/phoropter. You will lose 8% of the reflex for each lens used due to reflections. Do not use a working distance lens and refract each meridian using a sphere only and convert to a sphere-cylinder combination for the subjective refraction.
- (iii) In some retinoscopes you can alter the sight hole size. For small pupils and patients with media opacities you should make sure you are using the large aperture sight hole to see as much light as possible.

4.5.5 Recording

Record your retinoscopy results as the spherocylindrical correction that neutralised the patient's refractive error after removing your working distance lenses. Do not use a degree sign as ° can look like a 0 and make an axis of 15° look like 150 degrees. Use 'x' rather than the word 'axis'. Record the spherical and cylindrical power to the nearest 0.25 D, and the cylinder axis to the nearest 2.5 degrees. The axis should be between 2.5 degrees and 180 degrees. Use 180 rather

than 0 degrees. Also record the monocular visual acuity with the retinoscopy result.

For example:

RE: $-2.00/-0.50 \times 105$	6/4.5
LE: -2.25 DS	6/4.5 ⁻²
OD: $+2.00/-1.00 \times 105$	20/20 ⁺³
OS: $+1.75/-0.75 \times 70$	20/25

4.5.6 Interpretation

On average, retinoscopy provides a refractive result slightly more positive than subjective refraction in young patients.¹⁹ This decreases with age, so that retinoscopy and subjective results are similar in presbyopic patients. As the stimulus to accommodation is greater in subjective refraction than in retinoscopy, the retinoscopy result in young hyperopes can be much more positive than accepted in subjective refraction. Errors can occur in retinoscopy if it is performed off-axis (Figure 4.6b), which will induce spherical and astigmatic errors, or if it is performed at an incorrect working distance, which will induce a spherical error.¹⁷ The most common working distance error is to work too close, particularly when the reflex is dim. Note that cylinder axes in the two eyes are often mirror images of each other.^{5,7} For example, right axis 175°, left 5°; right axis 20°, left 160°; right axis 45°, left 135°, etc.

4.5.7 Most common errors

1. Performing retinoscopy at an incorrect working distance, e.g. working at about 50 cm, while using a 1.50 D working distance lens.
2. Performing retinoscopy off-axis.¹⁷
3. Using lenses smudged with fingerprints when performing retinoscopy with trial case lenses. This is a bit like performing retinoscopy in patients with cataract. Student trial case lenses are notoriously smudged and you should try to get into the habit of cleaning lenses before using them.
4. Not concentrating on the movement in the centre of the pupil in a patient with large pupils.
5. Blocking the patient's view of the distance chart, thereby likely stimulating accommodation.

4.6 MONOCULAR SUBJECTIVE REFRACTION

Binocular subjective refraction is the preferred technique for experienced clinicians (section 4.12), but it

works most effectively if the starting point is reasonably close to the optimal refractive correction and this cannot be guaranteed with novice retinoscopists. Therefore monocular subjective refraction is the preferred technique when you start to learn subjective refraction.

4.6.1 Procedure

See online video 4.8.



1. Explain the procedure to the patient: 'During this test, I will place various lenses in front of your eye to find the lenses that give you the best vision. Don't worry about giving a wrong answer as everything is double checked.'
2. Sit or stand off to the side of the patient so that manipulation of the trial frame/phoropter is easy.
3. Begin with the net retinoscopy sphere-cylinder before each eye. The patient's distance PD should already be set in the phoropter or trial frame, which should be level and positioned appropriately.
4. The subjective refraction traditionally begins on the right eye. Occlude the left eye.
5. Determine the Best Vision Sphere (section 4.7 for phoropter-based refractions and section 4.8 for trial frame based refractions). This must be performed to ensure that the circle of least confusion is on the retina prior to the use of the Jackson cross-cylinder (JCC).
6. Check that the circle of least confusion is in an appropriate position prior to JCC using the duochrome test (section 4.9).
7. Determine the cylinder axis using the JCC (section 4.10).
8. Determine the cylinder power using the JCC (section 4.10).
9. If you have changed the cylinder power or axis, repeat the Best Vision Sphere assessment (step 5).
10. Measure VA.
11. Repeat steps 5–10 for the other eye.
12. Perform a binocular balance of accommodation (section 4.11).
13. Compare the monocular VAs with your subjective refraction result with the patient's vision or habitual VAs (as appropriate). If the VA is better with the patient's spectacles, then it is likely that your subjective result is incorrect. Repeat the subjective refraction (students should perhaps call their supervisor).

14. Compare the VA with the present subjective refraction with age-matched normal data (Table 3.1). If the VA is worse than expected, or worse in one eye compared to the other, remeasure the VA with a pinhole aperture. If the VA improves with the pinhole, either the patient has media opacity, typically cataract that is being bypassed by the pinhole, or the subjective refraction is not optimal and should be repeated. Note that visual acuity will not always improve with cataract, particularly if the opacity is dense and central.
15. If the final refractive correction in either eye is above 5.00 D mean sphere equivalent (MSE, the sphere plus half the cylinder; e.g., $-4.75/-1.50 \times 180$ has a MSE of -5.50 D, $+5.50/-2.00 \times 90$ has a MSE of $+4.50$ D), then measure the back vertex distance. This is the distance from the back surface of the lens nearest the eye to the apex of the cornea. Back vertex distance can be read from the millimetre scale on the side of the trial frame, from the back vertex distance periscope on the side of the phoropter, or by using a vertex distance gauge.

4.6.2 Recording

Record the refractive correction using the same format described for retinoscopy (section 4.5.5). Record the monocular VAs. If pinhole VA is measured and reveals no improvement in VA, record PHNI ('pinhole no improvement'); otherwise record the VA with the pinhole. For refractive corrections above 5.00 D equivalent sphere, record the vertex distance. Make sure that the prescription details that you provide to patients are clearly legible. Illegible prescription forms have been reported as a surprisingly common error in optometric practice.⁶

Examples of recording:

Monocular refraction (vertex distance 11 mm)

RE: $+6.00/-1.00 \times 35$	6/6 ⁺¹	
LE: $+6.25/-0.75 \times 145$	6/6	
OD: $-2.75/-0.50 \times 180$	20/15	
OS: -3.00 DS	20/15 ⁻¹	
RE: $-3.00/-0.50 \times 100$	6/12	PHNI
LE: $-2.50/-1.00 \times 75$	6/4	
(Vertex distance 12 mm)		
OD: $-7.50/-2.25 \times 35$	20/70	PH 20/30
OS: $-8.00/-1.50 \times 150$	20/20	

4.6.3 Interpretation

The subjective results should be compatible with the retinoscopy results in most cases, although young

patients may provide a more positive (less minus) correction than retinoscopy.¹⁹ Inconsistent results may be due to technique error or the patient may be an unreliable observer for behavioural or visual reasons. A subjective result that is significantly less positive (more negative) than the retinoscopy result or a subjective result more minus than suggested by unaided visual acuity could indicate latent hyperopia or pseudomyopia and a cycloplegic refraction may be required (section 4.13). A patient with reduced VA (typically in both eyes) and a retinoscope result that indicates emmetropia or slight hyperopia may have non-organic visual loss (section 4.12.6). The difference between the patient's own spectacles and the subjective refraction should be compatible with the difference between the habitual (with own spectacles) and optimal VAs (section 4.12.6).

4.7 BEST VISION SPHERE (MAXIMUM PLUS TO MAXIMUM VA; MPMVA)

There is no research literature that indicates that any best vision sphere procedure is better than another and an experienced practitioner could use a different technique for different patients or may always use a preferred approach. However, the MPMVA technique has the advantage that accommodation is well controlled when examining young patients. This technique is particularly easy when using a phoropter as the lens changes can be made quickly and easily.

4.7.1 Procedure

1. Occlude the left eye.
2. Determine the visual acuity of the right eye.
3. Add $+1.00$ DS to the spherical lens determined in retinoscopy and check the visual acuity. The VA should be reduced by about four lines. If the visual acuity only worsens by one or two lines (or gets better!), add additional positive power to the sphere until four lines of acuity are lost to ensure the eye is 'fogged'. Experienced practitioners may use a smaller fogging lens such as $+0.50$ DS.
4. Reduce the amount of fog by 0.25 DS and ask the patient: 'Are the letters clearer with Lens 1 or 2?' Check that visual acuity improves with the preferred lens.
5. Continue to reduce the amount of fog in 0.25 DS steps and stop when there is no improvement in visual acuity.

- Remember that the *average* acuity of a 20-year-old is about 20/15 ($\sim 6/4$, -0.14 logMAR; Table 3.1), so that most young patients should be able to read beyond 20/20.

4.7.2 Adaptation for older patients

Processing speed slows significantly with age, so provide a longer presentation time for each lens than you would normally do for younger patients.²⁰ Note that you are more likely to over-plus than over-minus older patients (section 4.7.3).

4.7.3 Interpretation

The MPMVA approach is designed to take advantage of a patient's depth of focus to provide the maximum range of clear vision.²¹ For example, after refraction, the retinal image should be conjugate with the distance VA chart at 6 m (20 ft). However, this does not take advantage of the depth of focus. For example, if the depth of focus was $+0.50$ D and the retinal image was conjugate with the distance VA chart so that 0.25 D of the depth of field was in front of the VA chart and 0.25 D behind it, the chart would be clear from 2.4 m (8 ft) to 'beyond' infinity. Using the MPMVA technique places the distal edge of the depth of focus conjugate with the VA chart.²¹ Therefore, if the depth of focus is $+0.50$ D, use of the MPMVA technique ensures that the range of clear vision is from 1.5 m to 6 m (5 to 20 ft). However, using this technique does mean that patients are slightly under-minused or over-plussed by 0.16 D as the distance VA chart is at 6 m (20 ft) and not infinity. This can be offset in young patients due to a lead of accommodation ($+0.25$ DS) during distance refraction, but this does not occur in older patients who have lost accommodation.²¹ This effect can be aggravated if a truncated VA chart is used (i.e. only reducing plus to obtain a VA 'bottom line' of 20/20 or 6/6) and/or if the patient has a large depth of focus (such as older patients with small pupils) as there will be very slight retinal defocus over the entire range except at the precise point of conjugacy.²¹ Over-plussed/under-minused refractive corrections are more commonly found in older patients than under-plussed/over-minused ones.²² An indication that this has occurred is that the measured addition is lower than expected in the presbyope.

4.7.4 Recording

The results of MPMVA are not recorded as the technique is just part of the subjective refraction.

4.7.5 Most common errors

- Not monitoring the VA to ensure that a change in lens power results in the expected change in VA.
- Using a truncated VA chart with a 'bottom line' of 20/20 and only unfogging VA to that level. For example if your chart has a bottom line of 20/20, yet the patient can read 20/15, the patient would be slightly over-plussed/under-minused if they were only unfogged to 20/20. Remember that the average acuity of a 20-year-old is 20/15 and some patients can see 20/10 (Table 3.1). Using the JCC when the circle of least confusion is in front of the retina, as it would be in this case, can lead to an incorrect determination of astigmatism.²³

4.8 BEST VISION SPHERE (THE PLUS/MINUS TECHNIQUE)

See online video 4.8.

The plus/minus technique is easier than MPMVA when using a trial frame as less lens changes are typically required. However, it does not provide as good control of accommodation in young patients as the MPMVA technique. For this reason, one or more check tests (duochrome and/or the $+1.00$ blur check) are typically used with the plus/minus technique in presbyopic patients.



4.8.1 Procedure

- Occlude one eye. Direct the patient's attention to the best acuity line.
- Check that any lenses you are using are clean and free of fingerprints. Student trial case lenses are notoriously smudged and a patient will not be able to see through a dirty lens.
- Add $+0.25$ DS and ask: 'Are the letters clearer, more blurred or the same?' ($+0.50$ DS can be used if the initial VA is relatively poor).
- If the acuity improves or *remains the same* with the additional plus, then exchange the spherical lens that is in the trial frame for one that has $+0.25$ DS added. For example, if the patient has -3.00 DS in the trial frame and the letters look clearer with $+0.25$ DS, then exchange the lens for a -2.75 DS lens.
- When exchanging plus lenses in a trial frame in a young hyperope, do not remove the plus lens until the new lens has been inserted,

otherwise accommodation could be stimulated. For example, if you have +2.00 DS in the trial frame and the patient indicates that additional plus power is required, insert the +2.25 DS lens first, and then remove the +2.00 DS lens.

6. Using the same approach, continue adding plus lens power in +0.25 DS steps, until the acuity first blurs. Stop at the most plus/least minus lens that does not blur the visual acuity.
7. If the visual acuity blurs with a +0.25 DS lens, then do not add it.
8. Direct the patient's attention to the best acuity line. Add -0.25 DS and ask: 'Are the letters clearer, more blurred or the same?' An alternative question when adding -0.25 DS is 'Does this help you read any more letters?'
9. If visual acuity improves with the lens, then exchange the spherical lens that is in the trial frame for one that has -0.25 DS added.
10. Add further minus lenses (in -0.25 D steps) *only as long as the visual acuity improves*.
11. If a young patient (i.e., the patient is able to accommodate) reports that vision is improved with the lens, but there is no improvement in visual acuity, ask, 'Do the letters definitely look clearer, or just smaller and blacker?' If the letters just look smaller and blacker, do not add the -0.25 DS.
12. If the patient reports no change or a worsening of vision, do not add the -0.25 DS.
13. Duochrome check: Use this as part of best vision sphere determination prior to using the JCC in younger patients (section 4.9).
14. The +1.00 blur check. Use this as part of best vision sphere determination at the end of monocular refraction in younger patients. Place a +1.00 DS trial case lens over the final best vision sphere correction. If the original VA is about 6/4 (the average VA for a young patient, Table 3.1), then VA will blur to about 6/12⁺ with +1.00 DS.²⁴ If VA is better than 6/12 with the +1.00 DS, then the patient may have been over-minused or under-plussed and the best vision sphere should be rechecked. Note that the four-line loss of VA with the +1.00 blur is an average and VA loss with +1.00 DS can reliably be as small as two lines or as large as 7.²⁴ The vision obtained with the ± 0.25 DS is the final arbiter of the best vision sphere and not the +1.00 blur test.

4.8.2 Adaptations to the standard procedure

Only use two options

It can be difficult for some patients to make a decision when there are three possible options of 'clearer', 'more blurred' or 'the same'. Some clinicians just present two options to the patient and ask whether the chart is 'clearer' or 'more blurred' or 'better with the lens or..... without it'. If the patient pauses and is clearly having difficulty deciding between the two options, you can then ask whether they look about the same. The patient will sometimes report that there is no difference even without the prompt. Another option used by some clinicians when refracting young patients and close to the final correction (as indicated by a good VA) is to ask whether a +0.25 DS is 'worse' or 'the same' and whether a -0.25 DS is 'better' or 'the same' on the basis that a +0.25 DS should either blur or relax accommodation and a -0.25 DS should either improve acuity or induce accommodation. There is no research literature to indicate whether one of these options is better than any other.

Provide some 'training' until responses are repeatable

The techniques listed above and described in the following sections assume that the responses provided by patients are always correct. Of course, it is seldom that they are always perfect. This can be detected during the subjective refraction when responses to the same changes in spherical power can be different at different times, or with experience it can be expected in patients whose responses to other procedures within the eye examination have been poor. It can be useful in such patients to give some 'training' to help patients provide more accurate responses. This can be done by repeatedly presenting the same spherical lens change to the patient until they repeatedly provide the same response. Alternatively, you can provide a comparison with +0.25 DS and -0.25 DS until the patient repeatedly reports the same preference. If a patient is providing unreliable responses or is unable to tell any difference with ± 0.25 DS, then use ± 0.50 DS or even larger steps.

4.8.3 Adaptations for older patients

Older patients, particularly those with reduced VA, may be unable to tell any difference with ± 0.25 DS, so that you should use ± 0.50 DS or even larger steps. Some older patients also prefer to have two options to choose from rather than three (see 4.8.2).

4.8.4 Recording

The results of the best vision sphere are not recorded as the technique is just part of the subjective refraction.

4.8.5 Most common errors

1. Not monitoring the VA to ensure that a change in lens power results in the expected change in VA.
2. Using trial case lenses smudged with fingerprints. Patients are not able to see well through smudged lenses.

4.9 DUOCHROME (OR BICHROMATIC) TEST

The duochrome or bichromatic test is commonly used as a check on the best vision sphere during monocular refraction. It is based on the principle of axial chromatic aberration, where light of shorter wavelength (e.g. green light) is refracted more by the eye's optics than light of longer wavelength (e.g. red light). Duochrome tests traditionally use a red filter (peak wavelength 620 nm) and a green filter (peak wavelength 535 nm) of equal brightness. The dioptric distance between the foci of these wavelengths is around 0.44 D.²³ An eye in a mildly myopic state (e.g. -0.25 DS) will see the target on the red filter more clearly; an eye in a mildly hypermetropic state (e.g. +0.25 DS) will see the target on the green filter more clearly. The test is more rarely used as a binocular balancing technique (section 4.11).

4.9.1 Procedure

 See online video 4.8.

1. Some clinicians dim the room lights as this dilates the pupil and slightly increases the chromatic aberration of the eye and provides more reliable responses.²⁵ It also reduces the veiling glare on projected charts.
2. Ask the patient: 'Are the rings (or letters/dots) clearer and blacker on the red or on the green, or are they about the same?'
3. If they look the same, check whether the responses are reliable by adding +0.25 DS (the rings on the red should look clearer) and then -0.25 DS (now green). If the responses are appropriate, this suggests that the best vision sphere has been obtained and the circle of least confusion is on the retina.

4. If the rings on the green look clearer, add +0.25 DS until you obtain a balance. Note the additional spherical power required to obtain a balance.
5. If the rings on the red look clearer, add -0.25 DS until you obtain a balance. Note the additional spherical power required to obtain a balance.
6. If more than ± 0.50 DS is needed to balance the clarity of the rings (or letters) on the duochrome, this usually indicates that the duochrome test is unreliable for this patient and the results should be ignored.
7. Prior to the use of the Jackson cross-cylinder: If the clarity of the rings changes from 'green' to 'red' with +0.25 DS or 'red' to 'green' with -0.25 DS, leave a young patient on the 'green' as they will be able to accommodate to bring the circle of least confusion onto the retina.
8. After the use of the Jackson cross-cylinder and prior to finalising the refractive correction: If the clarity of the rings changes from 'green' to 'red' with +0.25 DS or 'red' to 'green' with -0.25 DS, note the additional spherical power required to leave a young patient 'on the red'.
9. Use the additional lens power suggested by the duochrome test and double-check whether this additional power is preferred by the patient using MPMVA (section 4.7) or the plus/minus technique (section 4.8). Note that the duochrome should be used to indicate that you should double-check your result and should not be used as the arbiter of the final refractive correction.

Note: Some practitioners prefer to add +0.50 DS or +0.75 DS to the spherical correction so that the bichromatic test is initially 'on the red' and then reduce the plus power (or increase the minus power) in 0.25 DS steps until the targets on the red and green look equally black and clear.

4.9.2 Recording

The result of the duochrome test when used prior to the JCC is typically not recorded. However, some practitioners record the result of the duochrome at the end of the monocular refraction.

For example:

R: -1.00/-0.50 $\times$ 170	R = G 6/4
L: -1.25/-0.25 $\times$ 10	R = G 6/4
OD: -1.25/-0.75 $\times$ 20	R > G 20/15
OS: -1.75/-1.00 $\times$ 165	R > G 20/15

4.9.3 Interpretation

The duochrome is a check test and you should not use the test as a final arbiter of the best vision sphere. Some patients give poor results with the duochrome and always prefer one colour, regardless of the changes you make to the spherical refraction, and the test gives unreliable results with blur of more than ~ 1.00 D. Older patients, due to small pupils and the increased absorption of low wavelength light by the lens (particularly in nuclear cataract) tend to give more unreliable duochrome results. Colour defective patients can use the test, although the red side of the test will appear duller to protans. In addition, not all charts provide light of appropriate red and green wavelengths.

4.9.4 Most common errors

1. Not checking with ± 0.25 DS to make sure the patient's responses are reliable if they initially respond that the rings are equally clear on the red and green.
2. Relying on the result obtained with the duochrome test as the final arbiter of the spherical end point. It is a check test only and may suggest that you repeat part of the best vision sphere assessment.
3. Asking the patient whether the red or green looks brighter (the green will look brighter for a protan and the red for patients with nuclear cataract). You must ask whether the rings (or letters/dots) are clearer and blacker on the red or green.

4.10 ASSESSMENT OF ASTIGMATISM

Most patients have a slight amount of astigmatism. This could be due to astigmatism of the anterior and posterior surfaces of the cornea and/or lens and/or due to lens tilt and/or decentration. Large amounts of astigmatism appears to be hereditary.²⁶

4.10.1 Comparison of tests

There has been little comparison of the various tests to determine astigmatic power and axis in the research literature and the study by Johnson and colleagues provides limited information and further study is needed (section 1.1.2).²⁷ Many practitioners use the Jackson cross-cylinder (JCC) test as it is simple and easy to use and is designed to fine tune the cylinder found in retinoscopy or autorefraction. The method described for fan-shaped tests often assumes that no

retinoscopy result is available and even if it is available, the retinoscopy cylinder is removed and you start from scratch. However, it is important to be able to use another subjective test for astigmatism in case a patient responds poorly to the demands of the JCC. Fan-shaped tests have an advantage over JCC in that accommodation is well controlled as the patient is fogged prior to the use of the procedure. They also do not require the patient to be able to memorise two pictures presented sequentially and compare them. They can be used to quickly determine if any astigmatism is present after the best vision sphere procedure by asking patients whether any of the lines look clearer (the block and fan looks like a clown's face if set up as in Figure 4.9 and can be used with children in this way: Ask 'Do any of the hairs on the clown's head look clearer than the others?'). However, fan-shaped tests should only be used if they include an arrow or dial to refine the precision of the axis estimation, otherwise they are significantly limited in sensitivity.²⁸ A very simple test to estimate the astigmatic axis is axis

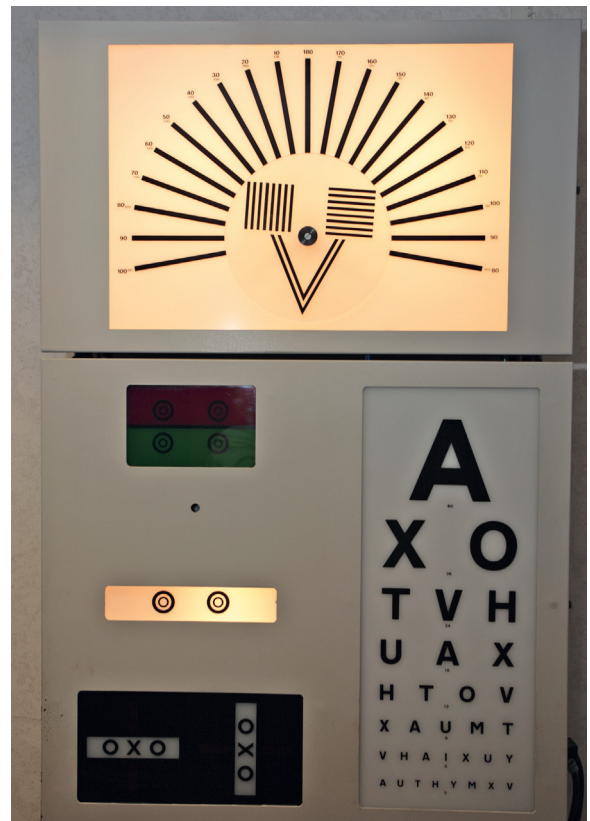


Fig. 4.9 A wall chart with the fan and block and Verhoeff ring targets illuminated.

rotation, which involves asking the patient to view the smallest line of VA they can see and rotating the correcting cylinder axis first clockwise and then anti-clockwise until the patient reports that the letters start to blur. The cylinder axis indicated by the technique is the mid-point between the two blur points so that if the two blur points are at 25° and 55°, the indicated cylinder axis is 40°. In patients where the subjective assessment of astigmatism is poor, it is advisable to consider multiple objective measures of astigmatism from retinoscopy, autorefraction, and (to a lesser degree and if the cylinder is not lens-induced) keratometry. The astigmatism present in the patient’s old spectacles should also be considered.

4.10.2 The Jackson cross-cylinder

The test only works if the circle of least confusion is on the retina so that it must follow a best vision sphere assessment. During the test you present two lenses to the patient, one after the other: when the correcting cylinder is not correct, one lens should increase the interval of Sturm and slightly blur vision and the other should decrease the interval of Sturm and slightly improve vision. The zero mean power of the cross-cylinder ensures that the circle of least confusion remains on the retina for both presentations. The effective axis shift is greater if the power of the correcting cylinder is low: A ± 0.25 JCC will shift the effective axis by $\pm 22.5^\circ$ when combined with a -0.50 DC, but will only shift the effective axis by about 7° when combined with a 2.00 DC.²³ Therefore when making changes based on patient responses to the JCC, the amount of rotation of the correcting cylinder should consider the power of that cylinder (Table 4.1).

Table 4.1 Estimated rotation of the cylinder axis for different cylinder powers when using the ± 0.25 Jackson cross-cylinder. This is based on the effective cylinder axis shift created²³

Power of the correcting cylinder (DC)	Estimated initial rotation required (± 0.25 JCC)
0.25	30°
0.50	20°
0.75	15°
1.00–2.00	10°
2.25+	5°

4.10.3 Procedure

See online videos 4.9 to 4.14.



1. Ensure that the best vision sphere is in place so that the circle of least confusion is on the retina: Use the MPMVA (section 4.7) or plus/minus technique (section 4.8) and check the end-point using the duochrome/bichromatic test (section 4.9). Some practitioners leave younger patients slightly over-minused/under-plussed ('on the green' with the duochrome) and assume that they will accommodate to bring the circle of least confusion onto the retina.
2. Isolate/indicate a circular letter or a line of letters one row above the present visual acuity. Alternatively, illuminate the Verhoeff rings (wall chart, Figure 4.9) or the collection of dots target (projector chart). Move the JCC in front of the trial frame/phoropter aperture (Figure 4.10).
3. Instruct the patient: 'I am going to show you two pictures of the * (target). Both pictures may be slightly blurred, but I want you to tell me which is the clearer of the two pictures, or whether they look the same'.
4. If cylinder was found with retinoscopy, proceed with step 6.
5. If there has been no cylinder found with retinoscopy, then set the JCC so that its minus cylinder axis (red dot) and the perpendicular plus cylinder axis (white dot) assume the 90° and 180° positions. It does not matter which dot

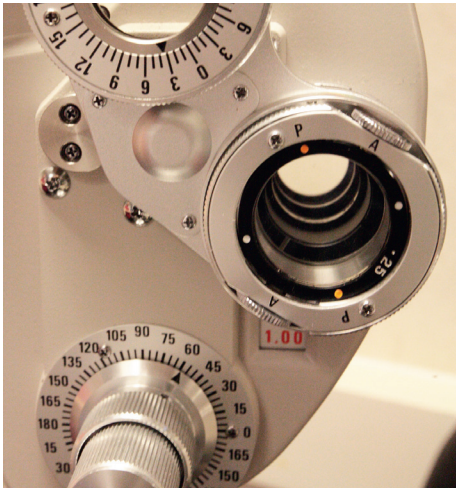


Fig. 4.10 A phoropter-based Jackson cross-cylinder set up to assess cylinder axis.

is at 90° and 180° . Refer to the current JCC orientation as 'Lens or picture 1'. Flip the JCC to reverse the positions of the minus and plus axes. Refer to this latter orientation as 'Lens or picture 2'. Note the orientation of the minus cylinder axis in the position which the patient reported that vision was best. Rotate the JCC so that the plus and minus cylinder axes assume the 45° and 135° positions (Figure 4.11). Repeat the above comparison and note the orientation of the minus cylinder axis of the chosen lens. If all the lenses seem equally clear, then there is no cylinder and you have completed the JCC test for this eye. If certain lens positions are preferred, then set the phoropter cylinder axis at or between the indicated axes (e.g., if minus cylinder was preferred at 180° and 45° , then set the correcting cylinder axis to the approximate midpoint, i.e. $\sim 25^\circ$). Place -0.25 or -0.50 D cylinder power in the phoropter and proceed with the next step. If you add -0.50 DC in older presbyopes, you should add $+0.25$ DS to the spherical lens to keep the circle of least confusion on the retina (younger patients should be able to accommodate to maintain the circle of least confusion on the retina).

6. JCC axis determination: Set the JCC so that the minus cylinder axis and the plus cylinder axis straddle the correcting cylinder axis (Figure 4.11). With modern phoropters the JCC will click into place at this correct orientation. Ask the patient to compare this initial lens position

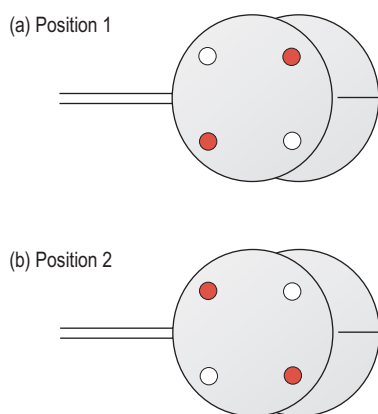


Fig. 4.11 Orientation of the cross-cylinder for axis determination in (a) 'picture or lens 1' and (b) 'picture or lens 2'.

'Lens 1', to its flipped counterpart, 'Lens 2' (Figure 4.11).

7. Adjust the correcting cylinder axes toward the minus cylinder axis (red dot) of the preferred lens position (1 or 2). The amount of rotation typically depends on the size of the cylinder (Table 4.1). This can be tempered by the response from the patient (see online video 4.12). For example, if the JCC response with a 1.00 DC was very strongly in favour of one lens/picture (and particularly if the visual acuity was down so that you suspect the astigmatism after objective refraction was incorrect by a significant amount), it may be better to rotate the cylinder by 10° or 15° rather than the 5° suggested in the table. Similarly, if the JCC response was weak and hesitant, you could make less of a change than that suggested in Table 4.1.
8. Repeat the comparison (use 'Lens 3 or Lens 4', etc., to indicate to the patient that you are not just repeating the previous presentation) and continue to adjust the axis dependent on the results. The amount of rotation of the cylinder should be reduced (approximately halved) at each change of the direction of rotation. For example, if a 0.25 DC was initially at 90° , and the JCC indicated a clockwise rotation was required, move it to 60° (Table 4.1). If the JCC then indicates that an anti-clockwise rotation was required, move the cylinder by 15° to the 75° position. Try to keep a mental note of previous decisions made with the JCC to help you 'zero-in' on the final axis. In the example above, if the JCC suggested another anti-clockwise movement was required, there would be little point in rotating the cylinder to 90° as the JCC has already been used at this position. Either 80° or 85° would be more appropriate. Continue until the patient notices no difference between the two lens positions (and you have bracketed the axis).
9. If the two *initial* lens positions appear the same, confirm that the current axis is the correct one by rotating the cylinder axes off by about the amount suggested in Table 4.1 and have the patient compare Lens 1 and 2 (see online video 4.10). The patient should return you to the initial axis orientation if it was correct. If they do not, they may have a range of cylinder axes positions in which the JCC positions look the same. In this case, you need to determine the extent of this range and place the cylinder axis

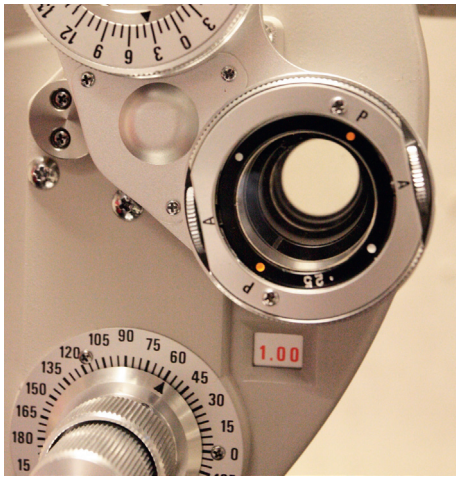


Fig. 4.12 A phoropter-based Jackson cross-cylinder set up to assess cylinder power.

in the middle of it (e.g., if the patient reports that the JCC positions look the same at 20° through to 40°, place the cylinder axis at 30°). You could also use a ± 0.50 JCC with such patients.

10. JCC power determination: Adjust the JCC so that either the minus axis (red dot) or plus axis (white dot) parallels the trial frame/phoropter cylinder axis (the JCC will click into place with modern phoropters; [Figure 4.12](#)). Have the patient compare the relative clarity of Lens 1 to Lens 2 ([Figure 4.13](#)).
11. If the patient reports that there is no perceived difference between the images shown, do not assume you have the correct power. Remove -0.25 D from the cylinder and repeat the comparison. If the initial lens was correct the patient will call for more cylinder by choosing the lens that has the minus cylinder axis (red dot) parallel to the phoropter axis. In this case, increase the cylinder power to its original amount. However, if you remove -0.25 DC and the patient again reports that there is no difference between the two pictures, the patient may have a range of cylinder powers in which the JCC positions look the same. In this case, you need to determine the least amount of cylinder for which the patient notices a difference with the JCC. You could also use a hand-held ± 0.50 JCC with such patients.
12. If there is a difference between Lens 1 and 2, then add minus cylinder (-0.25 D) if the patient prefers the minus cylinder axis (red dot) parallel

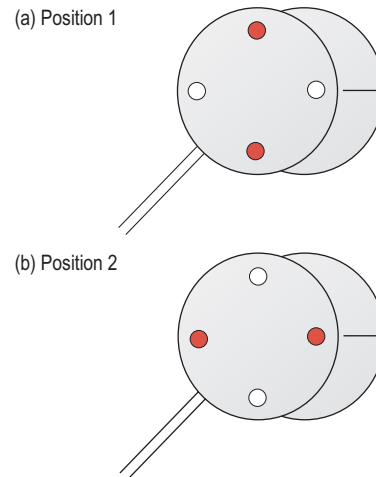


Fig. 4.13 Orientation of the cross-cylinder for power determination in (a) 'picture or lens 1' and (b) 'picture or lens 2'.

to the phoropter axis. Remove -0.25 DC if the patient prefers the plus cylinder axis parallel to the phoropter axis. Continue this process until no difference between Lens 1 and 2 can be detected or until the power has been bracketed to less than a 0.25 D (choose the least minus cylinder).

13. For each 0.50 D change in cylinder power, change the sphere power by 0.25 D in the opposite direction (e.g., if you add -0.50 DC, then add $+0.25$ DS before comparing the lens positions). This is to ensure that the circle of least confusion remains on the retina.

4.10.4 Poor JCC technique: 'Nudge, nudge, same'

This is a common technique used by students and means 'nudging' the cylinder axis by 10–15 degrees or so (essentially regardless of the cylinder power and not really knowing the exact value of the axis you have moved it to or from) in the direction indicated by the JCC until the patient first indicates that both views look the same. The cylinder axis position that first receives a 'same' response is taken as the true cylinder axis. This technique is inefficient and will lead to an incorrect result in some cases. A 'same' response from the patient may not indicate the correct cylinder axis for the following reasons (also see online video 4.11):

1. Accepting an initial response of 'same' to indicate that your retinoscopy cylinder axis was



correct can mean that you would be *incorrect* by 90°! For example, if the retinoscopy result gave a cylinder at 20°, yet the real cylinder was at 110°, the patient is likely to respond that the two images of the JCC look the same. Note that the JCC axes would be at 65° and 155° with a cylinder axis at either 110° or 20°. Unfortunately, it is not uncommon for novices to be incorrect in cylinder axis by 90° in retinoscopy.

2. Some patients have a range of axes over which they believe that the two JCC images look the same. In these cases, the axis should be placed in the middle of the range. For example, if the patient responded 'same' from 150° to 180°, the cylinder should be placed at 165°. Using the first 'same' response would likely place the cylinder axis at ~150° or 180°.
3. Patients can provide unreliable responses, especially during the first few presentations, so that a 'same' response could just be an incorrect response. You can be far more confident that you have obtained the correct cylinder axis if you have 'bracketed' it.

4.10.5 Examples of efficient JCC procedures for cylinder axis

Two simple examples are provided here, but there are a larger number of examples for JCC cylinder axis and power determination on the website. (see online videos 4.9 to 4.14).

1. **Use appropriate changes in axis and 'bracket' the final result**

Cylindrical axis before JCC: -1.25×80

- (i) The JCC is set so that the minus cylinder axis (position 1: 35°, position 2: 125°) and the plus cylinder axis straddle the correcting cylinder axis of 80° and is clicked into place at this orientation. The patient choice (minus cylinder axis at 35°) indicates that the correcting cylinder should be moved clockwise. As the cylinder is -1.25 DC, it should be moved clockwise by 10° (Table 4.1) from 80° to 70°.
- (ii) The patient choice indicates that the correcting cylinder should be moved clockwise again. Move it from 70° to 60°.
- (iii) The patient choice indicates that the correcting cylinder should be moved anti-clockwise. This is a change in direction of movement of the JCC, so the amount of

change of the correcting cylinder should be halved to 5°. The correcting cylinder should be moved 5° anti-clockwise to 65°.

- (iv) The patient cannot discriminate between the two lens positions and the true cylinder axis position has been determined. Note that this axis has been bracketed. i.e., appropriate responses with the JCC have been obtained slightly above (clockwise from 70°) and slightly below (anti-clockwise from 60°) the final axis.

Cylindrical axis changes during JCC were 80 – 70 – 60 – 65.

Cylindrical axis after JCC: -1.25×65

2. **Do not accept that an initial 'same' response suggests that the axis is correct.**

- (i) The correcting cylinder is $-0.75 \times 80^\circ$. The JCC is set so that the minus cylinder axis and the plus cylinder axis straddle the correcting cylinder axis of 80° and is clicked into place at this orientation. The patient cannot discriminate between the two lens positions and responds that they look the 'same'. However, there is no firm indication that the true cylinder axis position has been determined as this axis has not been bracketed (section 4.10.4).
 - (ii) Move the cylinder axis by ~10° to 70° as the cylinder power is -0.75 (Table 4.1) and if correct the 'same' response suggests you are close to the final axis. The patient choice indicates that the correcting cylinder is anti-clockwise from 70°.
 - (iii) To confirm 80° as the final cylinder, move the cylinder axis to 90°. The patient choice indicates that the correct cylinder is clockwise from 90°.
 - (iv) Appropriate responses with the JCC have been obtained slightly above (clockwise from 90°) and slightly below (anti-clockwise from 70°) the final axis. The final axis has therefore been 'bracketed' by appropriate responses.
- Cylindrical axis changes during JCC were 80(S) – 70 – 90.
- Cylindrical axis after JCC: -0.75×80 .

4.10.6 Adaptations to the standard procedure

If a patient has provided poor responses in other parts of the eye examination, it can be useful to repeat the

same JCC task to the patient at the start of the procedure until they start providing the same response each time. If accurate responses are never obtained, you may need to use a ± 0.50 JCC. A hand-held cross cylinder may be held over the phoropter in these cases. If a patient still cannot provide reliable answers, then you may need to use an alternative assessment of astigmatism.

4.10.7 Adaptations for older patients

1. **Use longer presentation times:** Processing speed slows significantly with age,²⁰ so provide a longer presentation time for both Lens 1 and Lens 2 than you would normally do for younger patients.
2. **Use a ± 0.50 JCC:** If a patient with reduced VA is unable to tell any difference with the ± 0.25 JCC, then use a ± 0.50 JCC or even a ± 1.00 JCC. A hand-held cross cylinder may be held over the phoropter in these cases.
3. **Ask for a response from two options:** It can be difficult for all patients and particularly older patients to make a decision when there are three possible responses of 'Lens 1', 'Lens 2' or 'the same'. Some clinicians just ask whether the image seen with Lens 1 or Lens 2 is better. Using such a technique, the patient often indicates at some point that the two presentations look the same. Alternatively, after the patient has confidently provided several responses of 'Lens 1' or 'Lens 2', they may hesitate and appear unsure. At this point you could ask whether the two presentations look the same.

4.10.8 Recording

The results of the JCC are not recorded as the technique is just part of the subjective refraction (section 4.6).

4.10.9 Interpretation

Solsona retrospectively analysed 51,000 patients with astigmatic corrections greater than or equal to 0.75 D and found that 67% had mirror symmetry within 10°. ⁷ This means that the two axes should add up to approximately 180°: Both axes could be 90° or both axes 180° (i.e. 0° and 180°); one axis 175°, the other 5°; one axis 20°, the other 160°; one axis 45°, the other 135°, etc. You may wish to recheck astigmatic axes that do not follow this pattern, particularly if one axis has changed significantly from a previous

examination or is significantly different from the retinoscopy result.

Typically, younger patients will have 'with-the-rule' astigmatism, with a steeper vertical meridian (minus cylinder axis between 160–20), likely due to pressure from the eyelids. This lid tension decreases slowly with age, so that with-the-rule astigmatism slowly disappears and older patients typically have 'against-the-rule' astigmatism (minus cylinder axis between 70–110).⁵ Note that this change with age is slow and any significant refractive correction changes between eye examinations 1–3 years apart are likely to be largely spherical in nature. Significant changes in astigmatism over a 1–3 year period are likely to be due to refraction error at test or retest or possibly due to ocular pathology such as keratoconus, cortical cataract, chalazion, etc., causing significant astigmatic changes.³

4.10.10 Most common errors

1. Using the 'nudge, nudge, same' technique (section 4.10.4).
2. Using too short a presentation time in older patients. Using a longer presentation time, and repeating the two views when the patient is unsure, can actually provide a quicker determination of the cylinder axis and power as the responses provided are more reliable.
3. Presenting the target for longer in position 2 compared to position 1 or vice-versa. The patient should see the two presentations for the same amount of time.
4. Poor alignment of the JCC with the correcting cylindrical lens in the trial frame. This can lead to problems in determining the cylinder axis. Check that the handle of the JCC is in alignment with the axis of the correcting cylindrical lens when determining the cylinder axis.
5. Believing that removal of the JCC in trial frame refraction is an option, i.e., offering 'position 1...2...or (removing the JCC) the same'.

4.10.11 Alternative techniques: Fan and block, sunburst, Raubitschek arrow, etc.

There are a variety of fan-shaped tests but all use a similar methodology. Those tests that do not include axis refinement using a rotating arrow or dial are not described as they provide poor estimates of cylinder axis and power.²⁸

1. Occlude the left eye.
2. Starting with the objective refraction result, perform BVS (sections 4.7 and 4.8; keep the cylinder found during retinoscopy in the phoropter/trial frame).
3. Remove the minus cylinder estimate from retinoscopy so that the patient is fogged (techniques that suggest you measure VA to estimate the approximate cylinder power with the best vision sphere result, assume that you do not have any estimate of the cylinder from retinoscopy or autorefractometry or the patient's old glasses or keratometry and this is a very rare situation).
4. In case the retinoscopy cylinder estimate was incorrect (and too low), add +0.50 DS to ensure that both focal lines are in front of the retina (this allows for an underestimation of the cylinder during retinoscopy of 1.00 DC). Larger amounts of additional plus can be used, but then it is likely that you will need to subsequently reduce this before the patient is able to see a difference in clarity in some of the lines on the fan.
5. Present the 'fan' to the patient and ask them to indicate which lines of the fan are clearest, if any (Figure 4.9). It can be helpful to indicate how these lines could be described by the patient: 'Are the lines at 2 o'clock clearest, or those at 10 o'clock?'
6. If the patient states that all the lines are equally clear, reduce the spherical correction in +0.50 DS steps and repeat the presentation of the fan.
7. If the patient states that some lines are clearer than others, rotate the arrow (or 'T' or dial) to point in the same direction as the clearest lines indicated by the patient.
8. Fine tune the arrow position by ensuring that the two sides of the arrow or dial are equally clear.
9. Ask the patient to compare the two blocks (Figure 4.9; or lines on the different parts of the T, etc.) and the blocks/lines in line with the arrow should be clearer than those that are perpendicular.
10. Increase the cylinder power until the two blocks or two parts of the T are equally clear. Provide the lowest cylinder power if the two blocks cannot be exactly matched in clarity.
11. Reduce the plus/increase the minus power of the sphere until maximum VA is achieved.
12. Refract the left eye.

4.11 BINOCULAR BALANCING

During monocular refraction, the occluder can induce proximal accommodation and accommodation due to vergence (by acting like a cover test) in the eye behind it, so that the eye being refracted may also be accommodating.²⁹ A binocular balance of accommodation is typically performed after a monocular refraction to relax and balance accommodation in the two eyes. The test need not be performed if the patient does not have binocular vision or if the patient is older than ~60 years of age or pseudophakic and has no accommodation, unless a recheck of the best vision sphere is thought to be useful.

4.11.1 Comparison of binocular balancing tests

There has been little comparison of the various binocular balancing techniques in the research literature and the study by West and Somers provides limited information and further study is needed (section 1.1.2).³⁰ Some tests directly compare the vision in the two eyes (prism-dissociation balance, alternate occlusion) and are directed towards balancing accommodation while others are based on binocular refraction techniques (e.g., polaroid, monocular fogging, Humphriss) and determine the spherical correction in conditions close to the patient's normal viewing situation.

The alternate occlusion test continues to use an occluder, acts like a cover test and does not allow binocularity, so that its usefulness over monocular refraction seems limited. The prism dissociated binocular balance is also fully dissociated, so that fusional vergence is not present and accommodation may not be at the same level when binocular.²⁹ Both these tests need the patient to have equal VA in the two eyes to be able to provide accommodative balance. Other tests, such as the Polarisation balance, monocular fogging and Humphriss immediate contrast test, are minimally dissociated and aim to determine the spherical correction in conditions similar to the patient's normal viewing situation so that vergence and pupil size are in their normal binocular state. Polaroid tests on computer-based systems are best if they include three lines of VA with a fusion lock line that is seen by both eyes. With only two lines, one seen by the right eye and one by the left, the lines may float freely and cause confusion. Fogging of one eye by a small amount in the monocular fogging technique has several advantages in that it relaxes accommodation and suppresses central vision whilst maintaining peripheral fusion. Both the polaroid dissociated (or prism-dissociated)

balance tests can be used with the duochrome (section 4.9), where balance is achieved by gaining the same endpoint in both eyes (i.e. red = green in both eyes, or 'just on the red' in both eyes).²⁹ The duochrome and monocular fogging techniques can balance accommodation in patients with unequal monocular VA. The Turville Infinity Balance, which is not described here, appears to be rarely used nowadays, although it has the advantage that the measurement procedure inherently includes a screening test for decompensated heterophoria and suppression. However, it requires physical movement of a septum on a mirror, which makes it somewhat cumbersome.

4.11.2 Procedure: Polaroid binocular balance of accommodation

Polaroid balance tests typically include several VA lines with one (or more, dependent on the programme) line seen by the right, left and both eyes, respectively. The line seen by both eyes provides a fusional lock.

1. Place the polarised filters before both eyes.
2. Add +0.50 DS to both eyes.
3. Ask the patient if the letters are clearer on the line seen by the right eye or left eye or if they are both the same.
4. If one line is clearer, add +0.25 DS to that eye until the two monocularly seen lines are equally blurred.
5. If a balance cannot be achieved, use the lenses that provide the best vision to the dominant eye (section 5.11.2 for dominancy testing) or the closest match.
6. Remove the polarised filters.
7. Remove the fog in binocular 0.25 DS steps until you obtain maximum visual acuity.
8. If the patient can read the bottom line of your chart (and this is larger than 6/3 or 20/10), you can allow extra minus/less plus that makes your bottom line of letters 'clearer'. Ensure that the bottom line of letters is 'definitely clearer and not just smaller and blacker.'

4.11.3 Procedure: Monocular fogging balance (modified Humphriss)

 See online video 4.15.

1. Fog the left eye until the visual acuity is reduced by 3 or 4 lines less than the tested eye. Typically +0.75 DS or +1.00 DS is required.
2. Repeat the best vision sphere assessment using the plus/minus technique (section 4.8).
3. If significant positive power needs to be added, such as for some patients with latent hyperopia, it is likely that this will relax accommodation in both eyes. To ensure that the amount of fogging lens is still effective add additional plus power to the left eye and check that visual acuity is blurred by 3–4 lines.
4. Remove the fog from the left eye then fog the right eye by 3 or 4 lines and repeat the plus/minus best vision sphere technique for the left eye.

4.11.4 Procedure: Humphriss Immediate Contrast

The following procedure is based on the technique described by Humphriss.³¹

1. Fog the left eye until visual acuity is reduced by 3 or 4 lines less than the tested eye. Young patients with normal vision would usually require adding +0.75 DS or +1.00 DS to give a visual acuity of 6/9 to 6/12 (20/40).
2. Ask the patient to look at the smallest line they can see on the letter chart (Humphriss suggested using a 6/12 or 20/40 letter but few clinicians follow this and the rationale is not clear).
3. Place a +0.25 DS lens in front of the right eye for about 1 second (or longer if the patient appears to need more time) and then replace this with a –0.25 DS for about 0.5 seconds (or half the time given to the +0.25 DS lens).
4. Ask the patient 'Are the letters clearer with Lens 1.....or Lens 2?'
5. Examples of the situation occurring in a fully corrected, slightly over-minused and slightly over-plussed eye are shown in Table 4.2. The image seen with each lens is determined by the clarity of the image in the clearer eye, modified by the effects of binocular summation.
6. If the patient immediately reports that the –0.25 DS is definitely clearer, repeat the demonstration of the lenses and ask if the –0.25 DS 'is definitely clearer or just smaller and blacker'. Only add –0.25 DS if the patient immediately reports that the lens is definitely clearer.
7. If the patient reports after some consideration that the –0.25 DS lens is clearer, do not add –0.25 DS.
8. If the patient reports that the +0.25 DS is clearer or that there is no difference, add +0.25 DS to the refractive correction.

Table 4.2 An indication of the changes made to the clearer eye and the interocular difference when either +0.25 DS or -0.25 DS is used with a +1.00 fogging lens in the Humphriss immediate contrast technique

	With the +0.25 DS lens		With the -0.25 DS lens	
	Clearer eye	Interocular difference	Clearer eye	Interocular difference
Corrected	+0.25 DS	+0.75 DS	-0.25 DS	+1.25 DS
Over-minused by -0.25 DS	Plano	+1.00 DS	-0.50 DS	+1.50 DS
Over-plussed by +0.25 DS	+0.50 DS	+0.50 DS	Plano	+1.00 DS

9. Because you have added +0.25 DS to the right eye, it is assumed that accommodation will have been relaxed in both eyes. To ensure that the amount of fogging lens is still effective add +0.25 DS to the left eye.
10. Continue to compare the -0.25 DS and +0.25 DS until the +0.25 DS is immediately rejected.
11. Repeat the procedure on the left eye with the right eye fogged.

4.11.5 Procedure: Prism-dissociated blur balance of accommodation



See online video 4.16.

1. Occlude the left eye (or ask the patient to close their eyes; the increasing diplopia produced by the prisms can be distressing) and isolate the 20/40 (6/12, 0.5) row of letters.
2. Introduce the Risley prisms before both eyes, so that there is 3^Δ base down before one eye and 3^Δ base up in front of the other eye. It is important that equal prism before each eye is used to equalise any image degradation by the prisms.
3. Add +1.00 DS to the right eye and check whether the 20/40 line is blurred. They should be blurred, but readable. Add further plus power in +0.25 D steps until the 20/40 is just blurred.
4. Remove the occluder (or ask the patient to open their eyes) and ask the patient if they see two 20/40 (6/12) lines of letters, one above the other.
5. If the patient cannot see both lines, first check that both apertures are open. If they are, cover each eye in turn, so that the patient can see the position of the line seen by each eye. The patient should then be able to see both targets at the same time. If the patient still cannot see two lines, then one eye is likely suppressing and a binocular balance is not required.
6. Add plus lenses in +0.25 DS steps to the left eye until both eyes have equally blurred images.
7. If a balance cannot be achieved, use the lenses that provide best vision to the dominant eye (section 5.11.2 for dominance testing) or the closest match.
8. Remove +0.25 DS from both eyes, and ask whether the two images remain equally blurred (you may need to isolate the 20/30, 6/9 line for this comparison). If one image is clearer, add +0.25 DS to the eye with the clearer image until both eyes have equally blurred images. If a balance cannot be achieved, use the lenses that provide the closest match.
9. Remove the Risley prisms (ask the patient to close their eyes while this is done) and display the bottom part of the visual acuity chart. Check the visual acuity to ensure that the best acuity line *has not* been achieved.
10. Remove the fog in binocular 0.25 DS steps until you obtain maximum visual acuity. If the patient can read the bottom line of your chart (and this is larger than 20/10, 6/3), you can allow extra minus/less plus that makes your bottom line of letters 'clearer'. Ensure that the bottom line of letters is 'definitely clearer and not just smaller and blacker.' This should be no more than -0.50 DS extra than the refractive correction used to see 20/20 (6/6).
11. Measure monocular and binocular VAs, especially if the binocular difference is more than 0.25 D from the monocular subjective. If monocular visual acuity is reduced in one eye following this procedure, recheck the results.

4.11.6 Recording

The monocular subjective refraction result and the correction after prism-dissociated balance can both be recorded with the accompanying VA results. Alternatively, the change in spherical power made with the binocular balance can be recorded. The binocular VA is also measured after the prism balance. For example:

Monocular subjective refraction

OD: +2.75/−0.75 × 175 20/15

OS: +1.75/−0.50 × 10 20/15

Prism balance

OD: +3.00/−0.75 × 175 20/15

OS: +2.00/−0.50 × 10 20/15

OU: 20/15

Monocular subjective refraction

RE: −1.50/−1.25 × 160 6/4.5

LE: −1.25/−1.00 × 20 6/4.5

Polaroid balance: +0.25 DS RE.

BE: 6/4.5

4.11.7 Interpretation

Typically, binocular balance tests either find no change in refractive correction from the monocular refraction result or find a small amount of additional positive lens power in one eye, or more rarely both. However, with latent hyperopia there can be a significant increase in the amount of plus accepted with this technique. This is because monocular subjective refraction can lead to possible over-minusing or under-plussing, particularly in patients with hyperopia, pseudomyopia and antimetropia, as the occluder can stimulate accommodation in the non-tested eye and thus an equivalent increase in accommodation in the eye being tested.

4.11.8 Most common errors

1. Binocularly balancing patients over 60 years of age and pseudophakes who have no accommodation to balance.
2. Binocularly balancing patients who do not have binocular vision or who have unequal visual acuity.
3. Prism dissociated blur: Using a truncated VA chart and not allowing extra minus/less plus that makes your bottom line of letters 'clearer'. This can lead to an over-plussed/under-minused refractive correction, particularly when associated with a MPMVA technique in older patients.²²
4. Monocular fogging and Humphriss Immediate Contrast: Using too large a fogging lens, such

as +1.50 DS or +2.00 DS (as used as a working distance lens during retinoscopy). It is possible that this degree of retinal image degradation could cause the accommodation system to adopt an open-loop response leading to stimulation of accommodation by around 1.00 D, rather than a relaxation of accommodation.³²

5. Monocular fogging and Humphriss Immediate Contrast: Failure to modify the fogging lens when +0.50 DS or more has been added to the fellow eye.
6. Humphriss Immediate Contrast: Presenting the +0.25 DS and −0.25 DS for an equal amount of time.

4.12 BINOCULAR SUBJECTIVE REFRACTION

Subjective refraction should be performed under conditions that simulate the patient's normal distance viewing situation (including vergence, accommodation and pupil size; although differences in pupil size do not affect refractive correction^{33,34}) as closely as possible. A major advantage of binocular refraction over monocular refraction is better control over, and greater relaxation of, accommodation. This is particularly important when measuring the refractive error in patients with hyperopia, pseudomyopia and antimetropia. In monocular refraction, the occluder can also act like a cover test and manifest any horizontal heterophoria (with associated changes in accommodation) and any vertical or cyclophoria that could lead to an incorrect assessment of astigmatism. Binocular refraction is also preferred in patients with latent nystagmus as the occluder used in monocular refraction manifests the nystagmus and makes subjective refraction difficult. Finally, binocular refraction has the advantage of being slightly quicker than monocular refraction because no binocular balancing is required.

Unfortunately, binocular refraction is not possible with a small number of patients. For example, some patients with highly dominant eyes find it very difficult to give good subjective responses with their non-dominant eye during binocular refraction, and these patients are better refracted monocularly. In addition, some binocular refraction techniques provide difficulties to some patients. For example, patients with cataracts can find polaroid binocular refraction difficult because of the reduced illumination provided by the polarised filters. Finally, binocular refraction only

works efficiently if the refractive corrections are reasonably close to the optimal correction at the start of the procedure. It is therefore often used for contact lens over refraction where the residual prescription is likely to be small. However, inexperienced students, whose retinoscopy skills still need practice, should use monocular refraction until their retinoscopy skills improve. Clearly, the technique can only be used with patients that have binocular vision. Refraction can be performed binocularly using monocular fogging (modified Humphriss), Humphriss Immediate Contrast (HIC), and polaroids. The polaroid, monocular fogging and HIC techniques for binocular balancing have already been described and their advantages discussed. Monocular fogging refraction can only be used with the plus/minus technique (section 4.8) and JCC, as MPMVA determination of the best vision sphere and fan and block determination of astigmatism require the tested eye to be blurred. Polaroid refraction, with for example the AO Vectographic system, uses a chart that has letters on one half polarised at, say, 90 degrees and letters on the other half polarised orthogonally (in this example at 180 degrees). The patient views the chart with polaroid filters that transmit the letters from one half of the chart to one eye and the other half of the chart to the fellow eye. Light from the background of the chart and a central vertical bar is transmitted to both eyes. This technique provides all the advantages of binocular refraction. Disadvantages include that the light transmitted by the polarising filters is reduced by 50%. This makes the letters of slightly lower contrast than normal and this can be a problem when refracting patients with some conditions such as cataract. Another problem is that it can be difficult to economically produce polarised letters in very small sizes below 20/20 or 20/15.²⁸

4.12.1 Procedure: Monocular fogging

1. Begin with the net retinoscopy sphere-cylinder before each eye. The patient's distance PD should already be set in the phoropter or trial frame, which should be level and positioned appropriately.
2. Explain the procedure to the patient: 'During this test, I will place various lenses in front of your eye to find the lenses that give you the best vision. Don't worry about giving a wrong answer as everything is double checked.'
3. The subjective refraction traditionally begins on the right eye (or the poorer eye if you determine there may be a poor eye from the case history).
4. Occlude the right eye and fog the left eye until the visual acuity is reduced by 3 or 4 lines less than the tested eye. Typically +0.75 DS or +1.00 DS is required. Remove the occluder from the right eye.
5. Determine the best vision sphere (sections 4.7 or 4.8) and cylinder power and axis using the JCC (section 4.10). Check the end result sphere using the duochrome (section 4.9) and measure VA.
6. Remove the fogging lens from the untested eye and fog the right eye. Determine the optimal subjective refractive correction in the left eye using the plus/minus technique and JCC and measure VA.
7. Remove the fogging lens and measure binocular VA.
8. Compare the monocular VAs with the habitual VAs and age-matched norms and measure the vertex distance if required (section 4.12.3).

4.12.2 Procedure: Polaroid binocular refraction

1. Begin with the net retinoscopy sphere-cylinder before each eye. The patient's distance PD should already be set in the phoropter, which should be level and positioned appropriately.
2. Explain the procedure to the patient: 'During this test, I will place various lenses in front of your eye to find the lenses that give you the best vision. Don't worry about giving a wrong answer as everything is double checked.'
3. The subjective refraction traditionally begins on the right eye (or the poorer eye if you determine there may be a poor eye from the case history).
4. Place the polarised filters before both eyes and direct the patient to the chart that is seen by the right eye
5. Determine the optimal subjective refractive correction in the right eye using your preferred techniques for best vision sphere and astigmatism assessment (sections 4.7 to 4.10) and measure VA.
6. Repeat for the left eye after directing the patient to the chart that is seen by the left eye.
7. Remove the polarised filters and measure binocular VA.
8. Do not perform a binocular balance as accommodative balance can be assumed.
9. Compare the monocular VAs with the habitual VAs and age-matched norms and measure the vertex distance if required (section 4.12.3).

4.12.3 Check tests after refraction

1. Compare monocular VAs after your refraction with the patient's vision or habitual VAs as appropriate. If the VA is better with the patient's spectacles, then it is likely that your subjective result is incorrect. Repeat the subjective refraction (students should perhaps call their supervisor).
2. Compare the VA with the present subjective refraction with age-matched normal data (Table 3.1). If the VA is worse than expected, or worse in one eye compared to the other, remeasure the VA with a pinhole aperture. If the VA improves with the pinhole, either the patient has media opacity, typically cataract that is being bypassed by the pinhole, or the subjective refraction is not optimal and should be repeated. Note that visual acuity will not always improve with cataract, particularly if the opacity is dense and central.
3. If the final refractive correction in either eye is above 5.00 D mean sphere equivalent (MSE, the sphere plus half the cylinder; e.g., $-4.75/-1.50 \times 180$ has an MSE of -5.50 D, $+5.50/-2.00 \times 90$ has an MSE of $+3.50$ D), then measure the vertex distance. This is the distance from the back surface of the lens nearest the eye to the apex of the cornea. Back vertex distance can be read from the millimetre scale on the side of the trial frame, from the back vertex distance periscope on the side of the phoropter, or by using a vertex distance gauge.

4.12.4 Adaptations to the standard procedure

Patients do not give perfect answers

The techniques listed above and described in the previous sections assume that the responses provided by patients are always correct. Of course, it is seldom that they are always perfect. This can be detected during the subjective refraction when responses to the same changes in spherical power or JCC can be different at different times or with experience it can be expected in patients whose responses to other procedures within the eye examination have been poor. It can be useful in such patients to give some 'training' to help patients provide more accurate responses. This can be done by repeatedly presenting the same task to the patient (in the best vision sphere assessment or JCC) until they start providing the same response each time. If accurate responses are never

obtained, you may need to change the power of the spherical lens changes and/or JCC as indicated below.

Patients providing unreliable responses

Make sure that your instructions are accurate and technique is competent. If a patient is providing unreliable responses or is unable to tell any difference with ± 0.25 DS or a ± 0.25 JCC, then use ± 0.50 DS or a ± 0.50 JCC or even larger steps. If responses remain unreliable you may need to use other techniques. It would also be advisable to obtain additional objective information if available.

Patients with reduced visual acuity

Similarly, if a patient with reduced monocular or binocular VA is unable to tell any difference with ± 0.25 D, then use ± 0.50 DS or a ± 0.50 JCC or even larger steps using a trial frame. It is well understood that such procedures should be used for patients with visual impairment. However, the same applies for any eye with reduced vision (e.g., patients with a unilateral amblyopic eye or unilateral cataract).

Hyperopes, pseudomyopes and antimetropes

In these patients, perform a binocular add technique after the binocular balance: place $+0.25$ DS in front of BOTH eyes, and ask if the letters become clearer, more blurred or are unchanged. As before, if the acuity improves or *remains the same* with the additional plus, then continue adding $+0.25$ DS binocularly until the acuity first blurs. Stop at the most plus/least minus lens that does not blur the visual acuity. If the binocular visual acuity blurs with the $+0.25$ DS lenses, then do not add them.

4.12.5 Recording

For example:

Binocular refraction (vertex distance 12 mm)		
RE: $-8.00/-1.00 \times 45$	6/5 ⁺²	
LE: -7.25 DS	6/5	BE: 6/5 ⁺³
OD: $+2.75/-0.50 \times 95$	20/15 ⁻³	
OS: $+2.00/-1.25 \times 82.5$	20/20 ⁺¹	OU: 20/15
(Vertex distance 12 mm)		
OD: $-7.50/-2.25 \times 35$	20/70	PHNI
OS: $-8.00/-1.50 \times 150$	20/20 ⁺²	

Make sure that the prescription details that you provide to patients are clearly legible. Illegible prescription forms have been reported as a surprisingly common error in optometric practice.⁶

4.12.6 Interpretation

A subjective result that is significantly less positive (more negative) than the retinoscopy result or a subjective result more minus than suggested by unaided visual acuity could indicate latent hyperopia or pseudomyopia and a cycloplegic refraction may be required (section 4.13).

The difference between the patient's own spectacles and the subjective refraction should be compatible with the difference between the habitual (with own spectacles) and optimal VAs. For example, if the patient has a visual acuity of 6/12 in their spectacles and 6/4.5 after subjective refraction, you could expect the subjective refraction to be 1.00 DS more myopic than the spectacle correction ($-0.25 \approx 1$ line of logMAR visual acuity). Thus, a 6/12 VA with a spectacle correction of $-1.00/-0.50 \times 180$ would suggest a refractive correction of $-2.00/-0.50 \times 180$. If the subjective refraction was $-2.50/-0.50 \times 180$ or even $-3.00/-0.5 \times 180$, this could suggest you have over-minused the subjective refraction. Changes in hyperopic refractive errors are more difficult to explain in this way, as they are dependent on the amount of accommodation the patient has (and therefore their age). Changes in astigmatism that are not due to pathology are usually small.⁵ Patients with refractive error change that is a result of cataract or other eye disease will not typically follow the same rules for improvement in visual acuity (e.g., nuclear cataract can cause a 1.00 D myopic shift with only a 1–2 line improvement in visual acuity).

A patient with reduced VA (typically in both eyes) and a retinoscope result that indicates emmetropia or slight hyperopia may have non-organic visual loss (also called functional or psychogenic visual loss).^{35,36} It may be accompanied by visual field defects, which are often tubular.³⁶ In young children, this is often because the child wishes to wear glasses (perhaps their best friend or a parent wears glasses), but can be due to social problems at home or school and can include sexual abuse.^{35,36} In adults, non-organic visual loss is linked with trauma (typically head trauma), chronic pain conditions including migraine and underlying minor psychiatric problems that included feelings of stress, anxiety and depression.³⁶ A useful test, particularly with children, is to perform a subjective refraction using a variety of lenses that have no effect on VA (such as a combination of +0.25 DS and -0.25 DS in a trial frame) and encourage the patient to read further down the VA chart. In many cases, the patient can be encouraged to read normal or near normal VA in this way and if ocular health appears normal, a diagnosis of non-organic visual loss can be

made and reassurance given to the child and parent (section 2.4.2).

4.12.7 Most common errors

1. Not monitoring the visual acuity to ensure that a change in lens power results in the expected change in visual acuity.
2. Using poor patient instructions or leading questions.
3. Not checking a subjective refraction that leads to sub-optimal visual acuity with a pinhole.
4. Not recording the vertex distance with a refractive correction above 5.00 DS.

4.13 CYCLOPLEGIC REFRACTION

This involves a determination of the refractive error when the patient's accommodation has been totally or partially paralysed using a cycloplegic drug.

4.13.1 When is a cycloplegic refraction necessary?

A cycloplegic refraction may be necessary if there are any indications of excessive or fluctuating accommodation during the refraction. Accommodative fluctuations can lead to wholly incorrect results of objective and subjective refraction. In addition, excessive accommodation, particularly during subjective refraction, can lead to a very over-minused (or under-plussed) refractive correction. Indeed, a myopic refractive correction can be found in a hyperopic patient due to excessive accommodation during refraction and such patients are defined as pseudomyopes.

The following can indicate the need for a cycloplegic refraction:

- Accommodative problems suggested in the case history (for example, difficulty changing focus, distance vision blur after a lot of near work).
- Patients with esotropia or convergence excess esophoria.
- Accommodative fluctuations indicated by a fluctuating pupil size and/or reflex during retinoscopy.
- A retinoscopy result significantly more positive (>1.00 DS) than the subjective result.
- A subjective result significantly more minus (>1.00 DS) than suggested by unaided visual acuity.
- A patient with myopia and esophoria.

- Of course, cycloplegic refractions are only used with patients who have accommodation, and usually with those who have the most accommodation: children. The least toxic drug and the lowest dosage (concentration and number of drops) that will produce sufficient cycloplegia should be used. Other assessments of the accommodative system are required (sections 6.9 to 6.11) if the cycloplegic refraction result is unrevealing.

The key disadvantages of cycloplegia are the temporary symptoms of blurred vision and photophobia experienced by patients. The degradation of vision is caused by the abolition of the accommodation response and increase in ocular aberrations as a result of dilated pupils. Adverse effects and allergic reactions to cyclopentolate are rare and the severe reactions such as psychosis, hallucinations, ataxia and incoherent speech have only been reported for the 2% concentration (or multiple drops of 1%), which should be avoided.³⁷ In all cases, choose the drug with the least possible adverse effects and the lowest concentration that will allow you to efficiently attain the cycloplegia that you require. For example, research has suggested that cyclopentolate 1% is sufficient to produce good cycloplegia, with an effect similar to atropine 1%, in patients with accommodative esotropia and that tropicamide 1% is as effective as cyclopentolate 1% for the measurement of refractive error in most healthy, non-strabismic infants.^{38,39}

1. It is often useful to attempt a 'dry' (non-cycloplegic) binocular refraction first as this can provide very useful information (interpretation, [section 4.13.5](#)).
2. Obtain informed consent: Explain why you want to use a cycloplegia and explain the visual effects (near vision blur, pupil dilation and increased light sensitivity) and their duration (dependent on the drug used and the dosage). Also tell the patient that the drops will sting a little initially, but that the stinging will disappear.
3. Unless there are indications that suggest the possibility of a narrow anterior angle (such as high hyperopia or anterior segment

abnormality), it may be unnecessary to conduct a full examination of the anterior angle prior to cycloplegic instillation. Cycloplegia is typically performed on young children who will have wide anterior angles due to the thin nature of the lens in childhood. The 'shadow test' (section 7.5) is easier to perform with young children and will often suffice.

4. Instil an appropriate cycloplegic drug (section 7.8).
5. Ask the patient to sit in the waiting room for about 20 (tropicamide) to 30 minutes (cyclopentolate) until the drug has obtained maximum or near maximum effect. Check that sufficient reduction in accommodation has been obtained by quickly checking the patient's amplitude of accommodation. Anisocoria could indicate unequal cycloplegia. Add another drop if sufficient accommodation reduction has not been obtained.
6. Perform retinoscopy and/or autorefractometry in the usual way. If subjective refraction is not possible, it is useful to have both objective measures. When performing retinoscopy, you must concentrate on the central 3–4 mm of the pupil. The peripheral part of the pupil may show a different reflex motion due to aberrations and these should be ignored. Often, a cycloplegic refraction is performed on young children, so that the refraction ends after retinoscopy and/or autorefractometry.
7. Subjective refraction should be attempted if possible.

Record the cycloplegic used and the time of instillation. Then record the refraction results (retinoscopy and subjective if both used) in the standard manner, with the approximate time of the refraction. As an alternative to noting the times of instillation and refraction, you could note the period of time the refraction was performed after instillation of the cycloplegic.

For example:

2.30 pm: 2 drops cyclopentolate 0.5%
Retinoscopy, 3.00 pm: RE: +2.00 DS 6/6⁻²
LE: +1.75/-0.50 × 180 6/6⁻³
1 drop tropicamide 1%, refraction 20 minutes after
instillation.
Retinoscopy: OD: +1.75/-1.00 × 170 20/20⁻²
OS: +1.25/-0.50 × 7.5 20/20⁻¹
Subjective: OD: +1.50/-1.00 × 170 20/20⁻¹
OS: +1.00/-0.50 × 7.5 20/20

4.13.5 Interpretation

Clearly there are limitations to many of the measurements made in 'dry' (non-cycloplegic) refractions of patients with excessive or fluctuating accommodation, but there are also limitations in 'wet' (cycloplegic) refractions and all must be considered when prescribing and deciding on the best patient management. During wet retinoscopy it is vital to concentrate on the reflex in the central 3–4 mm and ignore the reflex in the periphery that is influenced by peripheral aberrations. For this reason it can be particularly useful to obtain two objective measures of cycloplegic refractive and use both retinoscopy and autorefraction. Autorefraction provides a particularly accurate assessment of refractive correction under cycloplegia in children.^{15,16} Also note that the cycloplegic VA is likely to be slightly reduced compared to the VA after a dry refraction due to the peripheral aberrations.

In some patients, the VA after dry retinoscopy can provide useful information about the VA the patient will likely obtain in new spectacles if the full cycloplegic refraction is prescribed. During retinoscopy there is little stimulus for patient accommodation, unlike during subjective refraction, so that the retinoscopy result is typically significantly more hyperopic (or less myopic) than subjective. Therefore, the VA measured after dry retinoscopy is often reduced. However, note that this is because the patient cannot appropriately relax their accommodation during the subjective refraction and the refractive correction found with retinoscopy is likely to be more accurate. It is important to record both the retinoscopy result and the subsequent VA as it can give an indication of the likely distance VA with any new spectacles. Here is an example:

The 12-year-old patient complains of distance vision blur and frontal headaches after a lot of close work.

Dry retinoscopy:	RE: +1.50/−0.50 × 165	6/18 ⁻¹
	LE: +1.75/−0.75 × 15	6/12 ⁻²
Dry subjective:	RE: −0.25/−0.50 × 170	6/5
	LE: Plano/−0.75 × 15	6/5 ⁻²
Autorefraction:	RE: Plano/−0.50 × 170	6/6 ⁻¹
	LE: +0.25/−0.75 × 12.5	6/6 ⁻²

This large reduction in hyperopia from retinoscopy to dry subjective is indicative of active accommodation during the subjective refraction. In this particular case the subject has become a slight pseudomyope. The difference between a pseudomyope and latent hyperope is small; both are due to accommodative spasm, but the latent hyperope is hyperopic in the dry subjective and the pseudomyope is myopic. Due to proximal accommodation effects, these types of patients provide

autorefractor results more similar to the dry subjective results than to retinoscopy. Clearly a cycloplegic refraction is required:

Grade IV (shadow test), 2 drops cyclopentolate 0.5% (2.30 pm):

3.00 pm wet refraction:

Retinoscopy:	RE: +2.00/−0.50 × 180	6/6 ⁻³
	LE: +2.00/−0.50 × 180	6/6 ⁻²
Subjective:	RE: +1.75/−0.50 × 175	6/6
	LE: +1.75/−0.50 × 5	6/6
Autorefraction:	RE: +2.00/−0.50 × 165	6/6 ⁻¹
	LE: +1.75/−0.75 × 10	6/6

The cycloplegic results confirm that the dry subjective and dry autorefractor results were incorrect and due to the patient's inability to relax accommodation. What should you prescribe? The dry retinoscopy results indicate that if you prescribed the full cycloplegic result, the patient would initially see about 6/18 in each eye. Without the cycloplegic, the patient would be unable to relax accommodation and would see very poorly in the distance. This would improve over time as the hyperopic spectacles helped the patient to relax accommodation, but the blur could be a disincentive to initially wearing the spectacles and this should be considered. A compromise prescription may work:

RE: +1.00/−0.50 × 165 LE: +1.00/−0.75 × 10

This is likely to initially blur distance VA to about 6/9+, which the patient should be able to cope with, yet will sufficiently relax the accommodation to improve the patient's symptoms. The patient should be seen within about a month and the prescription could be increased at that point if required. The effect on symptoms, visual acuity and binocular vision should be considered when deciding on the amount of hyperopia to correct in a young person with accommodation.

Even more than for routine refraction results, you should not automatically prescribe the results found in cycloplegic refraction to the patient, although this may be required for patients with accommodative esotropia. A reduced amount of plus power is usually prescribed to compensate for ciliary muscle tonus. For infants and young children, a full hyperopic correction may not be given to ensure emmetropisation is not hindered,⁴⁰ and the fact that hyperopia is normal for infants.

4.13.6 Most common error

Neutralising the retinoscopy reflex seen for the whole of the pupil. The periphery of the reflex should be ignored, and you should concentrate on the centre

of the pupil when interpreting retinoscopy reflex movements.

4.13.7 Alternative procedure: Mohindra near retinoscopy

Mohindra near retinoscopy was developed as an alternative to cycloplegic refraction in children and infants.⁴¹ It may be used when a cycloplegic refraction is contra-indicated or when it is extremely difficult to instil the drops. A dim retinoscope light is used as a fixation target and seen in complete darkness it provides little stimulus to accommodation, so that patients assume their resting focus due to tonic accommodation. This is typically +0.75 DS, so that when working at 50 cm, −1.25 DS rather than the standard −2.00 DS (i.e. the working distance lens) is added to the final retinoscopy result.⁴¹ You need to dim the retinoscope light as low as possible while ensuring it still provides you with an easily visible retinoscopy reflex. Turn off all room lights and perform retinoscopy using a lens rack or individual trial case lenses. An infant will only hold a steady gaze for a short period of time, so that you need to perform the test quickly. The standard technique is to occlude the non-fixating eye using your hand or the parent's hand. However, this can cause infants to become agitated and even begin to cry, so that performing the test binocularly may be preferable in some cases.³⁹ Some studies that have compared Mohindra near retinoscopy with cycloplegic retinoscopy have indicated that the test is variable and should not be used while others have suggested that the test is comparable to cycloplegic retinoscopy.^{39,42} It would appear that to become competent with the technique, it needs to be performed regularly and this is a disadvantage for the primary care optometrist who only occasionally examines an infant.³⁹ Saunders and Westall recommend adding −0.75 DS for infants (<2 years) and −1.00 DS for children (over 2 years) rather than the original −1.25 DS.⁴²

4.14 THE READING ADDITION

4.14.1 Presbyopia and the reading addition

About the age of 40–45 years of age (earlier for some ethnic groups, people with short arms or working distances and hyperopes, later for people with long arms/working distances and myopes) most people become presbyopic.^{43,44} This means that they do not have enough accommodation to be able to read or perform other near work clearly and comfortably. These patients require a positive lens addition to the

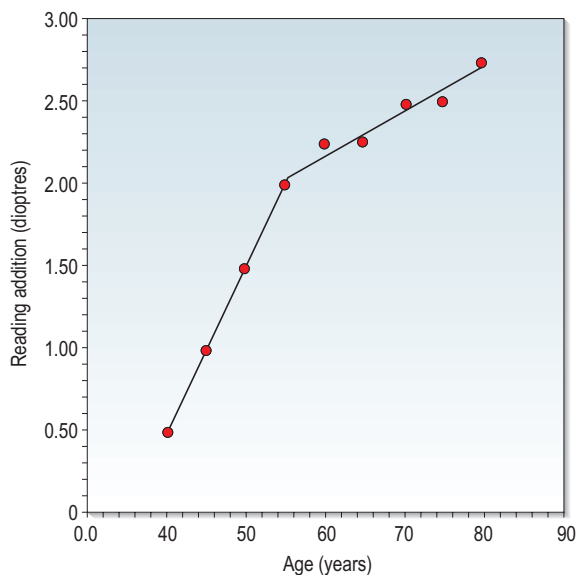


Fig. 4.14 The near addition as a function of age from the data of Pointer⁴⁴ and Blystone.⁴⁶

distance refractive correction. This is called the reading or near addition. With increasing age and further losses in accommodation, the power of the reading addition needs to be increased. At 55–60 years of age, accommodation is essentially zero (what can be measured clinically is probably depth of focus).⁴⁵ Although the average reading addition continues to increase after age 60 years, it does so at a slower rate (Figure 4.14) and is likely due to the increases in add needed by some older subjects due to a reduced working distance that is required to improve vision to compensate for reduced visual acuity.^{43,44,46,47}

4.14.2 Comparison of tentative addition techniques

A determination of the reading addition begins with a tentative addition being determined prior to refinement. This is similar to using an objective measurement of refractive correction (retinoscopy, autorefraction) as a starting point for subjective refraction of the distance correction.

In a very useful study, Hanlon et al. determined the required reading addition of 37 dissatisfied patients who returned to a university clinic due to improper add power.⁴⁸ From the case history information in the review (recheck) examination, it was determined whether the improper addition was too low or too high. For each patient, their reading addition was then determined using four methods (age, ½ amplitude of

accommodation, NRA/PRA balance and binocular cross-cylinder). The percentage of additions for each test that gave the same result as the improper addition or worse (higher than an improper addition determined too high or lower than an improper addition determined as too low) was determined. They reported that the simplest and quickest test, asking the patient their age, accounted for the fewest errors (14%). The other techniques gave errors in 61% (binocular cross-cylinder), 46% (NRA/PRA) and 30% ($\frac{1}{2}$ amplitude) of cases. This suggests that for most patients the tentative addition should simply be based on age. Over the age of about 55 years, the patient's working distance appears to determine their addition as accommodation is zero, so this can be a useful additional measurement in patients of this age.⁴⁷

The tentative add estimates based on accommodation tests provide an estimate for both eyes and unequal estimates of the tentative addition in the two eyes can indicate that the distance refractive correction has not been adequately balanced and needs to be rechecked. This 'double checking' of the spherical powers of the distance refraction in presbyopes may be an advantage to inexperienced refractionists. Note that for patients over 60, these tests are measuring depth of focus and not accommodation, which is zero.

Another alternative for experienced clinicians, would be to use the patient's symptoms with their old near correction, which is similar to the test used by Hanlon and colleagues⁴⁸ to determine if additions were low or high; i.e. their gold standard test.

4.14.3 Comparison of techniques for determining the final reading add

An incorrect reading addition is a common cause of patients' unhappiness with their new spectacles, although progressive addition lenses may have decreased the number of problems in recent years as they are more forgiving of over-plussed near corrections.^{22,48,49} To help to avoid such complaints, it is important to determine the range of clear near vision required by the patient and prescribe spectacles that fulfil those requirements. It is difficult to determine appropriate near working distances and ranges in a phoropter and an addition determination using a trial frame with trial case lenses is recommended.

4.14.4 Procedure: Tentative addition by age and working distance

Estimate the tentative reading addition by age and working distance.

Table 4.3 Tentative near addition estimates as a function of age up to the age of 60 years. These estimates should be adjusted for working distances. Patients with longer working distances will need a slightly smaller add and vice versa

Patient age (years)	Tentative add (D)
45	+1.00
50	+1.50
55	+2.00
60	+2.25

1. For patients less than 60 years of age: Age is a good predictor of the tentative addition and suggested values that are given in Table 4.3.⁴⁸ If the working distance is much less than 40 cm, increase the tentative addition appropriately. For example, if the working distance is about 33 cm increase the addition by +0.50 (the difference in dioptric terms between 40 cm or 2.50 D and 33 cm or 3.00 D). If the addition is needed for computer work and therefore the working distance is about 50–60 cm, decrease the tentative addition by about +0.50 DS.
2. For patients over 60 years of age: Estimate a tentative reading addition from the patient's working distance, with a small reduction made to allow for depth of focus.⁴⁷ In this way, working distances of 50, 40 or 33 cm (dioptric values +2.00, +2.50 and +3.00) indicate tentative additions of +1.75, +2.25 or +2.50 DS, respectively, with higher additions allowing slightly more for depth of focus.⁴⁷

4.14.5 Procedure: Tentative addition as a proportion of the amplitude of accommodation

This is most useful for presbyopes less than 55 years of age. In older patients, their accommodation is essentially zero and age-related pupillary miosis means that any measurement of amplitude of accommodation essentially measures their depth of focus, and the rules become less useful.

1. Measure the amplitude of accommodation (section 6.9).
2. Calculate the tentative reading addition from the following calculation:

Tentative reading addition = working distance in dioptres – $\frac{1}{2}$ of the amplitude of accommodation in dioptres (some clinicians subtract $\frac{2}{3}$ of the amplitude).

4.14.6 Procedure: Binocular or fused cross-cylinder

1. Adjust the phoropter to the near PD, occlude the untested eye (typically OS) and position the cross-hatch target at the patient's working distance (or 40 cm).
2. If the patient has significant astigmatism (>1.50 DC), check that the horizontal and vertical lines of the target appear equally clear. If they do not, the astigmatic correction should be rechecked at distance. If equal clarity can still not be achieved, the astigmatic correction should be checked at near.
3. Dial the cross-cylinder (+0.50/−1.00 × 90) into the phoropter.
4. If the expected addition is high ($>+2.00$ DS) add +1.00 DS to the distance correction. Ask the patient to close their eyes while you dial the extra power into the phoropter.
5. Ask the patient: 'Are the lines running up and down or those running from side-to-side clearer?' The presbyopic patient should report that the horizontal lines are clearer.
6. Add plus lenses in +0.25 DS steps until the patient reports that the vertical lines are just clearer than the horizontal.
7. Repeat steps 2 to 6 for the other eye.
8. If the tentative addition for each eye differs, recheck the results. If they remain different, the binocular balance of the distance refractive correction should be rechecked.
9. Allow both eyes to see the target and reduce the plus power in both eyes until the horizontal and vertical targets appear equally clear.

4.14.7 Procedure: Balancing negative and positive relative accommodation (NRA/PRA)

1. Adjust the phoropter to the near PD and attach the near point card. Make sure that the optimal distance refractive correction is in place and that both eyes can view the near point card.
2. Direct the patient's attention to letters one or two lines larger than their best near VA on the near point card. Ask the patient if they are clear. If they are not clear, add plus sphere power,

+0.25 D at a time, until the patient reports that the letters are clear. This becomes the 'initial tentative near addition'.

3. Negative relative accommodation (NRA): Add plus lenses binocularly, +0.25 D at a time, until the patient reports the first sustained blur. 'First sustained blur' means that the patient notices that the letters are not as sharp and clear as they were initially, even if the patient can still read them. The total amount of plus added is the NRA.
4. Return the lenses in the phoropter to the 'initial tentative near addition' found in step 2.
5. Positive relative accommodation (PRA): Add minus lenses binocularly, −0.25 D at a time, until the patient reports the first sustained blur. The total amount of minus added is the PRA.
6. Adjust the 'initial tentative near addition' that would provide equality for NRA and PRA. The adjusted figure is the 'final tentative addition'. For example, if the 'initial tentative near addition' was +1.00 and sustained blur points were found with a +2.00 and a +0.50 add, the NRA would be +1.00 (2.00−1.00) and the PRA would be −0.50 (0.50−1.00). A 'final tentative near addition' of +1.25 DS would equalise the NRA and PRA (they would both be 0.75 DS). The change suggested by the NRA/PRA is their algebraic sum divided by two. In this example, that would be $0.50/2 = +0.25$ DS.

4.14.8 Procedure: Tentative addition using the patient's symptoms and habitual correction

This technique is best described by using some examples.

Example 1: 50-year-old patient, wearing bifocal spectacles:

RE +1.00 DS 6/9
LE +1.00 DS 6/9

Reading addition +1.25D. N5 with difficulty R and L. Students must remember that patients read through their near vision correction (distance refractive correction + reading addition) and NOT their reading addition. The refractive correction for near is RE: +2.25 DS, LE +2.25 DS. Given that the average change in distance spherical refractive correction with age in presbyopes who do not develop nuclear cataract is a hyperopic shift,⁵⁰ a common change for the patient in the example above is for the distance correction to change to:

RE: +1.50 DS 6/5 LE +1.50 DS 6/5.

Table 4.4 Tentative addition based on patient symptoms and habitual near correction from example 1

Symptoms regarding near vision	Tentative addition	Tentative addition
1 Difficulty reading, blurred near vision, easier if near work held further away	One that provides NV Rx of +2.75 DS	+1.25 DS
2 No problems	One that provides NV Rx of +2.25 DS	+0.75 DS
3 Difficulty reading, has to hold too close to be able to read easily	One that provides NV Rx of +1.75 DS	+0.25 DS

With the new distance correction of +1.50 DS, the tentative addition would be estimated as shown in [Table 4.4](#).

Note that for the most common case (namely, a patient finding difficulty reading and easier if near work held further away), the most appropriate tentative add is the same as the habitual add. Because the distance correction has increased by +0.50 DS, the near vision refractive correction has increased to +2.75 DS and would likely alleviate the symptoms.

Example 2: Some patients develop nuclear cataract with age and this can lead to a myopic shift to the refractive correction.¹ For example, 72-year-old patient; present spectacles and habitual VA:

OD: +0.25/−0.50 × 95 20/30
OS: +0.25/−0.50 × 85 20/30

Reading addition +2.25 D. OD and OS: 20/20 at 30 cm.

(The mean sphere equivalent of the *near* correction is therefore +2.25 DS.)

If the distance refractive correction undergoes a small myopic shift and the new distance correction is:

RE −0.25/−0.50 × 100 20/15^{−3}
LE −0.25/−0.50 × 90 20/15^{−2}

The mean sphere equivalents of the distance refractive correction is −0.50 DS, so that appropriate tentative additions would be estimated as shown in [Table 4.5](#).

Note that an increased tentative add (compared to their habitual add) is suggested if the patient has no

Table 4.5 Tentative addition based on patient symptoms and habitual near correction from example 2

Symptoms regarding near vision	Tentative addition	Tentative addition
1 Difficulty reading, blurred near vision, easier if near work held further away	One that provides NV Rx of +2.75 DS	+3.25 DS
2 No problems	One that provides NV Rx of +2.25 DS	+2.75 DS
3 Difficulty reading, has to hold too close to be able to read easily	One that provides NV Rx of +1.75 DS	+2.25 DS

symptoms to counteract the minus shift in the distance correction. This situation is not uncommon because while these patients are under-minused in their habitual spectacles (at both distance and near) they adapt by using a slightly closer reading distance, which provides a little magnification to help counteract reduced visual acuity due to the cataract.

Leaving the reading addition the same at +2.50 DS, under the misapprehension that this would provide the same near correction as in the old spectacles, would leave the patient under-plussed by +0.50 DS. An under-plussed near correction, particularly in patients with nuclear cataract, has been shown to be a cause of patients rejecting new spectacles.²²

4.14.9 Procedure: Final reading addition and range of clear vision (Summary in [Box 4.2](#))

See online video 4.17.

1. If you have determined the distance refractive correction in a phoropter, add the distance correction to the trial frame using trial case lenses.
2. Ask the patient if they read in normal room lighting or with an additional ‘reading’ light and only use additional lighting if the patient indicates they use such lighting at home.



Box 4.2 Summary of the near addition procedure

1. Add the distance correction to the trial frame using trial case lenses.
 2. Ask the patient if they read in normal room lighting or with an additional 'reading' light and use additional lighting if indicated.
 3. Determine the near visual tasks the patient would like to perform and the relevant working distances.
 4. Explain the procedure to the patient.
 5. Ask the patient to hold the near VA chart at the distance they would like to read/work at.
 6. Determine a tentative addition. This is most easily obtained from the patient's age (if less than 60 years of age) or from their working distance (if over 60 years).
 7. Determine the final addition by the preferred working distance or trial lens method.
 8. Determine the range of clear vision with the binocular reading add.
 9. If you are unable to obtain a range that encompasses all the required near working tasks, consider a progressive addition lens, compromise near addition or an intermediate addition.
 10. Record the final addition(s), acuity and range of clearest vision obtained with the addition(s).
-
3. It can be useful to use a chair without arm rests or tilt the arm rests out of the way when measuring the patient's near working distance as they can influence the measurement.
 4. Ask the patient to hold the reading card at their preferred near working distance(s) and measure this distance(s). For example, depending on the patient's occupation and hobbies (as determined in the case history), you may need to determine at what distances a patient sews, reads and uses their computer. Instruct a patient who has complained that they habitually have to place their near work too close or too far away than they would like, to hold the near VA chart at the distance they would like to read/work at rather than the distance they may have adopted to be able to see clearly.
 5. Explain the procedure to the patient: 'I am now going to determine the power you need for your reading glasses/bifocal/progressive lens.'
 6. Tentative addition determination: From one or a combination of the techniques that can be used to estimate a tentative reading addition ([sections 4.14.4 to 4.14.8](#)), obtain an estimate of the reading addition for the indicated working distance and add these lenses to the trial frame.
 7. Determine the final addition for the required near working distance(s). This can be performed in one of two ways:
 - (a) Preferred working distance method. Ask the patient to hold the near VA chart where the lenses in the trial frame provide the best vision. Ask the patient if this distance corresponds to their preferred near working distance. If it does not, then change the reading addition appropriately: increase the addition power if you wish to decrease the working distance and decrease the addition power if you wish to increase the working distance provided. Continue this process until the working distance obtained with the trial case lenses equals their preferred working distance.
 - (b) Trial lens method. Direct the patient's attention to the best acuity paragraph of text on the near chart. Add -0.25 DS and ask if the letters become clearer, more blurred or are unchanged. Confirmation lenses (± 0.25 DS flippers) are useful for this task ([Figure 4.15](#)). If the acuity improves with the additional minus, then continue adding -0.25 DS until the near acuity or clarity does not improve with the additional -0.25 D. If the vision is unchanged or decreased with -0.25 DS lenses, then do not add them. Add $+0.25$ DS. If the visual acuity is unchanged or decreased, then do not add the lens. If visual acuity improves with the lens, then add further plus lenses (in 0.25 D steps) only as long as the near VA or its clarity improves.
 8. Determine the range of clear vision with the binocular reading add. This is important as the range decreases with higher add powers ([Table 4.6](#)). It is particularly important if you are intending that the reading addition will be used for tasks at more than one working distance.
 - (a) To determine the near endpoint of the addition's range, ask the patient to move

- the reading card slowly in until they first notice blur for the best acuity paragraph. Measure this distance.
- (b) Determine the far endpoint of the addition range by asking the patient to move the card slowly away from them until the best acuity paragraph just blurs.



Fig. 4.15 Confirmation lenses used in subjective refraction with a trial frame.

9. If you are unable to obtain a range that encompasses all the near working tasks that the patient has indicated they perform, you may consider that some form of progressive addition lens will provide the range of clear vision required. Alternatively, you could determine whether a compromise near addition would work. For example, the patient may have a preferred reading distance of 40 cm, but the addition that provides best clarity at this distance doesn't provide adequate clarity for their computer at 67 cm. A compromise addition providing best clarity at 50 cm, but adequate clarity at 40 cm and 67 cm may work. Alternatively, you may need to determine individual additions for their different working distances that could be provided in several pairs of single vision spectacles or multifocals.
10. Record the final addition(s), acuity and range of clearest vision obtained with the addition(s).

Note that if this assessment ends with the patient unable to read the smallest print on your chart (e.g., N5, 20/25, 0.4 M) with their optimal near refractive correction and the patient does not have an additional 'reading' lamp at home, they should be strongly advised to obtain one.

Table 4.6 Calculations of the range of clear vision with different working distances and subjective measurements of amplitudes of accommodation

Age	Amplitude of accommodation (D)	Near add (D)	Working distance (cm)	Range of clear vision (cm)
45	3.5	+0.75	40	133–24
		+1.25	33	80–21
50	2.5	+1.25	40	80–27
		+1.75	33	57–24
55	1.50	+1.75	40	57–31
		+2.25	33	44–27
60+	1.00	+2.00	40	50–33
		+2.50	33	40–29
		+3.00	29	33–25

Depth of focus effects are included in the latter measurements and are therefore included in these calculations. The near add was calculated from the equation: near add (D) = working distance (D) – 1/2 amplitude of accommodation. The far point of clear vision (m) was calculated from the inverse of [working distance (D) – 1/2 amplitude] and the near point of clear vision (m) was calculated from the inverse of [working distance (D) + 1/2 amplitude]. Note the significant reductions in the range of clear vision with increased add.

4.14.10 Recording

Record the tentative addition and the method(s) of determination (when an undergraduate student). This is not usually necessary when experienced unless you are using a variety of tentative addition tests and want to keep a track of which tests was used for each individual patient.

Also record the final addition(s), as well as the acuity attained and range of clarity for the addition.

Examples:

Tentative add (age) +1.50 DS.

Final add +1.50 DS @40 cm, VA: N5 R and L, range 25–67 cm.

Tentative add (working distance) +2.50 DS.

Near add +2.25 DS @35 cm, VA: 0.4M OD and OS, range 25–50 cm.

4.14.11 Interpretation

Most additions are equal for the two eyes. Unequal additions require further testing: either a retest of the near addition endpoints used for each eye or a recheck of the distance binocular balance. The prescribing of unequal additions between the eyes is the exception and is rarely satisfactory. Assuming no accommodative insufficiency, the power of the addition usually increases with age in patients above 40–50 years. Patients in poor general health can ask for a higher addition than is normal for their age and working distance. In some cases a reading addition that is low for a patient's age and working distance can indicate that the distance refraction has been over-plussed/under-minused.²² Practitioners rarely give additions greater than +3.00 D in patients with normal visual acuity. It is prudent to keep the addition as weak as possible to keep a large range of clear vision (Table 4.6).

4.14.12 Most common errors: Reading addition

1. Estimating the tentative addition of a patient over 60 based on their age and not their working distance. For example, a tall 70-year-old patient with healthy eyes and a working distance of 50 cm (dioptric value 2.00 D) will not appreciate the suggested tentative addition based on age of +2.50 D, as it is too strong.
2. Not determining the patient's near vision needs and subsequently prescribing an addition that gives an inadequate range of clear near vision for those needs.
3. Estimating instead of measuring the near point distances with a tape measure.
4. Over-plussing a near correction by giving extra plus when it provides no change in vision.⁴⁹
5. Under-plussing a near correction.²² This can particularly occur with patients undergoing nuclear cataract induced refractive changes in the distance prescription that may require a significantly increased reading addition.

4.15 PRESCRIBING

Some optometrists, particularly if inexperienced, routinely prescribe the refractive correction determined during the subjective refraction.⁵¹ However, for some patients more experienced clinicians tend to consider both the patient's current glasses and the subjective refraction result and prescribe a correction somewhere between these two using a selection of clinical maxims or 'pearls'.^{51–54} The literature regarding these clinical maxims is based on practitioners summarising the way that they successfully adjusted refractive corrections for patients unhappy with their initially prescribed glasses. Patients returning to their optometrist to complain that they are not happy with their glasses occurs in about 1–3% of cases and clearly you want to keep this figure as low as possible.^{49,51} Note that these maxims are generalities and must not be used as hard and fast rules. They must NOT be used in prescribing decisions for young children, which must consider the normal refractive error for their age and the need to encourage emmetropisation and prevent amblyopia.⁵⁵

4.15.1 Why not prescribe the subjective refraction result?

1. It might not be correct! It is always useful to demonstrate any refractive correction changes to the patient (section 2.4.1). Remember that the subjective refraction result can vary by up to 0.50 D for individual clinicians and up to 0.75 D between clinicians.^{56,57}
2. The changes made may be too hard to adapt to, particularly for large changes and/or in older patients. In addition to (hopefully) improved vision, new glasses provide changes in magnification. These alter the vestibulo-ocular reflex (this makes your eyes move at exactly the same speed but in the opposite direction to your head movements to make sure that your surroundings don't appear to move when your head moves) so that their surroundings can

seem to 'swim' for some patients with new glasses. Cylindrical magnification changes in different meridians (which may be different in the two eyes) are even more dramatic as floors and walls can appear to slope and round objects appear oval until the patient adapts to the new glasses. Older people tend to have greater problems adapting to new glasses.⁵³

4.15.2 Clinical maxims/pearls

1. **'If it ain't broke, don't fix it'.** Making changes of 0.50 D or more in patients with no symptoms who have good VA is a very common cause of patient dissatisfaction and spectacles needing remaking.⁵⁸ If a patient is happy with their glasses, but would like a new frame, the only change you can make by changing the correction (particular cylinder power or axis) is to make them unhappy. Remember that the subjective refraction result is not a perfectly repeatable measurement and can vary up to 0.50 D from test to retest.⁵⁶ The rule can also be used for either distance or near vision. For example, if a patient has good distance VA and is very happy with their distance vision, but needs a change at near; be wary of making large changes in the distance and just change the near addition.
2. **'If it ain't broke, don't fix it much'.** If a patient wants new glasses but has no symptoms and reasonable VA and you find a change of 0.50 D or more (particularly if spherical) that the patient appreciates when shown the comparison (section 2.4.1), prescribe about half the change in spherical power.⁵⁸ It is likely in such cases that the patient would start to develop symptoms in the following months, so that some change seems sensible.
3. **Don't make full cylindrical power and axis changes.** These can be particularly hard to adapt to for some patients, yet improvements in vision can be relatively small. Large changes in astigmatism are not common and may suggest a refraction error, cortical cataract or a lid lesion pressing on the cornea.^{1,3} When cylinder changes are moderate to large, generally make partial changes in cylinder power and axis (~half-way between the habitual correction and subjective result). Changes in power are more tolerable if the axes are not oblique. If there are significant VA changes and symptoms, you would be more likely to give more of the cylinder. Allow the patient to participate in the decision if possible. It can be useful to trial frame the partial correction you are going to prescribe.
4. **Be careful of reducing a myopic correction.** Myopia can decrease, particularly in patients aged 20–35 years, but be extremely careful of reducing a myopic correction in these patients, especially if there are no symptoms. Remember that if you are refracting at 6m or 20 ft, this is not infinity, so that patients are likely to be over-plussed by +0.17 D with a 6 m (20 ft) refractive correction. Also some low myopes tend to wear their Rx only for driving and especially at night and 'night myopia' may be an additional problem. Depending on the patient you may wish to prescribe the habitual correction (if it ain't broke, don't fix it) or prescribe half the reduction in myopia. Over-plussing the distance correction has been reported as the most common reason for failure of spectacle lens acceptance.²²
5. **Prescribe sufficient hyperopia to remove symptoms.** You would likely prescribe the full hyperopic correction if the patient was presbyopic (or nearing presbyopia), esotropic or has esophoria (particularly convergence excess). Otherwise consider prescribing a partial hyperopic correction that is sufficient to remove the symptoms. You are unlikely to prescribe glasses to a young, asymptomatic low hyperope as they have sufficient accommodation to cope with slight hyperopia. Similarly, why prescribe the full amount of hyperopia? It makes adaptation more difficult and can make it more difficult for the patient to see without their glasses (as they get used to not accommodating as much). The amount will depend upon the patient's symptoms, age, manifest and latent hyperopia. E.g., if fully manifest, then prescribe $\frac{1}{2}$ – $\frac{3}{4}$ of the Rx. The older the patient, the more likely you will prescribe $\sim\frac{3}{4}$ –full Rx. The more pronounced the symptoms, the more likely you are to prescribe more of the hyperopia. Over-plussing the distance correction has been reported as the most common reason for failure of spectacle lens acceptance.²²

4.15.3 Prescribing maxims for elderly patients at risk of falls

To help elderly patients in high risk groups avoid the potentially devastating consequences of a fall, the

following prescribing maxims should be followed.⁵⁹ Patients at high risk of falling include those over 75 years of age, with a history of falling, using more than three medications, taking antidepressants with systemic conditions that reduce mobility and patients who may be more dependent on their vision for balance control (patients with somatosensory system dysfunction such as diabetes and/or peripheral neuropathy; or those with vestibular system dysfunction, such as Ménière's disease).

1. Do not prescribe progressive addition lenses/varifocals and bifocals unless they have successfully worn them previously. These lenses double the risk of falling.⁶⁰
2. Do not make large changes in refractive correction as these can increase the risk of falls. Limit changes to 0.75 D and keep cylindrical changes to a minimum.^{53,59} The danger of cylindrical lens changes causing the perception of sloping floors and walls is obvious. The dangers of spherical magnification/minification to the perceived size and position of steps and/or stair edges and the effect on the vestibulo-ocular reflex gain (the world appears to 'swim') is similar. Note that elderly patients adapt less well to changes in refractive correction.
3. Prescribe an additional pair of single vision distance lenses for walking outside the home and when using stairs, etc., for established multifocal lens wearers who are fit and healthy. This has been shown to reduce falls risk.⁵⁹

4.15.4 Should you prescribe a small Rx?

Should you prescribe a small Rx, such as 0.50 D of hyperopia or hyperopic astigmatism? This can be a very difficult question. Here are some points to consider:

1. If there are no symptoms related to the use of the eyes and no other indications from other tests in the eye exam, then there appears to be no need to prescribe glasses.
2. Always consider other ocular causes of the symptoms, which might not be related to the small refractive error and include inadequate convergence, accommodative facility or vergence facility and decompensated heterophoria. Also consider non-ocular causes of headaches, including tension, migraine, nasal sinusitis and hypertension. Unfortunately, tension headaches, which

are a common headache, can be difficult to differentiate from ocular headaches as they are often frontal or occipital, get worse towards the end of the day and are better over the weekend.

3. If a patient has symptoms that are related to detailed vision tasks, you are more likely to prescribe a small correction if the patient does a lot of detailed work and/or if the patient has a personality that is detail-oriented, precise or intense.
4. The relative certainty of responses should help your decision of whether to prescribe a small Rx. If glasses are to be of any value, the responses during subjective refraction should be very certain, appropriate and repeatable.
5. Usually small corrections make little change to the VA (particularly if a truncated Snellen chart is used) and so basing decisions on VA improvements is usually not helpful.
6. The effect of the Rx on binocular vision tests can be helpful.⁶¹ For example, if binocular vision tests suggest that a heterophoria is decompensated with no refractive correction and compensated with it, then the spectacles are likely to help and should be prescribed.⁶¹
7. You can view prescribing glasses as a diagnostic tool. Often the only way to be certain whether the symptoms are due to the uncorrected refractive error is to prescribe it and see if the symptoms disappear. You could offer the patient a pair of basic loan spectacles to determine whether the refractive correction will relieve the symptoms. This approach is often used in medicine. However, be aware that spectacles can provide a placebo effect and relieve the symptoms for a short period before they return.

4.15.5 Should you make small changes to the refractive correction?

1. If there are no symptoms and a small change to the refractive correction and the patient wants a new frame, it may be better to stick with their old correction unless a significant improvement in VA over their old correction can be obtained ('If It Ain't Broke, Don't Fix It').
2. Consider the points in [section 4.15.4](#), in particular if a patient has symptoms which are

related to detailed vision tasks, you are more likely to prescribe a small change in correction if the patient does a lot of detailed work and/or if the patient has a personality which is detail-oriented, precise or intense. Consider the relative certainty and repeatability of responses during the subjective refraction.

3. Even if there is no change in refractive correction, a patient should always be asked if they want a new pair of glasses. They may want a change of frame or their old lenses may be scratched and need replacing.

REFERENCES

1. Pesudovs K, Elliott DB. Refractive error changes in cortical, nuclear and posterior subcapsular cataract. *Br J Ophthalmol* 2003;87:964–7.
2. Mutti DO, Mitchell GL, Moeschberger ML, et al. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci* 2002;43:3633–40.
3. Locke LC. Induced refractive and visual changes. In: *Diagnosis and management in vision care* (JF Amos, ed.). Boston: Butterworths; 1987, pp. 313–67.
4. Smith G. Relation between spherical refractive error and visual acuity. *Optom Vision Sci* 1991;68:591–8.
5. Leung TW, Lam AK, Deng L, Kee CS. Characteristics of astigmatism as a function of age in a Hong Kong clinical population. *Optom Vision Sci* 2012;89:984–92.
6. Steele CF, Rubin G, Fraser S. Error classification in community optometric practice – a pilot study. *Ophthalmic Physiol Opt* 2006;26:106–10.
7. Solsona F. Astigmatism as a congenital bilateral and symmetrical entity. (Observations based on the study of 51,000 patients). *Br J Physiol Opt* 1975;30:119–27.
8. Osuoben EP, al-Fahdi M. Differences between anatomical and physiological interpupillary distance. *J Am Optom Assoc* 1994;65:265–71.
9. Holland BJ, Siderov J. Repeatability of measurements of interpupillary distance. *Ophthalmic Physiol Opt* 1999;19:74–8.
10. Pointer JS. The interpupillary distance in adult Caucasian subjects, with reference to 'readymade' reading spectacle centration. *Ophthalmic Physiol Opt* 2012;32:324–31.
11. Brown WL. Interpupillary distance. In: *Clinical procedures in optometry* (JD Eskridge, JF Amos, JD Bartlett, eds.) Philadelphia: JB Lippincott, 1991, pp. 39–52.
12. Casillas E, Rosenfield M. Comparison of subjective heterophoria testing with a phoropter and trial frame. *Optom Vision Sci* 2006;83:237–41.
13. Elliott DB, Wilkes RD. A clinical evaluation of the Topcon RM-6000 autorefractor. *Clin Exp Optom* 1989;72:150–3.
14. McCaghrey GE, Matthews FE. Clinical evaluation of a range of autorefractors. *Ophthalmic Physiol Opt* 1993;13:129–37.
15. Walline JJ, Kinney KA, Zadnik K, Mutti DO. Repeatability and validity of astigmatism measurements. *J Refract Surg* 1999;15:23–31.
16. Zhao J, Mao J, Luo R, et al. Accuracy of noncycloplegic autorefraction in school-age children in China. *Optom Vision Sci* 2004;81:49–55.
17. Jackson DW, Paysse EA, Wilhelmus KR, et al. The effect of off-the-visual-axis retinoscopy on objective refractive measurement. *Am J Ophthalmol* 2004;137:1101–4.
18. Roorda A, Bobier WR. Retinoscopic reflexes: theoretical basis and effects of monochromatic aberrations. *J Am Optom Assoc* 1996;67:610–8.
19. Millodot M, O'Leary D. The discrepancy between retinoscopic and subjective measurements: Effect of age. *Am J Optom Physiol Opt* 1978;55:309–16.
20. Albinet CT, Boucard G, Bouquet CA, Audiffren M. Processing speed and executive functions in cognitive aging: how to disentangle their mutual relationship? *Brain Cogn* 2012;79:1–11.
21. Wang B, Ciuffreda KJ. Depth-of-focus of the human eye: Theory and clinical implications. *Surv Ophthalmol* 2006;51:75–85.
22. Hrynychak P. Prescribing spectacles: reason for failure of spectacle acceptance. *Ophthalmic Physiol Opt* 2006;26:111–5.
23. Bennett AG, Rabbetts RB. *Clinical Visual Optics*. 3rd edition. Oxford: Butterworth-Heinemann; 1998.
24. Elliott DB, Cox MJ. A clinical assessment of the +1.00 blur test. *Optom in Pract* 2004;5:189–93.
25. Rosenfield M, Aggarwala KR, Raul C, Ciuffreda KJ. Do changes in pupil size and ambient illumination affect the duochrome test? *J Am Optom Assoc* 1995;66:87–90.
26. Clementi M, Angi M, Forabosco P, et al. Inheritance of astigmatism: evidence for a major autosomal dominant locus. *Am J Hum Genet* 1998;63:825–30.
27. Johnson BL, Edwards JS, Goss DA, et al. A comparison of three subjective tests for astigmatism

- and their interexaminer reliabilities. *J Am Optom Assoc* 1996;67:590-8.
28. Borish IL, Benjamin WJ. Monocular and binocular subjective refraction. In: *Borish's Clinical Refraction* (WJ Benjamin, ed.). Philadelphia: WB Saunders, 2006.
 29. Rosenfield M. Subjective refraction. In: *Optometry: Science, techniques and clinical management* (M Rosenfield, N Logan, eds.). Edinburgh: Elsevier, 2009, pp. 209-28.
 30. West D, Somers WW. Binocular balance validity: A comparison of five different subjective techniques. *Ophthalmic Physiol Opt* 1984;4:155-9.
 31. Humphriss D. Binocular refraction. In: *Optometry* (K Edwards, R Llewellyn, eds.). Oxford: Butterworths; 1988.
 32. Rosenfield M, Ciuffreda KJ, Hung GK, Gilmartin B. Tonic accommodation: a review II. Accommodative adaptation and clinical aspects. *Ophthalmic Physiol Opt* 1994;14:265-77.
 33. Charman WN, Jennings JA, Whitefoot H. The refraction of the eye in the relation to spherical aberration and pupil size. *Br J Physiol Opt* 1978;32:78-93.
 34. Martin J, Vasudevan B, Himebaugh N, et al. Unbiased estimation of refractive state of aberrated eyes. *Vision Res* 2011;51:1932-40.
 35. Muñoz-Hernández AM, Santos-Bueso E, Sáenz-Francés F, et al. Nonorganic visual loss and associated psychopathology in children. *Eur J Ophthalmol* 2012;22:269-73.
 36. Lim SA, Siatkowski RM, Farris BK. Functional visual loss in adults and children patient characteristics, management, and outcomes. *Ophthalmology* 2005;112:1821-8.
 37. Jones LWJ, Hodes DT. Possible allergic reactions to cyclopentolate hydrochloride – case reports with literature review of uses and adverse reactions. *Ophthalmic Physiol Opt* 1991;11:16-21.
 38. Celebi S, Aykan U. The comparison of cyclopentolate and atropine in patients with refractive accommodative esotropia by means of retinoscopy, autorefractometry and biometric lens thickness. *Acta Ophthalmol* 1999;77:426-9.
 39. Twelker JD, Mutti DO. Retinoscopy in infants using a near noncycloplegic technique, cycloplegia with tropicamide 1%, and cycloplegia with cyclopentolate 1%. *Optom Vision Sci* 2001;78:215-22.
 40. Leat SJ, Mittelstaedt A, McIntosh S, et al. Prescribing for hyperopia in childhood and teenage by academic optometrists. *Optom Vis Sci* 2011;88:1333-42.
 41. Mohindra I. A non-cycloplegic refraction technique for infants and young children. *J Am Optom Assoc* 1977;48:518-23.
 42. Saunders KJ, Westall CA. Comparison between near retinoscopy and cycloplegic retinoscopy in the refraction of infants and children. *Optom Vision Sci* 1992;69:615-22.
 43. Millodot M, Millodot S. Presbyopia correction and the accommodation in reserve. *Ophthalmic Physiol Opt* 1989;9:126-32.
 44. Pointer JS. The presbyopic Add I, II and III. *Ophthalmic Physiol Opt* 1995;15:235-54.
 45. Charman WN. The path to presbyopia: straight or crooked? *Ophthalmic Physiol Opt* 1989;9:424-30.
 46. Blystone PA. Relationship between age and presbyopic addition using a sample of 3,645 examinations from a single private practice. *J Am Optom Assoc* 1999;70:505-8.
 47. MacMillan ES, Elliott DB, Patel B, Cox M. Loss of visual acuity is the main reason why reading addition increases after the age of sixty. *Optom Vision Sci* 2001;78:381-5.
 48. Hanlon SD, Nakabayashi J, Shigezawa G. A critical view of presbyopic add determination. *J Am Optom Assoc* 1987;58:468-72.
 49. Freeman CE, Evans BJ. Investigation of the causes of non-tolerance to optometric prescriptions for spectacles. *Ophthalmic Physiol Opt* 2010;30:1-11.
 50. Guzowski M, Wang JJ, Rochtchina E, et al. Five-year refractive changes in an older population: the Blue Mountains Eye Study. *Ophthalmology* 2003;110:1364-70.
 51. Howell-Duffy C, Scally AJ, Elliott DB. Spectacle prescribing II: practitioner experience is linked to the likelihood of suggesting a partial prescription. *Ophthalmic Physiol Opt* 2011;31:155-67.
 52. Hrynchak PK, Mittelstaedt AM, Harris J, et al. Modifications made to the refractive result when prescribing spectacles. *Optom Vision Sci* 2012;89:155-60.
 53. Werner DL, Press LJ. *Clinical Pearls in Refractive Care*. Boston: Butterworth-Heinemann, 2002.
 54. Milder B, Rubin ML. *The fine art of prescribing glasses without making a spectacle of yourself*. 2nd edition, Gainesville: Triad Pub, 2004.
 55. Leat SJ. To prescribe or not to prescribe? Guidelines for spectacle prescribing in infants and children. *Clin Exp Optom* 2011;94:514-27.
 56. Goss DA, Grosvenor T. Reliability of refraction – a literature review. *J Am Optom Assoc* 1996;67:619-30.

57. MacKenzie GE. Reproducibility of spherocylindrical prescriptions. *Ophthalmic Physiol Opt* 2008;28:143–50.
58. Howell-Duffy C, Hrynychak PK, Irving EL, et al. Evaluation of the clinical maxim: ‘If it ain’t broke, don’t fix it’. *Optom Vision Sci* 2012;89:105–11.
59. Elliott DB. Falls and vision impairment: guidance for the optometrist. *Optom in Pract* 2012;13: 65–76.
60. Lord SR, Dayhew J, Howland A. Multifocal glasses impair edge-contrast sensitivity and depth perception and increase the risk of falls in older people. *J Am Geriatr Soc* 2002;50:1760–6.
61. Dwyer P, Wick B. The influence of refractive correction upon disorders of vergence and accommodation. *Optom Vision Sci* 1995;72:224–32.

CONTACT LENS ASSESSMENT

CATHARINE CHISHOLM AND CRAIG A. WOODS

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Contact lenses are preferred over glasses by some patients because of perceived improvements in appearance, ability to wear for certain sports and various convenience issues (e.g., can wear off-the-shelf sunglasses, they don't fog up like glasses, can see better in rain, etc).¹ There is a relatively high discontinuation of contact lens wear (~16% US, ~30% Europe), but patients are more likely to be successful if you manage their expectations, fit them with lenses that suit their eyes and lifestyle and achieve better compliance with lens care.^{2,3} Worldwide, the majority of new lens fits are soft lenses but it is important to maintain RGP lens skills because they remain the first choice lens for a proportion of patients and account for around 8% of new fits (e.g. 2% UK, 4% Canada, 11% New Zealand, 21% Netherlands) and a significantly higher proportion of refits.⁴ It is not uncommon to fit a patient with more than one lens type, e.g. RGP lenses for day-to-day use with a small supply of soft single-use lenses for swimming and other sport. Some of you may wish to develop your skills further to offer more specialist care to those requiring complex lenses for therapeutic purposes, corneal irregularity, orthokeratology, etc. However, discussion of such lenses falls outside the scope of this book.

5.1 CONTACT LENS FITTING

The purpose of the preliminary contact lens fit examination is to:

1. Quantify ocular parameters to aid selection of the first trial lens.
2. Confirm the normality of the ocular tissues and to record for future reference any acceptable abnormality (such as a corneal scar resulting from a historical eye injury).
3. Discover issues that potentially preclude or limit contact lens wear, (and manage or refer if necessary), or issues that indicate the need for a particular type of contact lens.
4. Allow the recording of baseline data against which to judge possible contact lens induced changes.

In general, the patient needs to trial the contact lenses and return for the first follow-up check before the fitting is concluded and a lens specification can be issued. The preliminary examination includes the following, which are further described in subsequent sections:

1. A pre-fit case history to determine what the patient wants from contact lenses, what they know about them and to help determine whether they are suitable.
2. Measurements to help determine lens parameters: Horizontal visible iris diameter, pupil diameter (average and mesopic), palpebral aperture and lid position, corneal curvature and regularity and subjective refraction (unless a recent refraction has taken place).
3. Assessments to help determine suitability for lens wear: Anterior eye health and tear film quality. Examination of the posterior segment is only included in the pre-fit examination if any new symptoms or signs indicate that further investigation is warranted or if there has been a significant time period since the last assessment.
4. Choose the trial lenses: After the preliminary assessment, you need to summarise your findings and discuss how they influence the

choice of lens type. There may be a clear indication for a particular type of lens, such as single-use lenses for a patient who only wants to wear lenses 2–3 times a week; or there may be a range of possible options and you should discuss the pros and cons of each lens type (including cost and impact of lens care use) with the patient, so that they can make an informed decision.

5. Post-trial assessment: Assess the performance of the trial lenses in terms of fit, compatibility with the eye/tear film and visual acuity
 - (a) It may be necessary to trial more than one lens to meet the patient's needs.
 - (b) Remove the lenses and check the eyes using the slit-lamp.
 - (c) Discuss your findings with the patient.
6. Teach the patient to handle and care for the lenses: Ensure the patient fully understands the dos and don'ts of lens wear and the importance of lens and lens case maintenance.
7. Final check of trial lenses: Allow the patient to trial the lenses for a few days. Undertake the first follow-up check up with the lenses in situ and if everything is satisfactory, order the final lenses and provide the patient with a copy of their contact lens specification. Further changes to the lens and an extended trial may be required before the fitting can be considered complete, particularly for some toric, multifocal or complex lens fits.

5.2 PRE-FITTING CASE HISTORY

Many of the issues covered in section 2.1 also apply during a contact lens examination, such as the importance of communication and putting the patient at ease. Trying contact lenses for the first time can be a very daunting process for some patients; a common worry is that the lenses will cause pain when they are placed on their eyes. Assure them that at worst the sensation is similar to having an eyelash in their eyes and at best they are simply not aware the lens has gone in. Spending sufficient time fully understanding a patient's wants with respect to contact lenses, determining what they know about them, explaining the issues and managing their expectations are important to limit contact lens drop outs.⁵ Make it clear from the start that a successful fit may require more than one appointment, particularly in the case of toric, lenses for presbyopia or more complex lenses, and that regular aftercare is essential. It is often useful, in the case of the potential wearer, to combine questions to

the patient with a tutorial approach embracing areas such as lens types, hygiene, wearing times, etc., thereby exchanging information. The information gained should be considered to determine patient suitability and motivation. Suitability may be determined by clinical, social or financial constraints. Motivation may depend on social, occupational, sports, refractive, visual or psychological factors.⁶

5.2.1 Procedure for pre-fitting contact lens case history

1. Start with a general observation of the patient. Particularly note the patient's ability to speak and articulate, intellectual capacity, emotional state, cleanliness, length of fingernails, use of eye make-up, size of fingers, roughness of skin and dexterity.
2. Age and gender information allows you to think about the most likely contraindications or challenges to contact lens wear, and their association with these factors, for example, older females are more likely to have poorer tear quality, indicating careful lens material selection and perhaps the use of ocular lubricants.
3. Ask the following questions:
 - (a) **Why do you want to wear contact lenses?** Start by finding out what has sparked an interest in contact lenses. Any previous history of contact lens wear should be investigated thoroughly to determine the types of lenses worn, and any reasons for discontinuing lens use. Don't be afraid of refitting a patient who has failed to wear contact lenses successfully in the past as many contact lens drop-outs are due to poor compliance, or associated with older lens designs and materials, rather than a lack of patient suitability.⁷
 - (b) **What would you like to wear the lenses for?** This will range from a complete replacement for spectacles through to occasional social wear. Others may want to sleep in their lenses for convenience or practical reasons (e.g. travelling abroad, antisocial working hours). If they don't want to sleep in their lenses overnight, are they likely to occasionally nap in their lenses, for example, on the train home from work? Dumbleton et al. reported over 60%

of single use soft lens wearers had napped or slept in their lenses.⁸

- (c) **What do you know about lenses?** This is an opportunity to explain the different types of lenses and the pros and cons of each. This could be an opportune time to introduce the cost of the different types of lens. For those that wear their lenses four or more days a week, monthly or fortnightly disposable lenses are more cost effective than daily disposable lenses.⁹ It is important that the patient understands from the start the cost of the lenses, fitting and aftercare appointments, along with the importance of regular aftercare to maximise healthy and successful contact lens wear. Explain that there are some risks involved in contact lens wear but if they follow instructions carefully, these are exceedingly small. Direct them to an independent website that provides unbiased, generic information on contact lenses, such as the *British Contact Lens Association*, *American Academy of Optometry*, *the Cornea and Contact Lens Society of Australia* or *Contact Lens Update*.
 - (d) **How do you feel about inserting lenses and touching your eye?** Patients can be very motivated but those that cannot bear to hold their lids apart will generally not succeed. Usually females are more comfortable touching their eyes as they are used to applying cosmetics. If the patient is nervous, demonstrate how they can gently touch the conjunctiva in the lower fornix with their finger, while they look up and suggest they do this a couple of times over the next few days, prior to the fitting visit. This will give them confidence.
 - (e) **Are you willing to clean the lenses after each wearing episode, or is convenience a major factor?** You will have to outline what is involved in lens care as they may have preconceived ideas having watched a family member cleaning their lenses inadequately.
4. Medical and ocular history. If the patient has recently undergone an eye examination in your practice, check all the points mentioned on their record card, record them again on the contact lens record and ask open questions to ensure nothing has changed since the eye examination. For those who attend for a contact lens fit with a spectacle prescription from elsewhere, a full history routine is required, as for a standard eye examination but modified to take account of previous or potential contact lens wear. Questions should cover:
 - (a) General health including whether the patient suffers from cold sores that may impact on contact lens handling at times. The medical history may reveal contraindications to contact lens wear, or the need for a particular type of lens or more regular aftercare check-ups (e.g. diabetes). Include a question about smoking as it is known to increase the risk of contact lens inflammatory events and would therefore direct you away from extended wear lenses.¹⁰
 - (b) Use of systemic medication particularly long-term treatment, e.g. steroids, beta-blockers, psychotropic agents (anti-depressants), regular use of over the counter pain medication. The main way in which medication can affect contact lens is through changes to the tear film.
 - (c) Ocular history indicates whether the patient has had previous ocular treatment or surgery, or contact lens problems in the past. A history of an ocular abnormality directs you to look for the manifestations of the disorder that may impact on suitability for contact lenses, or channel you towards a particular type of lens (e.g. RGP for an irregular cornea associated with a previous corneal injury). Previous surgery may dictate the lens type to be used, for example, RGP lenses post corneal refractive surgery. Are they prone to styes or chalazion that might be associated with recurrent blepharitis? Is the patient's refraction stable? If not, they should be advised that frequent changes to their contact lenses may be needed with financial implications depending on the type of lens.
 - (d) Family history information determines if there are any hereditary ocular and/or medical conditions that may be relevant.
 - (e) Information regarding the patient's occupation and hobbies is very useful, particularly when the patient is presbyopic as you need to ensure the lens chosen will give them good vision for the required working distances. Patients who spend

a lot of time looking at a display screen are more likely to suffer from dryness associated with a reduced blink rate.¹¹ You should ask specifically about water sports as the patient may require additional, single use lenses if they swim regularly, and should be advised regarding the use of goggles.¹² Contact sports also require careful lens selection with single use soft lenses most commonly providing the best option.

- (f) Environmental factors include regular exposure to a smoky atmosphere, an environment that is dusty, contains fumes, is of low humidity (associated with heating or air conditioning), or is unhygienic in some other way.

5.2.2 Patient records

Both positive and negative patient responses must be recorded. Remember that from a legal viewpoint, if the response was not recorded the question was not asked. Use standard abbreviations (Table 2.1) and avoid personal ones. Using the patient's own words, recorded in quotation marks, can be useful. An example is given below.

32-year-old Px. Caucasian, teacher

RFV: Wants CLs for rugby and occ. social use.
Girlfriend wears SCL which she cleans daily.
Happy to clean lenses. No previous CL wear.
Happy c Rx for work. Good DV and NV with Rx.
No HA. No other Sxs.

OH: Wears Rx constantly. This Rx 2 yrs old. Blunt rugby injury to RE 1/12 ago, seen by HES – all clear. No other OH. LEE: 1/12, Mr Brown, Smith's Opticians, Manchester. FOH: none.

GH = OK, occ. cold sores, no meds. No allergies.
LME: 4 yrs, Dr Patel, Didsbury. FMH: mat grandfather has Type II DM.

Hobbies: rugby (no Rx worn), hiking, swimming 1/7. Uses PC ~ 4 / 24, 6/7. Driver.

Observations: large fingers, slightly squeamish?

5.2.3 Interpretation

Interpretation of the data collected relies on an understanding of why questions are asked, and a good knowledge of lens characteristics such as wettability and lubricity (smoothness).

Selecting the most suitable lens modality, replacement schedule and lens type depends on:

- The patient's requirements including lifestyle.
- The patient's ocular characteristics.
- The financial position of the patient.
- The lenses you have available in your clinic. 3–4 types of single use lenses covering a range of materials and prices is useful.

Interpretation of the case history example in [section 5.2.2](#) suggests that the patient wants lenses for occasional use only, specifically for contact sports (rugby), and therefore a single use lens would be the best option if available in his prescription. This will avoid the issue of lenses sitting in solution for extended periods between wearing episodes. In addition, mud in the eye and lens loss are common in rugby and therefore single use lenses are preferred for hygiene reasons. Regular swimming is yet another indicator for single use lenses, and tight fitting goggles over the top will reduce the risk of complications from swimming in lenses. The patient will need to be advised not to wear their lenses when they are suffering from a cold sore or at least to take extra precautions in terms of hygiene before handling the lenses. This patient may need more time spent with them for insertion/removal training due to their large fingers and possible squeamishness.

5.2.4 Common errors

1. Not gaining a full understanding of what the patient wants from contact lenses.
2. Not recording all information obtained from the patient.
3. Assuming the same information is still current from the last eye examination.
4. Not applying all the information gathered to the selection of trial lens.
5. Agreeing to undertake a contact lens fit when the patient does not have a valid spectacle prescription (within recall date).

5.3 CORNEAL DIAMETER, PUPIL AND LID APERTURE MEASUREMENT

Palpebral aperture (PA) height is the vertical distance in millimetres between the upper and lower lid margins at the widest point. Horizontal visible iris diameter (HVID) is a surrogate measure of the actual corneal diameter. HVID aids the selection of lens total diameter for both an RGP and soft lens. PA in relation to lens size determines whether an RGP fit will be interpalpebral or lid attached, and has an influence on

the stability of soft toric lenses.¹³ Pupil size has an impact on the selection of presbyopic lens options and determines the size of the back optic zone diameter of an RGP lens.

5.3.1 Comparison of tests

Palpebral aperture height, HVID and pupil size are most commonly measured using a contact lens rule (Figure 5.1), with direct measurement of PA height and by matching the semicircles to the visible iris or pupil. Semi-circular templates and mm rules are equally accurate in estimating pupil size and measurements can be made in average and dim office illumination, but are not possible in scotopic illumination.¹⁴

Pupillometers are an expensive alternative and can provide pupil measurements at very low light levels, but the accuracy at higher light levels is similar to simple rulers and they are generally restricted to refractive surgery clinics, where pupil diameter measurements under controlled scotopic conditions are important.¹⁴

5.3.2 Procedure for PA height, HVID and pupil size measurement

1. Ask the patient to remove any spectacles.
2. Ask the patient to look directly at your dominant eye or an object held just below your eye.
3. Measure the palpebral aperture height using the mm rule on the contact lens rule held vertically, with the zero line aligned with the lower lid margin. Read off the average position of the

upper lid with the patient looking in the primary position of gaze.

4. Position the contact lens rule on their forehead so that the semicircles are facing downwards and the rule bisects the iris. Move the rule horizontally until the semicircle on the rule and the visible semicircle of the iris match in size and create a continuous circle. It is often easier to judge when the diameter is slightly too large and slightly too small and take the HVID value as the reading in between.
5. For pupil measurement, ask the patient to fixate an unlit distant object. Ensure that you do not get in the way of this fixation.
6. Measure the pupil size using the contact lens rule, similar to point 4.

5.3.3 Adaptation for pupil size measurement

1. For maximum pupil size: To measure under low illumination, a Burton lamp on the blue light setting is useful for providing sufficient illumination to view the pupil without causing significant pupil constriction, as the crystalline lens fluoresces under the UV light.
2. Minimum pupil size: Additional local lighting directed towards a near reading chart, can be used to measure the minimum pupil size at near, which is of interest when considering lens options for a presbyopic patient.

5.3.4 Interpretation

The average HVID value is 11.6 mm with a range of 10.2 mm to 13.0 mm.¹⁵ The rule-of-thumb for calculating corneal RGP total diameter is at least 2 mm smaller than HVID and for soft lenses is at least 2 mm greater than HVID. It is also useful to consider the corneal diameter when selecting the first soft trial lens as lens fit is most closely related to the sagittal height of the cornea, which is dependent on a number of factors including curvature and diameter. Larger corneas generally need a flatter base curve and smaller corneas, a steeper base curve.¹⁶

The maximum pupil diameter under low illumination is of interest when selecting an RGP trial lens. To minimise the risk of flare and halos at night, particularly in someone who drives for a living, the back optic zone diameter of the contact lens should be at least 1mm larger than the maximum pupil diameter, or even larger still if the lens is lid attached and sits superiorly.

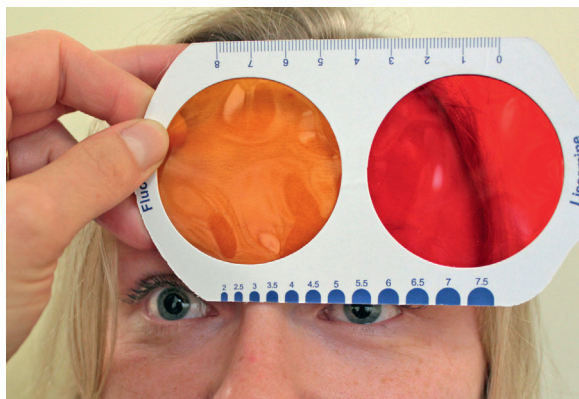


Fig. 5.1 Pupil size measurement with a contact lens rule.

The average palpebral aperture height is around 9.75 mm, commonly ranging from 9.0–10.5 mm. The size of the PA influences the RGP lens fit. A particularly large PA will result in an interpalpebral RGP fitting. A smaller PA means that a larger proportion of the superior cornea is covered by the lid and lid attached fitting is likely. The position of the lower lid has an effect on the success of translating multifocal RGP designs. Such lenses require interaction between the lower lid and lens in down gaze, in order to displace the lens upwards so that the near portion lies over the pupil. With a lower lid that is 1 mm higher or lower than the inferior limbus, translating designs are less likely to work. Such designs also require reasonable tension of the lower lid to facilitate translation.

The angle of the lids, both in the stationary position and with a blink, should also be noted as this can influence the rotation of toric soft and front surface toric RGP lenses. An eye with oblique lid alignment or an unusual lid movement on blink is more likely to suffer from rotational instability if fitted with a soft toric lens.¹³

5.3.5 Most common errors

1. Poor alignment resulting in a parallax error.
2. Failing to notice that the patient is narrowing their PA by squinting to see a blurred distant target.
3. Positioning yourself between the patient and target so they focus on you, resulting in pupil constriction.

5.4 CORNEAL TOPOGRAPHY

Corneal topography is a method of assessing the corneal profile or curvature. You will use this information in the initial assessments and monitoring of contact lens, orthokeratology and refractive surgery patients. Initial assessments will screen for keratoconus and other diseases that change corneal shape, provide baseline data for monitoring purposes and indicate appropriate initial fitting parameters for RGP contact lenses. When refractive surgery patients have postoperative irregular astigmatism or asymmetry, topography is an essential part of the 'refinement' (repeated treatment) process. It is minimally needed in the fitting of soft contact lenses as the fit of a soft lens is more closely related to the sag of the cornea rather than the curvature at its apex plus the limited range of radius and diameter of soft lenses means that the use of topographers for the determination of fit is not necessary.

5.4.1 Comparison of tests

The traditional method to assess corneal topography was using a keratometer. This is an instrument that projects a symmetrical image onto the corneal apex, using it as a reflective surface and applying the optical principles of a convex mirror to estimate the radius of curvature at two assumed perpendicular principal meridians. When more information is needed an instrument called a corneal topographer or videokeratographer or videokeratoscope is used. To collect more data points from the corneal surface these instruments project a Placido image (series of concentric rings) onto the cornea (Figure 5.2) and the reflected image is captured by a high resolution CCD camera and the data are processed by a computer. In addition to providing more detailed information, the area covered by these projected rings is wider than that of a keratometer, up to 10mm compared to 3.0 to 3.5 mm. Topographers will also calculate nominal primary meridian values for the two principal meridians for RGP lens fitting, negating the need to use a keratometer as well as a topographer. The increased accuracy and information obtained with a corneal topographer and their lowering price tag mean the days for keratometers are numbered. Anterior segment optical coherence tomography (OCT; section 7.11) provides valuable information about the real sagittal height of the cornea which is more predictive of soft contact lens fits than either keratometry or topography measurements.¹⁷ Knowledge of the profile of the corneo-scleral junction is helpful when fitting gas permeable scleral and semi-scleral lenses, both of which are seeing a resurgence in use for both irregular and regular corneae. OCT is likely to become more widely used in contact lens practice in the future.



Fig. 5.2 Placido rings used in some corneal topographers.

5.4.2 Procedure: corneal topography

While there are many different makes of corneal topographers, the following is a guide that is applicable to most, but you should also refer to the user guide for your specific instrument.

1. Explain the procedure to the patient: 'I am going to measure the shape of the front of your eye, the cornea.' You may add: '... so that I will know which contact lens to fit', etc.
2. Ask the patient to be seated in front of the topographer and to remove their glasses or contact lenses. If a contact lens wearer keeps their lens on, then you will measure the topography of the contact lens.
3. Most topographers hold patient information on their self-contained database, so complete these details before measurements begin.
4. The instrument's next prompt screen will have a selection of options; to review existing data or to collect data. Once you have selected *collect new data* the camera will turn on and the Placido rings will illuminate (Figure 5.2).
5. Ask the patient to place their chin on the chin rest at this point. This avoids unnecessary photophobia as the rings are already illuminated and the patient will have adjusted to the light levels. Either you adjust the instrument to align the camera with the cornea or it is automatic. The fine focusing to align the alignment targets will allow you to capture the image, either manually (pressing the button) or automatically. Before the image is captured ask the patient to blink a few times and then to hold from blinking.
6. Switch eyes, again this may be automatic or manual; usually the instrument moves, not the patient. Align and focus the targets and capture the image of the second eye.
7. The patient can now rest their head back while you confirm the captured images are acceptable and the instrument processes the data and generates the colour maps.

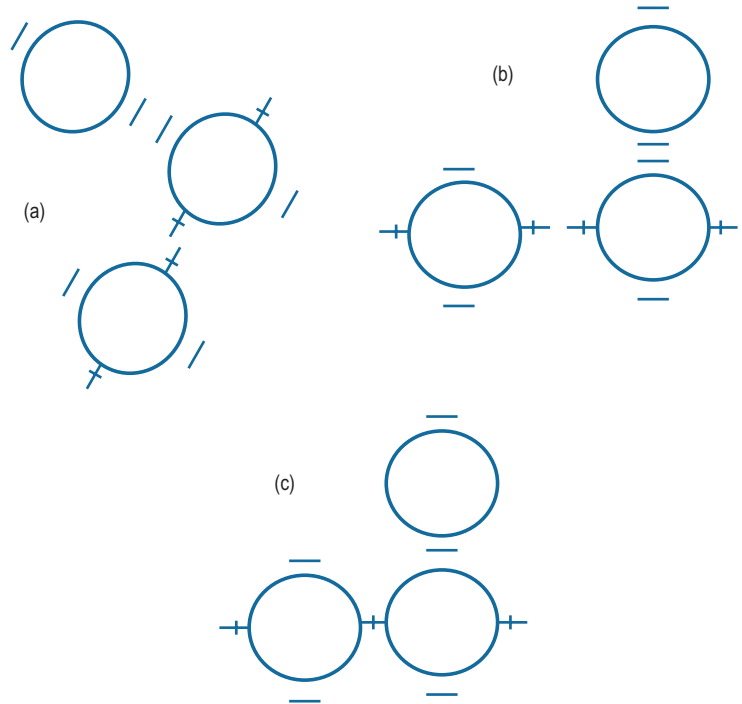
5.4.3 Procedure: Bausch and Lomb one-position keratometer

1. Seat the patient comfortably in front of the keratometer, and ask them to remove any spectacles. Sit opposite the patient, across the instrument table, and dim the room lighting.
2. Explain the procedure to the patient: 'I am going to measure the shape of the front of your

eye, the cornea'. You may add: '... so that I will know which contact lens to fit' or '... so that I can tell whether the contact lens is changing the shape of your cornea.'

3. Adjust the eyepiece of the instrument by directing the telescope to a distant object (such as the cubicle wall), turning the eyepiece anti-clockwise as far as it will go and then turning the eyepiece clockwise until the black cross hair just comes into sharp focus.
4. Adjust the height of the patient's chair and the keratometer to a comfortable position for both you and the patient. Ask the patient to lean forward and place their chin in the chin rest and forehead against the headrest. Occlude the eye not being tested by swinging the keratometer's occluder into place. Then adjust the chin rest so that the outer canthus aligns with the headrest marker.
5. Ask the patient to look at the reflection of their own eye in the centre of the keratometer and to open the eye wide after a full blink. If a high refractive error prevents the patient seeing their own eye, then ask them to look down the centre of the keratometer. Make vertical adjustments of the keratometer if the patient is unable to see into the centre or shine a pen torch through the observation eyepiece on to the patient's face – adjust the keratometer's height until the light shines on their eye.
6. Align the keratometer so that the lower right mire image is centred on the crosshairs, and lock it into place.
7. Adjust the focusing of the keratometer by turning the focusing knob until the mires are clear and the lower right mire is no longer doubled. You will need to keep one hand on the focusing knob and constantly adjust it to exclude doubling of the lower right mire.
8. Measure the principal meridian that is closest to the horizontal first. Rotate the instrument so that the plus signs are set 'in step' (Figure 5.3) and the minus signs are parallel. This ensures that the instrument is aligned precisely on a principal meridian. This is easier to judge when the mires are adjusted to be relatively close to the end point. Use one hand to adjust the focusing knob to ensure a single, clear plus sign. Note that you will need to constantly adjust the keratometer's position to maintain image focus, so keratometric measurements are always a two-handed operation. Note the radius of

Fig. 5.3 Alignment of the mires on a Bausch and Lomb keratometer. (a) The view when the mires are off the principal meridians. (b) The view when the mires are on the principal meridians. (c) The view when the plus and minus signs are overlapping to measure the 'horizontal' and 'vertical' radii of curvature/equivalent power.



curvature (or dioptric power) and orientation of this meridian.

9. Measure the second principal meridian, which is theoretically 90° to the primary one. Adjust the focusing knob to give the best focus for the minus signs and then adjust the vertical alignment wheel until the minus signs are superimposed (Figure 5.3). Note the radius of curvature (or dioptric power) and orientation of this meridian. On a toric cornea, the plus signs will be out of focus and not superimposed, but this does not matter as you have completed your measurement of the near horizontal principal meridian.
10. Repeat the measurements on the other eye.

5.4.4 Procedure: two position variable doubling type keratometer

1. Set up the patient and the instrument as described in steps 1–8 above.
2. Move the telescope forward by adjusting the focusing knob or joystick appropriately. You may need to make minor adjustments both horizontally and vertically to centre the mire images and achieve a view as depicted in

Figure 5.4. If the blocks and staircase are in step (Figure 5.4a), then the orientation of the instrument arc is aligned to one of the two principal meridians and you can now proceed to step 4.

3. If the mires you see are similar to Figure 5.4c, where the blocks and staircase are out of step, then the angle of the instrument arc is not aligned along a principal meridian. Move the arc slowly until the staircase and block mires are in step and are able to be brought into contact by turning the knurled knob situated below the arc as in Figure 5.4d. This is easier to judge when the mires are relatively close together.
4. Ask the patient to blink and then keep their eyes as wide open as possible. Turn the knurled knob situated below the arc until the staircase and block mires are just touching. You must simultaneously adjust the instrument position with your other hand to maintain focus of the mire images. If you turn the knob too much and the mires overlap, a yellow/white area of overlap will be seen. Adjust the position of the mires until they are just touching with no overlap. If the hair wire does not pass through the middle of the touching mires, make final

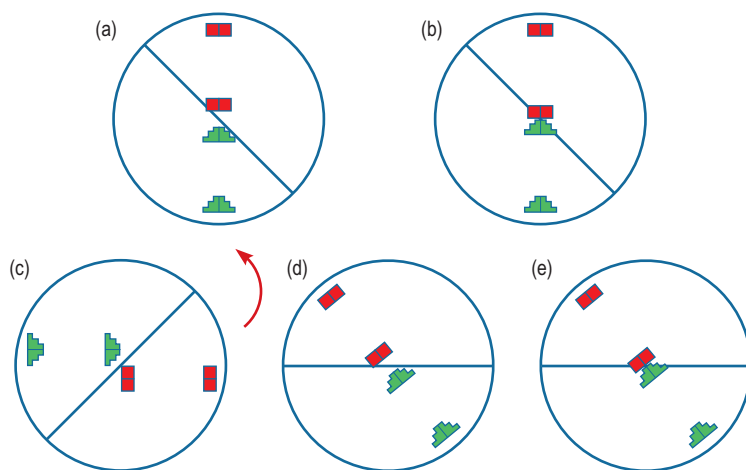


Fig. 5.4 The mire images as seen on the Javal-Schiötz keratometer.

(a) Aligned mire images along the horizontal. (b) Mires from 'a' touching with no overlap. (c) Non-aligned mire images. (d) Mire images from 'c' brought into alignment along an oblique meridian. (e) Mires from 'd' touching with no overlap.

horizontal and vertical adjustments to achieve this.

5. Read off the angle of the arc from the degree scale of the instrument and the radius of curvature along this meridian from the mm scale.
6. Turn the arc through 90° and make adjustments as in steps 4 and 5 to achieve a picture similar to [Figure 5.4b](#) or [5.4e](#). Note the reading off the scales. This is the corneal radius along the other meridian.

5.4.5 Recording

Topography results are usually printed and attached to the records ([Figure 5.5](#)). Many topographers display the corneal curvature data in a variety of ways:

Absolute colour map

This is a colour coded map where the different colours represent the same radius of curvature. Typically, steep areas of the cornea are shown as red, average areas as yellow through to green and flatter areas as blue. The colour scale covers the whole range of curvature values for the instrument's normative dataset. This allows comparison of corneal curvatures between patients and gives an idea of how steep or flat a patient's cornea is in comparison to the population. The disadvantage is that because there are a limited number of colours in the scale, the map may lack sensitivity to small changes in curvature.

Relative colour map

For the same data the topographer can also generate a colour map that distributes the colours only over

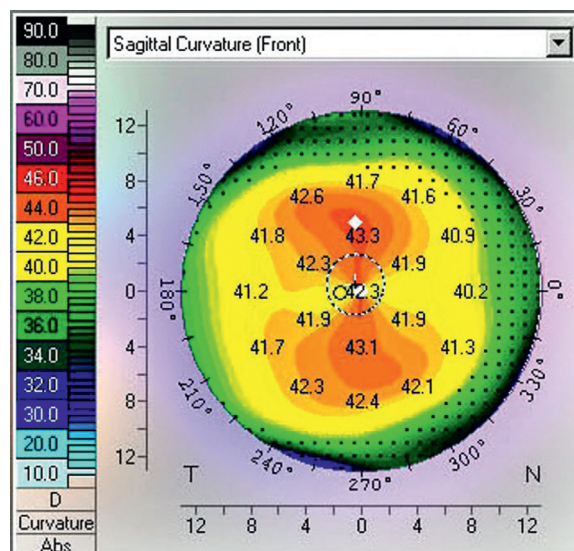


Fig. 5.5 A sagittal curve plot of the front surface of an astigmatic cornea.

the range of curvature values for that specific measurement. This reduces the steps so that the changes in colour for the scale increase sensitivity and provide more detail on shape change for that individual cornea. Caution should be taken when comparing relative colour maps between patients and between repeated measures as the same colour will not necessarily represent the same radius of curvature. As a consequence, a relative colour map may show an area of curvature as red because it is the steepest part of that cornea, but the absolute colour map may show the same area as green or blue because in comparison to the normative dataset that area is relatively flat.

Difference colour maps

These compare two measurements and allow a visualisation of the difference, which is helpful to observe change over time, i.e. the impact of wearing orthokeratology lenses or the progression of keratoconus.

Indices of symmetry: different topographers have different names for these indices that represent the coefficient of variability of a cornea, e.g. regularity index or keratoconus indices. They are a measure of how symmetrical a cornea is and, as the value increases, the symmetry decreases and can be taken as an indicator of the level of irregular astigmatism and an early indicator for the development of conditions such as keratoconus.

Keratometry results

These can be recorded with the radius of curvature of the horizontal meridian first, followed by the vertical as follows:

R 7.75 @ 175/7.60 @ 85

L 7.70 @ 180/7.60 @ 90

The @ nomenclature can be replaced by 'along' or 'al'. A degree sign ($^{\circ}$) should not be used after the axis direction. It is possible for the $^{\circ}$ to be confused with a 0, so that 15 degrees could become 150 degrees. If the mires are distorted, this must be recorded.

Alternatively, the results can be recorded in dioptres, in which case the amount of corneal astigmatism is usually calculated and recorded. Note that this is the total estimated corneal astigmatism due to the anterior and posterior corneal surfaces and is usually derived by assuming a corneal refractive index of 1.3375. The difference between the two powers equals the approximate total corneal astigmatism and the meridian with the lower power corresponds to the corneal cylinder axis. It can be useful to consider the amount of corneal astigmatism in relation to the spectacle astigmatism, when deciding whether a spherical RGP lens can be used to correct astigmatism.

e.g. OD: 42.00 @ 175/43.75 @ 85, -1.75×175 , mires distorted.

OS: 43.50 @ 180/44.25 @ 90, -0.75×180 , mires clear.

5.4.6 Interpretation of corneal curvature measurements

Corneal topography: This has the advantage of showing the corneal height over a wide range of locations, making it easier to differentiate between symmetrical astigmatism and asymmetrical astigmatism. This can be easily observed by viewing the colour

map. Astigmatism is represented on the map by the appearance of a bow-tie pattern. For symmetrical astigmatism this bow-tie pattern is seen as even bows on both sides (Figure 5.5). As the asymmetry increases, the disparity in the size of the bows increases. Increasing asymmetry in the pattern could be an indicator for correcting this astigmatism with soft toric lenses rather than RGP lenses, which may decentre due to the profile asymmetry. A pattern indicative of early keratoconus has an apex that is decentred inferior nasal (Figure 5.6). However, keratoconus can produce a range of different topographical patterns. Large changes in the degree of astigmatism within a short time can be indicative of keratoconus, lid neoplasms, pterygium, or a chalazion. Large changes in spectacle astigmatism without corneal astigmatic changes in the elderly are likely due to cortical cataract. Corneal curvature measurements can also be used to help indicate whether ametropia is refractive or axial. For example, a patient with increasing myopia but no change in corneal curvature probably has axial myopia. An anisometropia with different curvature readings probably has refractive anisometropia, while an anisometropia with similar curvature readings probably has axial anisometropia.

Keratometer readings: The power of the anterior corneal surface (F_c) is estimated from the radii measurements (r) using the equation $F_c = (n-1)/r$. The refractive index (n) of the cornea is about 1.376, but most keratometers use a value for n of 1.3375. The

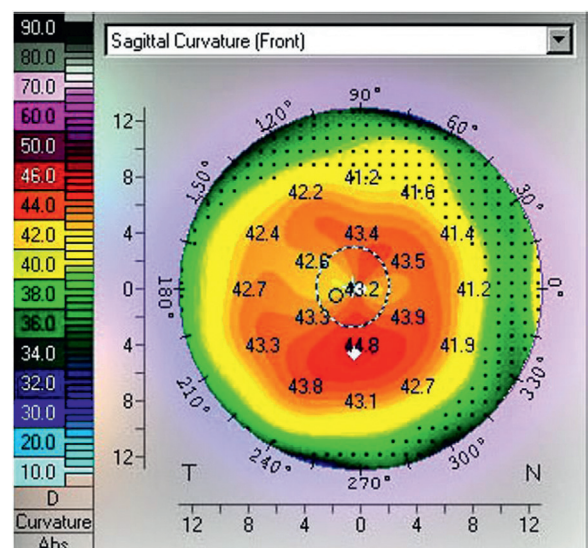


Fig. 5.6 A topography plot of the front surface of an forme fruste keratoconic cornea.

lower value for n is intended to compensate for the negative power of the posterior corneal surface. It is assumed that the posterior surface reduces the overall corneal power by about 10% but this amount varies between individuals. This also assumes that the two surfaces have the same proportion of astigmatism. Other factors that lead to errors in keratometry readings include the assumption that the cornea is spherical (most are elliptical) and that the visual axis runs through the corneal apex, which it usually does not.

A small radius value means a steep corneal surface, which is more powerful and more myopic (or less hyperopic). Larger radii mean flatter surfaces, which are less powerful and more hyperopic (or less myopic). The anterior radii of curvature of the cornea are usually between 7.25 mm and 8.50 mm, with myopes having steeper (smaller) radii and hyperopes having flatter (larger) radii. Dioptric powers range between 46.50 D and 40.00 D, and the anticipated corneal astigmatism is usually less than 2.00 D.

5.4.7 Most common errors

Corneal topography

1. Poor centration: not aligning the visual axis with the instrument's camera.
2. Poor focusing of the corneal reflection resulting in blurred ring edges.
3. Misaligning the alignment target, which displaces the Placido ring image.
4. Not getting the patient to keep their eyes wide apart so that the Placido ring image is obscured by the shadow from the lids.

Keratometry

1. Failing to maintain mire image focus when attempting superimposition of the mire image.
2. Not ensuring the patient keeps their head against the headrest.
3. Forgetting to focus the eyepieces.
4. Not centring the mire images.
5. Forgetting to calibrate the instrument regularly.

5.5 DETERMINATION OF CONTACT LENS POWER

The initial power of the trial contact lens is the spectacle refractive correction, which for powers above 4.00 DS needs to be corrected for the typical back vertex distance used in refraction of 10–14 mm. Refractive

powers can be adapted to help control binocular vision problems as with glasses, plus there are some conditions for which contact lenses are a positive indication, such as anisometropia and nystagmus.

5.5.1 Comparison of tests

To minimise error and reduce unnecessary chair time during the fitting of contact lenses, it is prudent for the patient to have undergone a recent eye examination prior to contact lens fitting, so they should attend with a copy of their spectacle prescription, which can be used as the starting point. If the visual acuity is similar in the two eyes and the patient is binocular, a binocular refraction is a quick way of confirming the prescription (section 4.12). Prescriptions greater than ± 4.00 DS will require a correction for back vertex distance before selecting a trial contact lens power.

Wavefront aberrometry allows the higher-order optical errors of the eye to be measured in addition to sphere and cylinder. In eyes with corneal irregularity as a result of keratoconus, for example, higher-order aberrations have a much more significant impact on visual quality. Wavefront aberrometry is likely to play a more prominent role in custom contact lens fitting in the future as lenses capable of correcting some higher order aberrations become available for keratoconic patients.¹⁸

5.5.2 Determination of power for a correction greater than 4.00 DS

For spectacle refractions of $\geq \pm 4.00$ D, a correction for back vertex distance (section 4.12.3) is required.

The power of the required contact lens F_{CL} is given by the equation:

$F_{CL} = F_{sp} / (1 - dF_{sp})$, where F_{sp} is the back vertex power of the spectacles and d is the vertex distance in metres.

Example 1:

Spectacle prescription: bvd 12 mm (0.012 m)

RE: -6.00 DS

LE: -6.50 DS

e.g., RE, $F_{CL} = F_{sp} / (1 - dF_{sp}) = -6.00 / [1 - (0.012 \times -6.00)] = -6.00 / 1.072 = -5.60$.

RE: -5.60 DS = -5.50 DS

LE: -6.03 DS = -6.00 DS

5.5.3 Determination of power for a soft contact lens

In the situation where a soft spherical lens is fitted to an eye with an astigmatic prescription, the power of

the trial lens should be the mean spherical correction, i.e. sphere + half the cylinder. For example:

Spectacle prescription = $-2.00/-1.00 \times 180$
 Power of trial lens (BVP) = $-2.00 + (-1.00/2)$
 = -2.50 DS

When fitting a spherical RGP lens to an eye with corneal astigmatism, the toric tear lens trapped between the lens and the eye neutralises the astigmatism, and therefore the trial lens power should be that of the spectacle sphere power alone, rather than the mean spherical error. In the above example, the trial lens power would be -2.00 DS.

5.6 PRELIMINARY SLIT-LAMP BIOMICROSCOPY AND TEAR FILM ASSESSMENT

The slit-lamp examination prior to lens fitting serves a number of purposes:

1. To examine the health of the anterior portion of the eye and adnexa.
2. To look for issues that potentially preclude or limit contact lens wear, or indicate the need for a particular type of contact lens.
3. To allow the recording of baseline data against which to judge changes over time, contact lens induced or otherwise.

The tear film and the way it interacts with the lens surface is very important in successful contact lens wear. A large proportion of contact lens drop-outs cite discomfort and symptoms of dryness as reasons for ceasing lens wear.¹⁹ A thorough assessment of the tear film and how it impacts on the ocular surface allows you to select a more suitable lens material, such as one with low water content (to limit dehydration) and high lubricity (to minimise friction). It also allows better management of the patient's expectations.

5.6.1 Procedure for preliminary slit-lamp and tear film assessment

For a detailed description of slit-lamp examination and tear film assessment, see sections 7.2 and 7.3. This section describes the procedures for assessing the tear film, which are generally undertaken as an additional component in the slit-lamp biomicroscopy examination. The tests shown to best predict contact lens induced dry eye in new wearers are symptoms, such as late in the day dryness. These symptoms can be reliably quantified using questionnaires.^{20,21} The signs useful as predictors are non-invasive tear break

up time and grading of lid parallel conjunctival folds.²²

5.6.2 Recording

It is useful to record and grade everything seen to provide baseline information. For example, grade 1 papillae on the lateral margins of the superior lid (online video 5.1) would not be considered abnormal but it is invaluable to note this prior to contact lens fitting. A number of grading scales are available but the most commonly used scales are from the Brien Holden Vision Institute (www.contactlensupdate.com/wp-content/uploads/2011/05/Grading_Scales_web.pdf) and the Efron grading scales, which are standardised images of common complications at different levels of severity.²³ Try to use just one grading scale, as this will improve your grading accuracy and repeatability over time. The detection of clinical differences can be improved by recording findings in 0.1 steps as these scales are generally quite coarse.²³



5.7 SOFT CONTACT LENS FITTING

5.7.1 Soft lens application

Patients will be anxious about lenses being applied to their eyes for the first time and you need to try to put the patient at ease (section 2.1). Patients need to be comfortable and feel part of the process, this must involve an appropriate informed consent process, where explaining what you do at each stage and answering any questions they may have is key.

1. Wash your hands thoroughly as per the World Health Organization (WHO) guidelines (www.who.int/gpsc/clean_hands_protection/en/): rub both sides of the hands, in between the fingers and the finger tips. Rinse thoroughly and dry with a lint free towel.
2. Check the lens specification on the container and expiry date.
3. Remove the lens from the container, place on your index finger (finger next to the thumb) tip and check whether the lens is inside out or the correct way round by:
 - (a) Checking the lens profile, which should be slightly bowl-shaped rather than saucer-shaped (Figure 5.7), and gently pinching the lens should result in the edges curving inwards rather than outwards.
 - (b) Using the crease test, which involves placing the lens in the palm of your hand

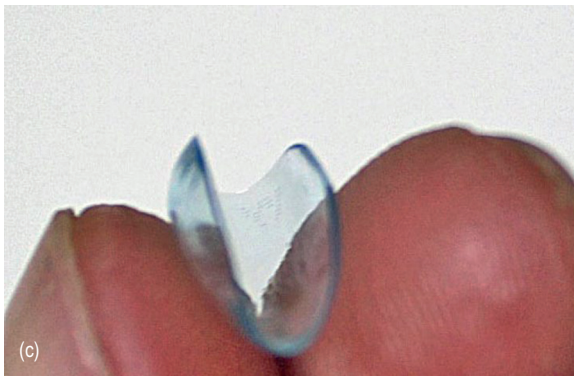
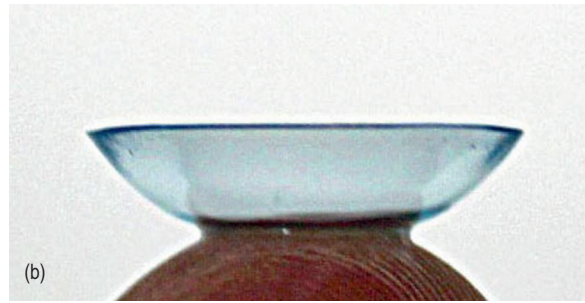
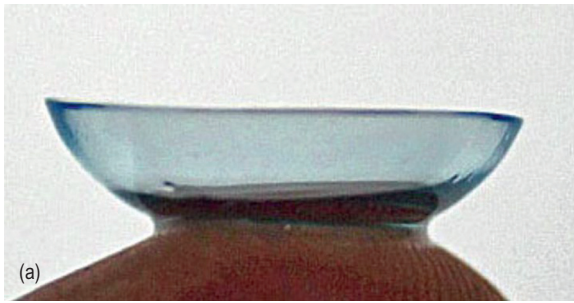


Fig. 5.7 Profiles of contact lenses (a) the correct way round (bowl shaped); (b) inside out (saucer shaped); (c) edges curving inwards when gently pinched.

along the main crease, cupping the hand slightly so that the lens is partially folded and looking to see if the edges roll inwards (correct) or outwards.

- (c) Some lenses have inversion indicator engravings. Make sure you know from which side of the lens the engraving should be correctly viewed.
- (d) If incorrect, simply pick up the lens and turn it over, repositioning it on your finger tip.
4. Check for debris or defects. Any debris should be rinsed off with saline or multipurpose solution. Defective lenses should be disposed of.
5. You should make sure you have your three key fingers reasonably dry; the index finger where the lens is resting, the middle finger of the same hand and the index finger (or thumb) of the other hand, these two 'extra' fingers will hold the eyelids apart during the application of the lens. If the lens or finger is too wet, there will be too much contact between the two and it will not be easy to apply the lens. Too little contact, usually as a result of lens dehydration, may result in the lens falling off the finger during application.
6. Stand slightly to the side of the patient on the side that you are going to apply the lens to first. This may necessitate rotating the patient's chair away from you. The following instructions assume that you will apply the right lens first using your right hand.
7. Ask the patient to rest their head against the head-rest of the chair, turning their head slightly away from you for the right eye application to make the process easier.
8. Explain that you are going to gently hold the lids apart and place the lens on the eye. Make it clear that once the lens is on, they will hardly feel it.
9. Ask the patient to look down and use the thumb (or index finger) of your left hand to lift their superior eyelid from just behind the lashes, and hold it firmly against the brow bone. Do not push in to the orbital cavity.
10. Ask them to look straight ahead and use the middle finger of your right hand to pull the lower lid down from just behind the lashes.
11. Gently place the lens on the eye in one of the following ways:
 - (a) On the inferior conjunctiva whilst the patient looks up;

- (b) On the temporal conjunctiva whilst the patient looks nasally;
 - (c) Directly on the cornea whilst the patient looks straight ahead.
12. The lens will most likely have a bubble of air underneath it when first applied, particularly if the lens has been placed on the conjunctiva, which is flatter than the cornea. Keep your finger in position initially and ensure the lens has adhered to the surface of the eye rather than sticking to your finger. A very gentle massaging motion will help this. Slowly withdraw your finger, asking the patient to gradually look straight ahead to centre the lens.
 13. Release the lower lid then ask the patient to look down before slowly releasing the top lid to cover the lens.
 14. They should now be encouraged to make slow, gentle blinking movements whilst looking down.
 15. Repeat for the left eye, standing on the other side of the patient and using your left hand to apply the lens.
 16. These instructions assume that you are able to use both your dominant and non-dominant hands for lens application, and will therefore use your right hand for the right eye, and left hand for the left eye. If this is not the case, you will have to use your dominant hand for one eye and reach over the patient, taking care not to touch their nose, in order to apply the lens to the other eye.

5.7.2 Problem solving

1. If lens application produces a sensation of grittiness or discomfort, ask the patient to look up, displace the lens down and/or temporal with your index finger and allow it to recentre. If the grittiness persists, remove the lens, check for debris and defects and reapply or replace as appropriate.
2. If lens application results in a stinging sensation and watering of the eye, remove the lens, rinse with saline and reapply. Profuse watering on lens application can be indicative of something on the lens, such as soap from hand washing, or a difference in tonicity or pH of the patient's tears and the solution on the lens. Significant lacrimation tends to give an apparently tight fitting lens on assessment; the hypertonic tears cause the lens to adhere to the surface of the eye,

especially lenses fabricated with ionic materials.

3. If a patient is very motivated to wear contact lenses but is very unsure with you placing a lens on their eye, teach them to apply and remove the lenses themselves during the fitting appointment.

5.7.3 Removal procedure

1. Wash your hands thoroughly as per the WHO guidelines.
2. Position yourself and the patient as for lens application ([section 5.7.1](#)).
3. Explain that you are going to gently hold the lids and slide the lens off the eye.
4. Ask the patient to look down and use the thumb (or index finger) of your left hand to lift their superior eyelid from just behind the lashes, and hold it firmly against the brow bone. Do not press into the orbital cavity.
5. Ask them to look up and nasal and use the middle finger of your right hand to pull the lower lid down from just behind the lashes.
6. Gently place the index finger of your right hand on the lens, slide it firmly down and temporal until it is completely clear of the cornea.
7. Bring your right thumb in and pinch the lens between thumb and index finger.
8. Release the lids.
9. Repeat for the left eye, standing on the other side of the patient and using your left hand to displace the lens and pinch it off.

5.7.4 Most common errors

Preparation

1. Having fingernails that are too long and/or dirty.
2. Approaching the eye from the front rather than the side, resulting in less contact between fingers and lids and therefore poorer lid control.
3. Not holding the lids firmly enough, therefore allowing the patient to blink during the application process.
4. Holding the lids right at the base of the lashes, or in front of the lashes, causing discomfort to the patient and increasing the risk of touching the cornea/conjunctiva.
5. Not ensuring that both your fingers and the patient's lids are dry before trying to handle

them. The patient's eye may water during the procedure and the lids may need to be dried with a tissue before reattempting application.

6. Not positioning the lens on the very tip of the finger. This is particularly important for practitioners with large fingers.
7. Lens too wet, such that surface tension draws it to the finger rather than the ocular surface.

Application

1. Allowing the patient to blink while there is still a large bubble under the lens. The lens is likely to be propelled out of the eye.
2. Not instructing the patient to blink slowly and gently once the lens has been applied. A hard, quick blink is more likely to propel the lens out of the eye if it is not completely in apposition with the cornea.

Removal

1. Pinching the lens off the eye whilst it is still on the cornea, risking damage to the cornea.
2. Putting insufficient pressure on the lens whilst sliding it off the cornea, resulting in little or no movement.

5.8 SELECTING A SPHERICAL TRIAL LENS

Having discussed with your patient the option of contact lenses to correct their vision and answered any questions they may have (an informed consent process), you have to select a lens that you think is suitable for the patient. Deciding what lens is best needs you to think about various lens options and parameters in the following order:

1. Lens replacement frequency: The majority of soft lenses are disposable and replaced either daily, two-weekly or monthly. Deciding the replacement frequency starts the process of restricting your choice of lens material.
2. Lens material: Due to their increased oxygen transmissibility, silicone hydrogel lenses are now the preferred option. When a silicone hydrogel lens material is not selected, this is usually because a parameter needed to fit that patient is not available. It may be that the best option is a daily disposable lens and a parameter is only available in a hydrogel material.
3. Lens power: This will be based on the patient's refraction, remember to convert the spectacle refraction to the ocular refraction when the back

vertex distance change impacts the refractive result ($>\pm 4.00$ D; [section 5.5.2](#)).

4. Base curve: While traditionally the lens base curve selection is driven by the patient's keratometry results, most soft lenses are available only with one or two base curves. For soft lens fitting, keratometry is therefore only really useful to establish normality as the lens with the flattest base curve is trialled first. You should change to the steeper base curve only if lens fit was not acceptable or if the patient complains of lens awareness.
5. Total diameter: The lens edge must always rest on the conjunctiva well clear of the limbus. Lens edges that align with the limbus will result in complications, reduced wearing times and discomfort. This parameter is theoretically determined by measuring the horizontal visible iris diameter (HVID) although lenses are rarely available in more than one diameter. So if the lens you have selected is too small, you are likely to have to select another lens brand. Lenses that are too large may simply be too hard to remove.

5.9 ASSESSMENT OF SPHERICAL SOFT LENS FIT

See online videos 5.2-5.8. Lens assessment has two phases, the initial brief phase followed by a detailed assessment. 

5.9.1 Initial brief assessment of lens fit

Having selected the best lens and placed them on the patient's eyes, the following procedure should be followed:

1. Initial gross observation: The first assessment is observational. Is the patient comfortable? Soft lenses are comfortable devices, even to the naïve wearer. If the patient has issues, follow the problem solving procedure in [section 5.9.5](#).
2. Initial patient assessment: Ask how the patient feels and if they can see, anticipating a positive response.
3. Closer inspection: Having established that the patient is comfortable and their vision is good, the next step is to make a close assessment of the lens fit, either with the naked eye or the slit-lamp. The basic need is to make sure the lenses are in the correct position and have not decentred.

4. First vision assessment: Lens centration can also be confirmed by assessing the patient's visual acuity; good acuity levels for a myope not wearing spectacles indicates the lens must be in place.

At this point the lens has probably not settled sufficiently to make an accurate assessment and it is often preferable to send the patient out of the consulting room, let them try the lens and see the world. If your risk assessment has determined that the patient is wearing a well-centred lens with acceptable acuity, say 6/9 (20/30) or better, then send the patient out for a walk, or if the vision or fit is questionable let them have a seat in the waiting room. The settling period should be for at least 10 minutes but may be longer if it fits better with your appointment schedule and the patient.²⁴

5.9.2 Detailed assessment of lens fit

▶ See online videos 5.2-5.8. As part of the detailed assessment you will need to carefully measure the vision and assess how the lens is fitting. As both of these are interlinked, the order will be determined on how the patient is doing.

1. When taking the patient back into your consulting room, ask how the lenses feel and how their vision is.
 - (a) If their response to both is positive then assess the vision first, followed by the assessment of fit.
 - (b) If they are uncomfortable, assess the fit first and then the vision.
 - (c) If they complain that the vision has deteriorated, this could be due to an adjustment need to the lens power or to the fit and the order of assessment is your choice. Degraded vision may also indicate a poor wetting surface. Using a retinoscope is a great way to get an instant impression; a poor wetting surface will develop shadows post blink.
2. Gross assessment of lens fit: While the patient is sat in the chair, observe the lens on the eye without magnification. You want to make sure the lens is still correctly centred and see if you can observe lens movement on a natural blink. Next, using your index finger, push the lower lid over the lens edge while the patient looks straight ahead, again observing to see if you can see lens movement.
3. Slit-lamp assessment of lens fit: The slit-lamp should be set up for direct illumination with low magnification ($\times 10$):
 - (a) With the patient looking straight ahead, observe how the lens moves with 2–3 blinks, this should only take 15–20 seconds. Sweep the observation microscope across the lens to observe movement temporally and nasally. You should also observe the lens size in relation to the HVID, making sure of good even coverage of the cornea and limbus.
 - (b) Post blink movement: Ask the patient to look up so you can see the inferior edge of the lens. Observe lens movement in this position with continued blinking as it is a good determination of overall lens movement.²⁵
 - (c) The push up: Place your thumb or index finger against the lower lid and use it to displace the lens, again observing the lens movement. It should displace easily and return to its former position in a smooth and rapid manner.²⁵ This is the single most valuable assessment of the fit of a soft lens.²⁶
 - (d) Finally, with the eye back in the primary position, ask the patient to look left and right, again observing the lens movement.
 - (e) During all of these assessments, the lens should demonstrate movement over the surface of the eye and the lens edge should not encroach the limbus. The patient's blinks should appear natural and not as if they are experiencing discomfort.
4. Assess lens movement: Most slit-lamps allow you to generate a very small circular spot of light, which is usually 1 mm in diameter. You can use this spot of light as an indicator of size when you are making observations through your slit-lamp using moderate magnification ($\times 16$ to $\times 20$). While the patient is either in the primary position of gaze or looking up, place the edge of the spot on the outer edge of the limbus or the inner edge of the lens and ask your patient to blink and observe the lens movement, estimate the amount of movement in relation to the size of the spot of light and record in mm. You should expect to record movement of no more than 0.5 mm.

5. Assess lens centration: While the patient is in the primary position of gaze, observe the lens through low magnification ($\times 10$ or less) and using a diffuse light source. This will allow you to gauge the lens position in reference to the centre of the pupil or the HVID. Record whether the lens is centred or has de-centration, recording the direction of that de-centration, i.e. superior, nasal, inferior, temporal. The grading system could simply record centration as ideal, good (+1), acceptable (+2) or poor (+3), with all except ideal having a direction indicator, e.g. +1T is good with temporal decentration.

5.9.3 The ideal lens fit

In the primary position the lens should be well centred with an even lip of lens extending beyond the limbus. The centration is graded with reference to the centre of the pupil (or the HVID). A grade of +3 (poor) is not acceptable and is thus only likely to be seen during an unsuccessful initial lens trial. A natural blink should induce movement that is observable but that does not move the lens edge, such that it encroaches on the limbus. If a lens moves excessively where the edge abuts the limbus, a tighter lens will be needed. If no movement is observable but the lens moves easily during the push up test then the fit is acceptable. When a lens does not move during the push up test then it is considered too tight and needs to be refitted with a looser fitting lens.

5.9.4 The extended trial

If the lens is well centred, shows good movement and the patient is comfortable, you have a lens that can be used for an extended trial. This would be over a couple of days, so would require the patient to have been taught how to handle and care for the lens. The length of the extended trial should fit in with your appointment schedule as well as be convenient for the patient and therefore varies from 3 days to 2 weeks. When the patient returns, treat the visit as the first aftercare visit. As the lens will have demonstrated good vision and good fitting before being dispensed, the likely issues will relate to adaptation, lens handling and care.

5.9.5 Solving lens fitting problems

1. Too tight, loose or decentred: A tight lens shows no movement with the push up test. A loose lens can be seen to move in the absence of a

provocative test such as the push up test and/or it decentres on upward gaze alone or it does not smoothly re-centre. A lens with excessive decentration encroaches the limbus with the lens edge. Lens centration is usually assessed in the primary position of gaze but excessive decentration on upward gaze should also be a cause for concern and indicates that a change in fit is needed. You can alter the fit by:

- Changing the base curve – flatter if too tight and steeper if too loose or decentred.
- Changing the lens diameter – smaller if too tight and larger if too loose or decentred.
- Altering the lens thickness – thicker if too tight and thinner if too loose or decentred.
- Switch to a silicone hydrogel material if your initial hydrogel lens was too loose and to a hydrogel lens if the initial silicone hydrogel lens was too tight or decentred.

In order for you to make any of the above changes, you generally have to change brand as most lenses are only available in one or two different base curves with no option to change lens diameter or thickness.

2. Too large: If the patient is having difficulty removing them, either flatten the lens fit and/or reduce the lens diameter.
3. Too small: If the lens is encroaching the limbus, then you should increase the lens diameter. You may improve the fit as well if you reduce the lens sagittal height by flattening the base curve.
4. Complaints of transient blur following a blink: You should anticipate the appearance of non-wetting areas ([Figure 5.8](#)) observable with a slit-lamp and using a retinoscope. The greatest challenge to manufacturers of silicone hydrogel lenses is to ensure the surface of the lens has been correctly produced and so if a faulty lens occurs, it is likely to have a surface defect. These defects usually present as non-wetting areas and will impact a patient's vision and comfort.

5.9.6 Over-refraction, VA and ocular motor balance

1. Over-refraction: In the majority of cases the trial contact lens power is selected to be as close as possible to the spectacle prescription, leaving a small over-refraction if any. In a patient with good binocularity, this allows the use of the quicker binocular over-refraction (section 4.12) rather than monocular followed by binocular

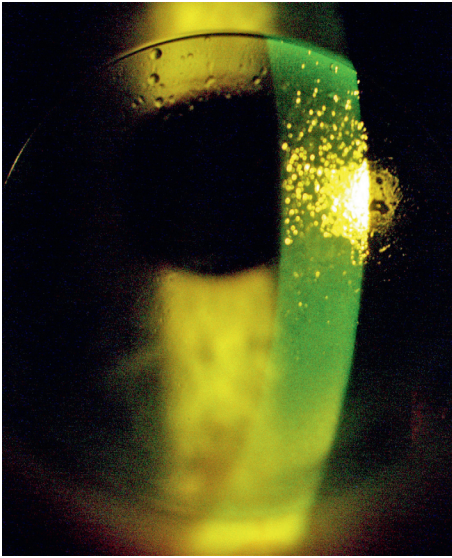


Fig. 5.8 Non-wetting area on an RGP lens.

balancing. Refraction is generally restricted to spheres only because patients with small degrees of astigmatism (<0.50 DC) in their spectacles are likely to be fitted with spherical soft contact lenses, leaving their astigmatism uncorrected, or spherical RGP lenses which will correct corneal astigmatism using the tear lens trapped behind the contact lens. Measurement of astigmatism should be undertaken if the visual acuity does not reach the expected level.

2. Visual acuity: With the over-refraction in place, distance and near VA should be assessed (sections 3.2 and 3.3). Also record the stability of VA after a blink. Vision that blurs immediately after a blink and then clears, suggests that the lens is loose; the blink causes lens movement. Vision that clears briefly immediately following a blink suggests the lens is tight, the blink flattens the lens against the cornea for a moment or that there are areas of non-wetting on the lens surface. Visual instability is less obvious for hydrogel soft lenses even when the fit is very poor, because the lenses are so thin and flexible.
3. Muscle balance: The ocular muscle balance should be checked for comparison with the preliminary measurement, particularly in patients known to have a heterophoria at distance and/or near. Control of a heterophoria may differ between spectacles and contact lenses (section 6.2). A cover test at distance and

near is usually sufficient. Higher myopes may complain of asthenopia during the adaptation phase, due to a transitory associated exophoria.

4. Recording example:

RE: CL power -3.00 DS

OR $+0.25$ DS 6/5, stable c blink

LE: CL power -3.00 DS

OR $+0.50$ DS 6/5, stable c blink

Back vertex power to be ordered: R) -2.75 DS,
L) -2.50 DS.

5.9.7 Post-fit health check

See online videos 5.9-5.11. Having removed the trial lenses, the final act before writing the lens order is to check the eyes for unwanted signs of contact lens wear. This involves a slit-lamp biomicroscope examination of the cornea and conjunctiva, looking for fluorescein and lissamine green staining (section 7.3). The findings should be recorded in a diagram and graded using the CCLRU or other grading scale, and compared with the preliminary assessment prior to lens insertion. Very occasionally the findings of the post-fit check indicate that the lens fitting process must begin all over again: circumlimbal staining of the conjunctiva indicates an interaction between the lens edge profile and the conjunctiva.²⁷ Lens edge designs vary significantly and swapping to a rounder edge profile can eliminate the staining. Alternatively, the high modulus of the lens may be the cause and a less stiff material can be trialled. A tight fitting lens can also cause such staining but this should have been identified during the fit assessment.

Another finding that would indicate the need to refit would be signs of corneal (punctate fluorescein staining) and conjunctival (lissamine green staining) desiccation, as the result of a lens material incompatible with a poor quality tear film. Don't confuse solution-induced staining with a lens fitting staining appearance (Figure 5.9) as the management to resolve either is different, i.e. with the first, you need to change the lens care system; with the second, you need to change the lens material or design.²⁸ With careful history taking and a thorough ocular and tear assessment informing the trial lens choice, this should be avoided.

5.9.8 Most common errors

1. Allowing the wearer to look up too high when assessing post blink movement.
2. Push up test: Positioning your thumb or fingers such that the lower lid rolls out during the push up test, resulting in minimal

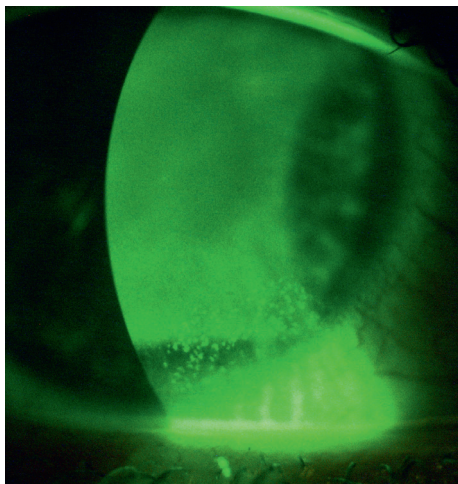


Fig. 5.9 Fluorescein punctate staining under cobalt blue illumination and a yellow barrier filter of the typical appearance during soft lens wear of dehydration staining. This should not be confused with the staining appearance for SICs, which generally has a symmetrical donut appearance.

contact between the posterior lid margin and lens edge and hence little or no movement on push up.

3. Overestimating lens movements having not used a small 1 mm spot to judge sizes, or estimated lens movement by comparing the HVID with the lens diameter.
4. Using the slit-lamp to assess lens fit with the rheostat set too high, such that the patient's eyes water and the fit is affected.

5.10 TORIC SOFT LENS FITTING

See online videos 5.12-5.14. When a patient has 0.75 DC or more of astigmatism in their spectacle prescription, they will most likely need this correcting in order to have optimised visual acuity with contact lenses. Around 47% of patients are estimated to have 0.75 DC or more of astigmatism in at least one eye.²⁹ Correction can be achieved using a toric soft contact lens regardless of the origin of the astigmatism. A spherical RGP lens (section 5.12.6) can also be used if the astigmatism is corneal in nature. A soft toric lens corrects the astigmatism by having a different lens thickness in each principle meridian. The lens must then be stabilised to prevent it from rotating. This is achieved using a number of different techniques including prism ballast and various forms of dynamic stabilisation in which raised areas of the lens interact with the eyelids.

Modern soft toric designs generally work very well and provide stable vision. There are some patients in whom rotational stability with soft torics can be challenging, including those with particularly angled eyelids or unusual lid movements on blink, or an oblique axis of astigmatism.

5.10.1 Trial lens selection

The majority of off-the-shelf toric lenses are only available in one base curve and diameter, therefore trial lens selection is simple but if the lens does not provide an adequate fit, a different brand must be trialled. These lenses are generally not available in every cylinder power and axis combination, with many brands offering between two and four different power options, for example 0.75 DC, 1.25 DC and 1.75 DC. The practitioner must select the nearest astigmatic power with the rule of thumb that it is better to under-correct than over-correct, as a smaller cylindrical correction gives less induced astigmatism if the lens does rotate, leading to more stable vision. Custom made toric lenses with any power, axis and dimensions are also available in a wide range of materials, but they are more expensive and therefore tend to be offered on a less frequent replacement schedule and never as a single use lens.

The trial lens power will require the spectacle prescription to be adjusted for back vertex distance (BVD) if one or both meridians have a power greater than 4.00 D. To do this, the power of each individual meridian is calculated, the BVD adjustment is applied to each meridian and the resulting powers are recombined (see section 5.5.2). The initial trial lens is selected in much the same way as a spherical trial lens with the frequency of replacement determined by the initial discussion of patient needs, the lens material determined by the history and preliminary examination (section 5.2), the diameter determined by the HVID measurement (section 5.3) but also the availability of a suitable cylinder power and axis. The method of stabilisation is also a factor and in patients with a similar prescription in each eye, it can be informative to trial a lens with a different stabilisation method in each eye.

5.10.2 Toric lens fit assessment

See online videos 5.12-5.14. The fit of a soft toric lens is assessed in the same way as a spherical soft lens (section 5.9). The only differences are that the lens should be left to settle for around 10–15 minutes before assessing and the orientation of the lens must also be

examined.³⁰ Rotational stability is essential for good vision with toric lenses, and the lens must remain reasonably stable as the eye moves around to avoid inducing astigmatism and blurring vision. It can be worth examining the fit and orientation before over-refraction as there is no point in checking the power of a lens that has poor rotational stability. To check the orientation:

1. Identify the location of the orientation marker or markers using diffuse light. The markings vary with lens brand and can be a single line at 6 o'clock, three lines centred on 6 o'clock or markers at 3 and 9 o'clock.
2. Note the position of the marker(s) as the patient blinks and with eye movements in a number of different directions of gaze.
3. Narrow the beam to a wide optic section (1–2 mm) and rotate it until it lines up exactly with the marker(s) on the lens. On a Haag-Streit type slit-lamp this is done by rotating the top of the illumination tower.
4. Read off the degree of rotation and note the direction and stability of rotation.

If the rotational stability of the lens is poor and varies with eye movements, a lens brand that uses a different stabilisation mechanism should be trialled instead. A lens that consistently rotates by the same amount in the same direction is perfectly acceptable as the axis of astigmatism can be adjusted using two possible methods:

- **LARS (Left Add, Right Subtract):** As you observe the patient, if the rotation is toward your left then you add the degree of rotation to the cylinder axis. If the rotation is toward your right then you subtract the degree of rotation to the cylinder axis.
- **CAAS (Clockwise Add, Anticlockwise Subtract):** As you observe the patient, if the rotation is clockwise then you add the degree of rotation to the cylinder axis. If the rotation is anticlockwise then you subtract the degree of rotation to the cylinder axis.

Whether you use LARS or CAAS the result is the same. This allows a contact lens to be ordered with an axis of astigmatism that differs from that of the spectacle prescription, knowing that this lens design will rotate to position the astigmatic power correctly.

For example: [Figure 5.10](#).

- Lens specification: Brand X 8.50:14.50/−2.00/−1.25 × 20.
- In the eye the orientation marking on the lens consistently rotates 10° anticlockwise from the

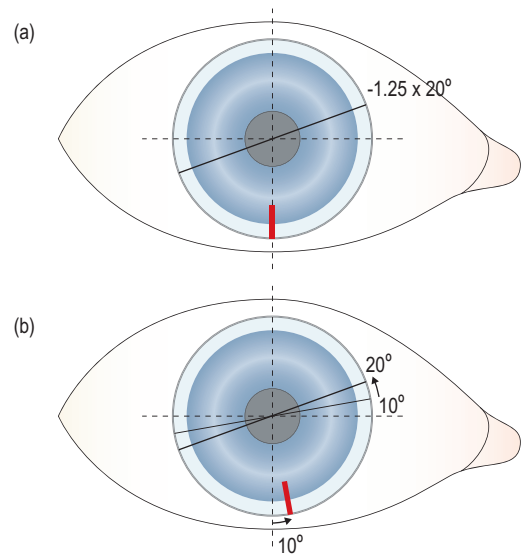


Fig. 5.10 CAAS rule drawing showing how the lens order can be altered to compensate for consistent rotation of a soft toric lens.

6 o'clock position where it should be, taking the cylinder power of the lens from the planned axis of 20° to 30°.

- A rotation of the marker from 6 o'clock in an anticlockwise direction indicates subtraction so the following lens is ordered:
Brand X 8.50:14.50/−2.00/−1.25 × 10.
- The lens is expected to rotate by 10° anticlockwise, taking the axis of the cylinder from 10° to the intended 20°.

5.10.3 Over-refraction of toric soft lenses

If a lens is not orientated correctly, the astigmatism of the lens will combine with the uncorrected cylinder of the eye and the resultant astigmatism will have an axis part way between the two, but there is no point in trying to measure this. A different lens should be trialled that either has a different axis of astigmatism (if the orientation is wrong but consistently at the wrong axis), or has a different stabilisation mechanism (if the orientation varies significantly with blinking and eye movements).

5.10.4 Common errors in toric soft lens fitting

1. Trying to correct astigmatic patients with a spherical soft lens.

2. Spending time over-refracting a lens that is rotationally unstable.
3. Trialling two lens brands with the same stabilisation mechanism in each eye

5.11 PRESBYOPIC SOFT LENS FITTING

The mushrooming of the ageing population is also reflected in the contact lens wearing population so that the need to correct presbyopia with contact lenses is increasing and will continue to do so.³¹ Fitting contact lenses that correct presbyopia can be challenging and you must adopt a philosophy of precision as the smallest level of uncorrected ametropia or miscalculation in reading addition will likely lead to a higher level in symptoms than expected. Be precise. As with non-presbyopes the preferred choice is to fit them with disposable lenses, to avoid the disadvantages associated with continued use of ageing lenses. As the required reading addition increases, the visual compromise needed to provide both distance and near vision increases and it is very likely you have to change the correction type you use.

5.11.1 Comparison of correction options

Using distance contact lenses with reading spectacles (known as over-readers in this situation) is probably the most commonly used option and as long as the patient accepts wearing reading spectacles, it is very successful. Morgan et al. reported 63% of presbyopes wearing contact lenses were not wearing a multifocal contact lens or monovision.³¹ Wearers do not have to be refitted with new contact lenses, just provided with over-readers, in the form of reading spectacles or half eyes (both of these can be in the form of ready readers and thus at relatively little cost) or spectacle multifocals (i.e. with a plano distance portion). There is no additional visual compromise unlike other contact lens corrections for presbyopia and this is the obvious choice for patients who have a high visual demand, whether for distance or at near, e.g. a patient who drives at night for a living. However, some patients will not appreciate the 'ageing' appearance and/or inconvenience of wearing over-readers and will prefer other options. Monovision provides a correction for distance viewing in one eye (the dominant eye) and near viewing in the other and so they are simple to fit. Current contact lens wearers only need a change in lens power in one eye and no refitting into a new design or material is required and lens costs are the same as distance only contact lenses. Patients who wear toric lens designs are ideal for monovision

because although there are some custom designed soft lenses that provide correction for both astigmatism and presbyopia, these are not available as disposable contact lenses. Monovision is successful so long as the patient can tolerate the induced blur, reduced stereopsis and possible retinal rivalry.³² As the reading addition increases, this blur increases and particularly when above +2.00 D may lead to symptoms especially when driving at night, where it is difficult to suppress the bright myopic blur circles seen by the non-dominant eye. Introducing modified monovision may solve these problems or refitting with a pair of distance contact lenses with over-readers. Monovision used to be the preferred option for correcting presbyopia mainly due to the poor optical designs and poor reproducibility of multifocal contact lenses, but significant improvements in design and manufacture of multifocal contact lenses has changed that preference.³¹

Because monovision has been successfully used for many years to correct presbyopia, a modified version has been developed that incorporates multifocal lenses, by correcting the dominant eye with a distance bias multifocal and the non dominant eye with the near bias multifocal or various combinations of single vision lenses and multifocal lens designs. The suggestion is that these multifocal lenses provide functionality for both distance and near and thus reduce the disparity between the eyes as well as the blur. You are likely to try different combinations to get the correct visual balance and so may consume more chair time.

Studies comparing multifocal lenses with monovision now report patient preference toward multifocals and away from monovision.^{33,34} The most commonly used multifocal lenses use a simultaneous lens design and are typically distance biased lenses, where the central portion of the lens contains the distance power and is surrounded by an increased relative positively powered region providing the near element. When a high reading add is required, near biased design lenses (the central portion contains the near power and is surrounded by an increased relative negatively powered distance vision region) will need to be used resulting in a marked reduction in distance correction and explains why a multifocal design has a reduction in performance for distance vision as the reading addition increases.³⁴

These optical portions can be formed by two distinct spherical zones but are usually aspheric and create a multifocal progression from the distance portion to the near portion. The majority of lens designs are the latter: aspheric and centre distance. Another multifocal approach uses multiple concentric rings of alternating distance and near powers and are available in both low,

medium and high reading additions. Situ et al., reported on the success of this lens design when refitting existing monovision wearers, with 53% still wearing the multifocal contact lens after one year.³⁵ Multifocal contact lenses have high levels of subjective preference and are very successful for lower reading adds, but there is a greater compromise in vision as the reading addition increases.³⁶ As a consequence, it is likely that distance contact lenses and over-readers become the preference as the reading addition increases. Disadvantages include the increased cost compared to single vision lenses and the fact that the multifocal design that works for your patient may not be available in the material that works for that patient.

An additional method to correct presbyopia with contact lenses uses translating designs where the contact lens has a distance correcting area and a near correcting area. In the primary position of gaze the distance vision area aligns with the primary visual axis and on downward gaze the lens translates such that the near vision area aligns with the visual axis of the eye. Translating soft lenses are only available in one design, which is not available as a disposable contact lens.³⁷ This limited availability restricts their usefulness and possibly reflects the limited success achieved with them; they are not frequently fitted due to their poor translation (limited unpredictable movement), increased discomfort (lenses are thicker and usually prism ballasted) and are only available as custom designs. These lenses are complex to fit and beyond the scope of this book. However, translating designs lend themselves well to being manufactured in RGP materials.

5.11.2 Fitting contact lenses for presbyopia

When assessing the performance of multifocal contact lenses or monovision it is important to let the patient have an extended trial with the lens and let them take them away for a few days. The optimum trial length need not be longer than 2–3 days.³⁸ Papas and colleagues also concluded that the reliability of clinical measures to determine success was limited and subjective responses were more reliable; ask the patient what they think about their vision.³⁸ Do they think it is successful? The assessment of visual acuity is used to optimise the lens power and to act as a safety measure, i.e. the driving standard.³⁸

Fitting the lenses is otherwise the same as that described in sections 5.9 and 5.10. In addition, note that:

1. **Over-Readers:** A reading addition (section 4.14) should be determined with the distance contact lenses in place. Do not use the reading addition determined with the spectacle prescription.
2. **Monovision:** you need to determine which eye will wear the distance contact lens and which will wear the reading lens; generally more success is found when the non-dominant eye wears the near powered lens.³² There are several methods to determine ocular dominance and two are recommended here:
 - Hole in the card technique.³⁹ A card is fabricated with a hole in the middle, the patient is asked to hold the card with both hands and to look through the hole at a distant target. They then close their right eye, if they adjust the position of the card, their right eye is distant dominant, if they do not their left eye is dominant.
 - Blur acceptance.⁴⁰ With the patient corrected for distance get them to observe the small letters of the distance acuity chart and place a +0.75 D lens over the right eye and then the left. Ask them which they prefer and when they can see the letters more clearly. They will prefer to have the +0.75 D trial lens placed over their non-dominant eye.

For example:
 RE: $-2.00/-0.25 \times 180$
 LE: $-2.50/-0.25 \times 170$
 Reading add +1.50 Dominance test: Right eye dominant
 Trial soft lens powers selected: R -2.00 D; L -1.00 D. i.e. Distance power in the dominant right eye and near in the left, with the small cylinders ignored.
3. **Monovision:** When you explain to the patient how monovision works, they may start covering one of their eyes to see the difference in vision. Ask the patient not to do this as it increases their awareness of the one aspect that results in monovision failing: the unacceptable blur from the near lens when looking in the distance. Remind the patient that they have never done that before wearing monovision.
4. **Multifocal soft lenses:** These are available in a variety of designs, but all have the same fitting requirement of precise centration. As these lenses are generally aspheric in nature, a decentred lens will induce visually compromising aberrations such as astigmatism, coma and curvature. Decentred lenses can be assessed using the slit-lamp. A decentred lens is likely to result in poor distance visual acuity

1. **Over-Readers:** A reading addition (section 4.14) should be determined with the distance

that cannot be improved. It is recommended that you follow the fitting guide developed by the manufacturer; all of the designs have subtle variations and a one fitting philosophy will not work. The following guide to supplement manufacturers' instructions is recommended to increase fitting success.⁴¹ It is summarised by the mnemonic **RISONS**:

R – Refraction: Do not use a current contact lens prescription as the starting point, perform a binocular refraction, with the reading addition determined at the patient's habitual working distance.

I – Initial trial lens: Base the lens power on the new ocular refraction, adjusting for any cylinder as necessary, select the reading addition using the manufacturer's guideline.

S – Settling time: This should be 15 to 20 minutes, i.e. longer than the time for single vision lenses.

O – Over-refraction: use full aperture lenses in a trial frame with the monocular fogging technique (section 4.12) in a trial frame to keep the binocularity, pupil size and gaze position (i.e. downgaze when checking near vision) as close to normal as possible. If the initial over-refraction is greater than 0.50 D, do not order the lenses but try a different diagnostic lens and repeat the over-refraction.

N – Near vision: Do not assess monocularly, maintain binocularity and only make unilateral adjustments when assessing distance vision.

S – Send away: Once the final trial lens is selected, allow an extended wearing trial of up to 4 days.

Modified monovision

The key is to find a balance in the vision that satisfies the patient's visual needs. The stepwise approach in Table 5.1, incorporating both straight multifocals and modified monovision, could be followed.

5.11.3 Solving problems

Remember that patients with presbyopic contact lenses can suffer with all the problems of standard lenses. For example, symptoms of fluctuating vision should lead you to reassess the patient's tear film stability and the lens fit. In addition:

1. Over-readers

Poor near vision: Check to make sure the distance vision is correct and then assess

Table 5.1 A stepwise approach incorporating both straight multifocals and modified monovision

Reading addition	Lens combinations	
	Dominant eye	Non-dominant eye
Near symptoms, pre-presbyope	Distance contact lens	Low add multifocal
<1.00 D	Multifocals (low add)	
<1.50	Low add multifocal	Mid add multifocal
<2.00	Multifocals (mid add)	
>1.75	Mid add multifocal	High add multifocal
>1.75	Multifocals (high add)	

whether the reading addition power is appropriate for the patient's habitual working distance(s).

2. Monovision

- Poor distance (or near) vision: Make sure the distance vision is optimised, including the correction of small cylinders. Reducing the reading addition in the eye corrected for near vision may improve the distance vision but at the expense of reducing the vision at near. The reverse could be considered with poor near vision symptoms. You may need to consider refitting with multifocals or modified monovision.
- Distance ghosting: This may be due to uncorrected astigmatism or the patient may have weak or variable dominance and not be able to suppress their non-dominant eye.

3. Multifocal soft lenses

- Poor distance vision: Make sure the distance vision is correct. If it is not, an increase in the distance power (–0.25 D) may improve the distance vision. However, this is likely to have a significant effect on near vision. This could be tried in the dominant eye alone. Reducing the reading addition in both eyes or in the dominant eye alone may improve distance vision but

again at the expense of reducing the vision at near.

- (b) Poor near vision: Make sure the distance vision is optimised. A reduction in the distance power (-0.25 D) may improve near vision with marginal change in distance vision. This could be tried in the non-dominant eye alone. Increasing the reading addition in both eyes or only in the non-dominant eye may improve near vision but possibly at the expense of reducing vision in the distance.
- (c) Distance ghosting: Likely to occur when the reading add is high, less so when aspherical designs are used and more so for the alternating concentric ring design.

4. High reading additions

If you have a patient who has been successful with either monovision or multifocal lenses and subsequent to an increase in reading addition has developed symptoms, refitting with modified monovision may resolve those symptoms. Ultimately refitting with distance contact lenses and over-readers may be the final solution.

5.12 FITTING RGP CONTACT LENSES

Corneal lenses are also known as hard contact lenses, GP lenses or rigid gas permeable (RGP) lenses. For convenience and consistency we will refer to them as RGP lenses. RGP lens use has gradually diminished to about 5–10% of lenses fitted because they need a significantly longer adaptation period compared to soft lenses, characterised by discomfort, possible vision fluctuations and the need to increase wearing time gradually during this adaptation period.⁴ They can be used to correct simple refractive error, but due to their rigid nature and hence their ability to trap tears behind the lens, they can also be used for more complex conditions such as irregular astigmatism, keratoconus, post-keratoplasty and refractive surgery as well as orthokeratology. This chapter offers a simplified approach to fitting RGP contact lenses and assumes you will be fitting standard lens designs and not custom ones.

5.12.1 Comparison of lens types

All RGP lenses have posterior (back surface) curves that are classified as follows:

- Back Optical Zone Radius (BOZR) – this is the primary central curve of the lens that

establishes a relationship with the cornea to optimise vision.

- Mid-peripheral radii – these curves create the area of the lens (mid periphery) that establishes the lens fitting relationship with the cornea and controls lens stability.
- Edge lift – the final peripheral curve forms the outer portion of the lens that creates a band of edge clearance. The curves are significantly flatter than the cornea. The purpose of this area is to optimise the tear pump and aid lens removal.

The cornea has a shape that is similar to an oblate ellipse; the curvature progressively flattening from the corneal apex out to its peripheral area at the limbus. RGP lens back surface designs try to mimic this shape change and do so generally using one of two approaches:

- Spherical designs: A spherical optical curve followed by spherical peripheral curves progressively increasing in flatness. These designs usually have three or four zones: the optical zone, mid-peripheral zone (one or two curves) and the edge band (one curve).
- Aspheric designs: True aspheric designs have the aspheric progression starting at the apex of the lens. The rate of flattening of the peripheral portion of the lens may have a consistent degree of eccentricity or a progressively increasing degree of eccentricity. Alternately the BOZR starts as a spherical curve and transitions through an aspheric curve of increasing asphericity. Regardless of the design the edge band is a flatter spherical curve. The edge band will appear narrow for aspheric designs compared to a spherical lens design.

Spherical designs have the advantage that you can change any curve to change the fit of the lens. This allows you greater control in designing the lens, for example, changing the optical area of the lens, increasing or reducing the edge lift, width or height. It is not possible to change an aspheric design other than the BOZR or the lens total diameter. However, the differing zones of a spherical design will have visible demarcations and these may present problems for patients with larger pupil diameters as the edge of the optical zone may lay within the pupil area and result in symptoms of blur or glare. The junctions between the different zones may compromise corneal physiology and leave concentric rings or compressions where lens and cornea touch. These do not occur with aspheric lenses unless the lens itself is too small. These lenses also generally show a closer alignment fitting relationship between the back surface of the lens and

the cornea, which some consider to be desirable, although too close alignment in fit may cause the lens to bind.

5.12.2 Observing how an RGP lens fits

The fitting relationship between the posterior surface of a contact lens and the front surface of the cornea can be observed by instilling fluorescein into the tear film and illuminating the eye with ultraviolet/blue saturated light from a Burton lamp or a slit-lamp using low magnification. Changing various aspects of the peripheral curves of the RGP lens can change the fitting pattern seen.

Some lens materials contain a UV inhibitor and so appear 'black' under UV light. This prevents observations of the fluorescing tears behind the lens and thus an assessment of the lens-to-cornea fitting relationship. When using materials that contain a UV inhibitor, observations can only be made with a slit-lamp, which provides a significant amount of blue light, but not a Burton lamp as it has a predominantly UV light source.

The basic goal when fitting an RGP lens is to ensure:

1. That the central apex of the cornea and lens either fit in alignment or demonstrate marginal apical clearance; an even, low level of fluorescence or a very slight gradual reduction in fluorescence centrally to the mid periphery of the lens will be seen.
2. The mid region of the lens should be aligned with the corneal surface, an even lower level of fluorescence compared to the BOZR area.
3. The edge of the lens has a band of high fluorescence, the edge lift.

5.12.3 Simplified fitting approach

The starting point when fitting an RGP lens is to determine three parameters: the BOZR, Back Optical Zone Diameter (BOZD) and total diameter (TD). The following can be applied to either a standard spherical lens design or an aspheric design:

1. **BOZR:** this should either equal or be 0.05 mm flatter than the flattest keratometry value (real or simulated), for example:
7.80 mm along 180; 7.90 mm along 90.
BOZR selected 7.90 mm or 7.95 mm. You have to decide if you find it easier to assess the fit of an RGP lens that has apical clearance or apical alignment. If you prefer definite clearance as your starting point, you may start with a trial

lens with a BOZD of 7.85 mm. Some aspheric designs are only available in 0.10 fitting steps, in which case the starting point would be 7.90 mm.

2. **BOZD:** this should be larger than the maximum (mesopic) pupil diameter of the patient (not needed if fitting aspheric lens designs). For a pupil diameter measuring 7 mm, the required BOZD should be 7.50 mm, not 6.50 mm. Some lens designs link the BOZD to the TD and so you may need to increase the TD to achieve the desired BOZD. This would obviously not be the case if you vary the parameters yourself – a level of complexity beyond the scope of this book and standard lens designs.
3. **TD:** should be about 2 mm smaller than the HVID (section 5.3). It is common for lens designs to have three lens diameters. They could be 9.50 mm, 9.80 mm and 10.20 mm, or 9.00 mm, 9.40 mm and 9.80 mm. So one approach would be to assess the patient's eye and decide if they have a small, medium or large HVID and select accordingly.

Once these parameters have been determined for both eyes, you have your first pair of trial lenses to assess. The following procedure is suggested:

1. Advise the patient you are going to place a lens on their eye. This first lens allows you to decide what changes will be needed so that the lens fits their eye more accurately.
2. Instil a local anaesthetic into both eyes (section 7.8) and allow the patient to settle.
3. While the patient settles, place the selected trial lens on the tip of the index finger of your right hand. If you want to pre-wet the lens, place a small drop of saline on the lens but do not use a lens conditioning drop as these drops can affect how easily the fluorescein spreads in the tears.
4. The lens insertion method is the same as for soft lenses, section 5.7.1.
5. Allow the lenses to settle, as there is little sensation for the patient the lens should settle quickly, 3–5 min.
6. Instil fluorescein and assess the lens fit, using a Burton lamp or slit-lamp.

5.12.4 Assessment of lens fit

See online videos 5.15–5.18. You are interested to know whether you have the desired fluorescein fitting pattern and how dynamic the fitting pattern is. Having



instilled the fluorescein (section 7.3.2), assess the fit using a slit-lamp as follows (Figures 5.11 to 5.14).

1. Ask the patient to place their chin on the rest and their head against the headrest of the slit-lamp and get them looking straight ahead.
2. Advise them to blink as and when they need to.
3. Observe the appearance of the fluorescein behind the centre of the lens and see how it changes with a blink. The goal is to get an
4. even level of fluorescence and/or just apical clearance. Too much fluorescence indicates a steep fit and unstable dark areas within the optical area are suggestive of a flat fit.

The fluorescence in the mid periphery of the lens should be darker than in the centre and appear even. A steep lens will have touch in the mid periphery of the lens and a flat fit will have too much fluorescein spilling from the optical area into the mid periphery. Changing the BOZR will change the mid periphery fit. There

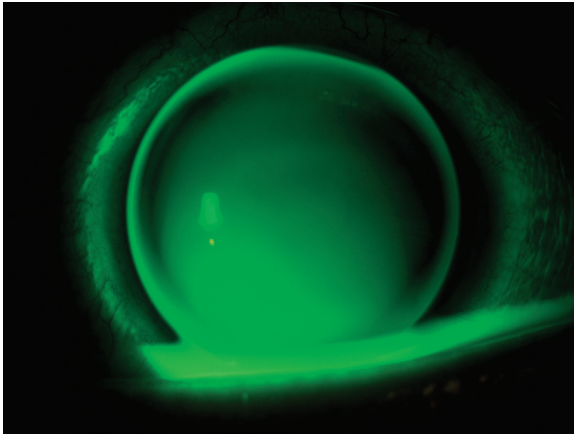


Fig. 5.11 Fluorescein tear film pattern with cobalt blue illumination and a yellow barrier filter for a steep fit for an RGP lens; marked apical clearance, mid peripheral bearing, narrow edge clearance.

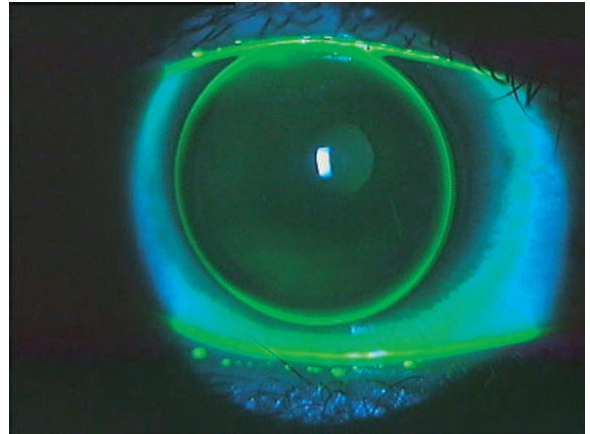


Fig. 5.13 Good alignment fit for an aspheric lens design; slight fluorescein haze at the corneal apex and in the mid periphery with an even narrow edge clearance.

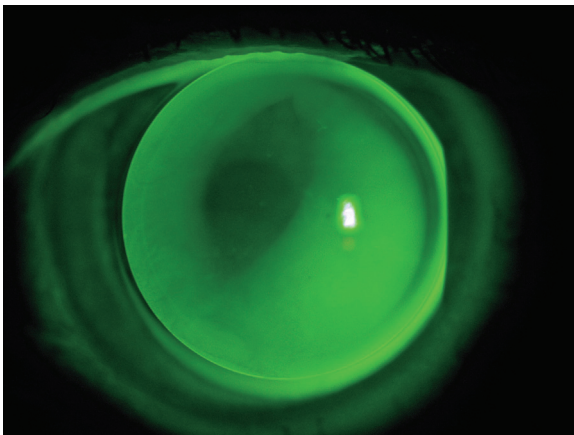


Fig. 5.12 Fluorescein tear film pattern with cobalt blue illumination and a yellow barrier filter for a flat fitting RGP lens; apical bearing, mid peripheral pooling, irregular excessive edge clearance associated with decentration.

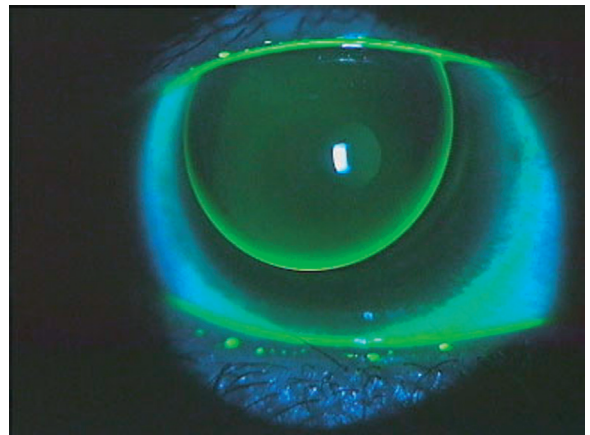


Fig. 5.14 Good lid attachment fit. Superior edge of the lens inherently rests under the upper lid. Slight fluorescein appearance at the corneal apex and in the mid periphery with an increasing edge clearance inferiorly.

should be a bright band of fluorescence around the edge of the lens. If you consider it to be too wide, you will need to try a design with a reduced edge lift; the ideal is a width of 1 mm. Changing the design to an aspheric will have that effect. Absence of an edge band of fluorescein is very uncommon, but can be increased by changing from an aspheric design to a C4 spherical design, or to a design of known increased edge lift.

5. Observe the lens movement on blink. This should be smooth and vertical. If the lens does not move very well it may be steep fitting. If the lens appears to rock around the corneal apex after a blink as it drops, it may be too flat.
6. Make your decision about the lens fit and adjust one of the three parameters accordingly: BOZR: a lens that is too steep, increase by 0.1 mm. A lens that is too flat, reduce it by 0.1 mm; BOZD: increasing the BOZD increases the sagittal depth on the lens and makes the fit steeper, reducing this makes the lens flatter; TD: if the lens looks too small, go bigger. Bigger lenses are likely to be more comfortable and more stable.
7. You can now repeat steps 2 to 4 for the left eye.

Inter-palpebral fit or lid attachment fit

The fit of an RGP lens can be described either as an inter palpebral fit or a lid attachment fit and is determined more by the characteristics of the patient's cornea/lid relationship than by the lens design. The factors that lead to a lid attachment fit are narrower palpebral apertures, smaller HVIDs and tighter lids.

5.12.5 Assessment of lens (and tear film) power

Once you have a lens that appears to have an acceptable fit for each eye, perform a spherical over-refraction and measure VA (sections 4.6 or 4.7). Alterations in the fit of an RGP lens can have very subtle changes to the patient's vision and you may find two fits that you think would work but the patient reports a preferable visual performance. Where you find this, go with the lens of optimum fit and preferred vision, alternatively select the lens with the steep BOZR.

Tear lens power: When you change the fitting relationship between an RGP lens and the cornea, the tear film behind the lens (the tear lens) will change; a steeper fitting RGP lens results in increased separation between the lens and the cornea and creates a more positive tear lens. Generally

increasing the sagittal depth of an RGP lens increases the positive tear lens power and therefore affects the over-refraction. The following rules of thumb apply:

Decrease the BOZR by 0.05 mm changes the tear lens power by +0.25 D, changing the over-refraction by -0.25 D.

Increasing BOZD by 0.50 mm changes the tear lens power by +0.25 D, changing the over-refraction by -0.25 D.

For aspheric designs, increasing the TD by 0.5 mm changes the tear lens power by +0.25 D, changing the over-refraction by -0.25 D.

For example:

7.80 (BOZR): 7.50 (BOZD) C4 design 9.80 -3.00, over-refraction of -0.50

If you modify the fit to:

7.75:7.50 C4 design 9.80 -3.00, the over-refraction will now be -0.75 D.

5.12.6 Correcting astigmatism with RGP lenses

Variations in corneal shape can be neutralised by the tear lens and a spherical RGP lens can mask corneal astigmatism. However, as the astigmatism increases, the fit of the lens becomes increasingly compromised resulting in decentration, instability or increased discomfort. To compensate for this, it is common practice to steepen the BOZR of the RGP lens using the following rule of thumb:

BOZR is steeper than the flattest keratometry value by $\frac{1}{3}$ of the difference between the keratometry values, e.g.: K readings: 7.80 mm along 180, 7.50 mm along 90.

BOZR selected is 7.70 mm as:

7.80 mm - 7.50 mm = 0.30 mm; $\frac{1}{3}$ of difference is 0.10 mm, 0.1 mm more than flattest (7.50 mm) is 7.60 mm.

1. **Toric RGP lens:** Compromising the fit of a spherical RGP lens to enable centration on an increasing toroidal cornea will result in corneal physiological compromise (3 and 9 o'clock staining), corneal moulding and spectacle blur.^{42,43} Compromised fits can also lead to increased discomfort, so that fitting a toric RGP lens may be more appropriate and is recommended once corneal astigmatism exceeds 1.50 D. Some authors recommend using toric lenses only when the corneal astigmatism is 2.00 D or higher.⁴⁴ Fitting toric lenses can be complex but here is a simple approach:

Refraction: $-2.00/-1.50 \times 180$

Transpose to cylindrical form: $-2.00 \times 90/-3.50 \times 180$

K readings: 7.50 mm (or 45 D) along 90;
7.80 mm (or 43.25 D) along 180

Lens trial selection:

7.55/7.85 (BOZR): 7.80 (BOZD) C4 design 9.80 (TD) $-3.50/-2.00$

The fit of a toric lens is likely to be steeper than an equivalent spherical lens design as both meridians are likely to be more closely in alignment. Consequently, start with a slightly flatter BOZR compared to the keratometry readings, as shown above. This diagnostic lens would need to be ordered to trial it as it is very unlikely you would have an RGP lens trial set unless you specialised in contact lenses. You should note that as you had ordered a toroidal lens that matches the toroidal shape of the cornea, the fluorescein fitting pattern will appear spherical and the tear lens behind the lens is spherical in profile.

Modifying a toric lens should be kept simple, keep the difference in the BOZRs to match that of the cornea. For example, if the fit of the lens here is thought to be too steep:

7.55/7.85 is too steep; change BOZR to: 7.60/7.90

Ordering an RGP toric design on the back surface of a lens to improve the fit of a lens will result in inducing astigmatism. If the lens is ordered as shown above, the manufacturer will automatically supply you with a bitoric lens to correct for this induced astigmatism. Greater complexity than this simplified approach is beyond the scope of this book.

2. **Irregular corneas:** Fitting irregular corneas is very challenging and requires a high level of skill and experience. Low levels of irregular astigmatism or early keratoconus can be fit using conventional RGP lens designs and you can try progressing to these fits as you gain confidence but be aware that at some point, standard designs will not work and very special designs will be needed. Before you get to that stage you need to attend specific courses on fitting complex lenses.

5.12.7 Ordering lenses

On completion of the trial fitting an RGP lens can be ordered for the patient, the details required for standard or aspheric designs are: BOZR, TD, BVP and lens design.

Most lens manufacturers will allow you to exchange lenses if you need to modify how it fits or adjust the lens power for a period of up to three months. RGP lens manufacturers understand the complexity of fitting RGP lenses and are very supportive and knowledgeable, especially about their lenses, and can help you to get it right. If something does not make sense, ask them and listen to their advice as it is in their interest you get it right.

Material choice

RGP lenses are available in a range of materials, and reasons for selecting a specific material might be that:

- The lens design chosen has a restricted material choice, i.e. aspheric designs.
- A material of higher permeability to reduce or minimize hypoxia is needed.
- A compromised fit needs a material of increased rigidity to reduce flexure.

5.12.8 Common problems

1. **Adaptation:** The biggest problem when fitting RGP lenses is encouraging the patient to get over the adaptation phase. You should optimise the fit of the lens as soon as possible and be encouraging to the patient. The initial wearing time may need to be shorter than is desirable and then gradually increased. If adaption is hard keep the wearing time reduced. Be prepared to accept that some patients cannot adapt to RGP lenses and that soft lenses may be preferable.
2. **Glare at night:** When a patient presents with the symptoms of glare at night with RGP lenses they are likely wearing a spherical lens design. The BOZD is likely too small and should be increased. If you cannot increase the BOZD any more then you should consider changing the design to an aspheric design.
3. **Fluctuating vision with blink:** When vision fluctuates after a blink the lens is likely to be fitting too steep, if it changes and is corrected by a blink the fit is likely to be too flat. Confirm this by reviewing the fit of the lens with fluorescein on the slit-lamp and reordering the lens with the corrected BOZR.
4. **Lenses dislodge:** If a blink causes the lens to occasionally dislodge, the lens could be too small (so increase TD), too steep (flatten the fit) or the edge lift is too high (reduce it or refit with an aspheric lens).

5.13 PATIENT INSTRUCTION FOR CONTACT LENS CARE

5.13.1 Lens care and maintenance

Other than single use lenses, all other contact lenses need a cleaning solution, a disinfecting solution and a condition solution and these requirements are usually combined as a multipurpose lens care system. As RGP lenses are not replaced as frequently as soft lenses, patients must be educated on the need of supplemental cleaning processes. With age, lenses become increasingly deposited (deposit removal may be needed on an ongoing basis) and scratched. You may consider introducing a planned replacement scheme whereby lenses are replaced on an annual basis.

5.13.2 Contact lens application and removal training

Spending the necessary time to teach a patient to handle their lenses correctly is an important part of the lens fitting procedure. It is an activity that is often delegated to support staff, which is fine as long as they are well trained and able to answer the patient's questions. Contact lens handling should be taught in a quiet area with good quality diffuse lighting that is away from the communal areas of the practice, to avoid putting pressure on the patient to perform in front of others. The patient should not be allowed to take the lenses away until they can safely apply and remove them and they have demonstrated a full understanding of the importance of hygiene, the cleaning regime and how to minimise the risk of complications.⁴⁵ With all aspects of compliance, it is important to give patients reasons why certain steps should be included, to encourage them not to drop them from their regime.⁴⁶ Do not simply give them a list of instructions. Areas to cover include hand washing, lens inspection, lens application technique, lens removal technique, lens cleaning, case cleaning, lens and case replacement, recommended wearing times, minimising risks: contact with water, napping, illness and when to seek advice.

The lens application procedure for a patient is almost identical to that for the practitioner (section 5.7.1), but the patient should lean over a mirror or use a mirror stood on a clean surface; for their right eye, they should position the lens on the very tip of the right index finger and use their right middle finger to pull down the lower lid and the left hand to lift the upper lid and it can be easier to place the lens directly on the cornea rather than on the conjunctiva and sliding the lens.

5.13.3 Cleaning lenses

With the exception of single use lenses, all contact lenses require cleaning after every wearing period. The current recommendation is for lenses to be rubbed and rinsed with the cleaning fluids prior to storage, so as not to leave the storage solution with too much to do in terms of microbial load.⁴⁷ Specific instructions vary between brands and types of lens solution but are summarised below:

1. Wash hands.
2. Remove one lens, place it in the palm of your hand and use a finger tip to gently rub the surface of the lens with contact lens cleaning solution (multipurpose or specific cleaning solution). Cupping the hand stops the lens from sliding around.
3. Turn the lens over and rub the other side.
4. Transfer the lens to the palm of the opposite hand and rinse thoroughly.
5. Place the lens in a dry case and fill with solution (multipurpose, hydrogen peroxide or other specific storage solution).
6. Place lids tightly on the vials and leave for 4–6 hours depending on the manufacturer's instructions.
7. Before applying lenses, the solution should be neutralised if required (hydrogen peroxide). In the case of multipurpose solutions, it is advisable to rinse the lenses with fresh solution prior to insertion.

5.13.4 Case cleaning and replacement

This is just as important as good lens care but frequently overlooked.⁴⁸ The patient should be shown how to clean their case and the importance of removing the biofilm should be explained.

1. Following lens application, empty the case and rinse it out with fresh solution.
2. Rub the case thoroughly with a clean, lint free tissue.⁴⁹
3. Rinse the case again to remove any debris and leave to air dry, upside-down in a room other than the lavatory.
4. Replace the case at least every 3 months.
5. Never reuse old solution.

5.14 CONTACT LENS AFTERCARE

The contact lens fitting procedure can be considered complete once a new patient has completed their first

aftercare visit and the lenses deemed successful. For new patients, a number of aftercare visits might be undertaken during the first six months of wear but after this period, the frequency of appointments is a matter of practitioner judgement and depends on the characteristics of the patient. Those with a higher risk of complications (e.g. poor compliance, extended wear, diabetic, smoker, history of problems) should be seen more frequently, as should those who are more likely to exhibit ocular changes that may require a change in lens power, fit or material (unstable refraction, medication that may lead to tear film changes, etc.) For other patients, a recall period between 6–12 months is the norm in clinical practice.

The purpose of a contact lens aftercare examination is to:

- Identify any difficulties the patient may have with their eyes and lenses.
- Ensure that the patient's needs are met by the current contact lenses.
- Consider the lens parameters and make changes where indicated.
- Ensure that the lenses are not having an adverse effect on the eyes and manage where necessary.
- Check patient compliance with lens wear and care instructions and re-educate where required, to maximise healthy, successful lens wear and reduce the risk of future complications.

For a summary of aftercare routine, see [Box 5.1](#).

Box 5.1 Aftercare routine

1. Patient discussion: reason for visit, details of current contact lens wear, medical history, compliance, needs from contact lenses
2. Assessment of vision
3. Over-refraction and ocular motor balance
4. Assessment of lens fit and condition (slit-lamp)
5. Observe patient removing lenses
6. Slit-lamp assessment of the anterior segment including tear assessment
7. Assessment of corneal shape: corneal topography or keratometry to monitor changes in curvature and regularity
8. Ophthalmoscopy and/or other supplementary investigations, if indicated
9. Refraction if indicated
10. Summary of outcomes and re-education of patient regarding lens care and wear

5.14.1 Patient discussion – aftercare history taking

- (a) Determine the reason for visit (chief complaint if any). This is undertaken using the same form of questioning as used in the eye examination and involves the use of LOFTSEA to gather all the appropriate information about the complaint (section 2.3). It is also important to determine whether lens removal is associated with cessation of the complaint or whether symptoms persist. Remember, it is possible that the complaint is completely unrelated to contact lens wear.
- (b) The patient should be questioned specifically about other symptoms, which again may or may not be related to contact lens wear: distance vision, near vision, eyestrain, headaches, ocular pain, discomfort, dryness and diplopia.
- (c) A complete description of the contact lenses currently worn is needed. This may just be a matter of confirming that the practice notes are correct:
 - (i) 'What type of lens (or lenses) do you use?' (soft, gas permeable, toric, multifocal, etc.), brand and specification if known and recommended frequency of replacement (single use, two weekly, monthly, etc.). Note that some patients may use more than one type, for example monthly disposable toric lenses for general use and single use lenses for swimming, or a presbyope might be wearing single vision lenses with reading glasses for work and single use multifocal lenses for socialising.
 - (ii) 'Who prescribed the lenses?'
 - (iii) 'How long have you been wearing this type of lens?'
 - (iv) 'How old is your current pair of contact lenses?'
 - (v) 'How often do you replace your lenses?' (as opposed to 'How often are you *supposed* to replace your lenses?')
- (d) Contact lens history:
 - (i) 'How long have you worn contact lenses in total and have you tried any other lens types in the past?' If other types have been worn or trialled, it is important to ask further questions to ascertain why a particular lens type was abandoned, to avoid wasting time retrialling a lens type

in the future that failed to provide satisfaction in the past.

- (ii) 'Have you ever had to stop contact lens wear for any reason, even for a short time?'
If a positive answer is given, further questioning will be required to ascertain the reason for ceasing lens wear.
- (e) Wearing habits:
 - (i) 'When did you put your contact lenses on today?'
 - (ii) 'How many days per week do you tend to wear your lenses?'
 - (iii) 'How many hours of comfortable lens wear do you achieve on average in a day?', 'When do you generally take your lenses out at night?' and 'How long would you like to wear them for?' If there is a mismatch between these two periods of time, the current lenses are not meeting the patient's needs and another lens should be trialled.
 - (iv) 'What is the longest time that you wear your lenses for?'
 - (v) 'How often do you sleep or nap in your lenses?'
 - (vi) 'Do you ever shower in your lenses or use them for water sports, including swimming?'
- (f) General questions:
 - (i) 'When was your last contact lens aftercare?'
 - (ii) 'When was your last eye examination?'
 - (iii) 'Do you have an up to date pair of spectacles that you could wear should you be unable to wear your lenses for a few days?'
- (g) Questioning should also cover more general aspects of ocular and systemic health (section 2.3) as these issues can impact on contact lens wear. In addition, you should remember that you remain responsible for the health of the whole eye, even during a contact lens aftercare, and you must not become blinkered and assume that a particular symptom is contact lens related. It is particularly pertinent in contact lens wearers to ask 'Do you smoke?' since this significantly increases the risk of microbial keratitis.¹⁰
- (h) During a contact lens aftercare appointment, you will also need to ascertain how compliant the patient is. Studies show that up to 90% of patients are non-compliant.⁸ In some cases, this is because they do not know or understand how

they should be looking after their lenses, while in other cases, they know what they should be doing but do not follow the full instructions due to laziness or a lack of understanding of the purpose of a particular stage and they will tend to give the correct answer if they know they are being tested. Questioning should cover:

- (i) 'What cleaning solutions do you use?' (assuming the lenses are not single use lenses).
- (ii) 'How do you clean your lenses?' If time allows, it is generally more informative to ask the patient to demonstrate lens handling and cleaning than describe it.
- (iii) 'Do you always wash your hands and dry them thoroughly, prior to handling your lenses and/or case?'
- (iv) 'How do you store your lenses if you are not wearing them?'
- (v) 'How frequently do you replace your lens case?' and 'What do you do with your lens case once you have applied your lenses?' and 'How do you clean your case and how often?'
- (vi) With all patients, it is essential to reinforce instructions regarding lens and case care along with healthy wearing habits, but to also explain why certain steps are included, to improve compliance.
- (i) Occupation, hobbies, computer use and driving (section 2.4.3). You should ask specifically about water sports because of the increased risk of microbial keratitis associated with allowing lenses to come into contact with water.⁵⁰

Example case history – Graphic designer, driver

CC: 'Eyes become gritty during the day at work' c CLs since starting new job 6/12 ago. Affects OU equally and gives gen. feeling of eyestrain. VDU all day. Becomes a problem after ~5 hrs. Eases when CLs removed. DV and NV c CL and specs OK. No H/A. No other Sxs.

OH: SCLs for last 6 yrs. 6/7 for ~8 hrs, 16 hrs max. Monthly disp hydrogel, brand X. No previous CL wear. Fitted by Dr Andrew, Bradford. CLs replaced ~1/12. Current 5 weeks old! Lenses in for 6 hrs today. Never sleeps in CL. No previous probs c CL.

Last AC 11/12 ago. LEE: 18/12. Has up to date specs – good DV and NV. No other OH. Dr Keirn, Bradford. FOH: parents both myopic.

GH = OK, no meds. No allergies. Non-smoker. LME: 12/12, Dr Patel, Bradford. No FMH. Hobbies: Swimming 2×/week (monthly CL c goggles), climbing. Uses PC ~7/24.

Sol'n: multipurpose brand Y. Washes hands superficially. Rubs lens each side for 30 seconds and rinses with soln each time worn. Rubs lens case with tissue and leaves to air dry each day. Replaces case every 2 / 12.

In this case, the areas of interest are the discomfort after 5 hours of wear and some aspects of compliance. The patient cannot wear their lenses comfortably for as long as they would like and it is important to determine the reason for this dryness and manage it appropriately (e.g. look for conditions such as meibomian gland dysfunction that frequently cause dry eye, try ocular lubricants, refit with a lens material with lower water content and better lubricity). The eyestrain is probably related to the dryness but an association with refractive error and/or binocular vision problems should be ruled out. Lens and case care appear to be good, but hand washing needs intervention and additional single use lenses for swimming should be considered in addition to goggles in a regular swimmer.

5.14.2 Over-refraction, acuity and ocular motor balance

See [section 5.9.6](#).

5.14.3 Assessment of lens and lens fit

▶ See online videos 5.19-5.21. Assess the fit as described in [sections 5.9](#) (soft lenses) and 5.12 (RGP lenses). An unacceptable fit requires you to trial a different lens or book the patient in as a matter of urgency for a refit.

Whilst the patient is on the slit-lamp biomicroscope, the integrity of the contact lens and the condition of the lens surface can be examined. Specular reflection off the pre-lens tear surface can be very informative (section 7.2.3) and using the placebo disc from a topographer is also useful to assess the global impact surface deposits are having on the tear film stability, by observing the disruptions in the quality of the placebo disc image as well as measuring the non-invasive break-up time (NIBUT; section 7.3.5). All lenses need to interact with the tear film and it is inevitable that the lens surface will become deposited; in fact some of the interactions and deposition are desirable as they help condition the lens and contribute to its wettability. Clinically observable lens surface deposition has been shown to occur within minutes of wear and significant

amounts after just one day of wear.^{51,52} The level, composition and appearance of deposition on the lens surface is influenced by the tear film, environmental variables such as air quality, lens care products used, cosmetic and skin care products and industrial environments (particles and vapours), the replacement frequency of the lens and the lens material.^{53,54}

5.14.4 Management of deposition

If a patient presents with lens surface deposition that is clinically significant, the following strategies should be considered:

1. Change lens material: For hydrogel materials Group II (ISO system of contact lens materials classification BS EN ISO 18369-1: 2006/DAM1) tend to have increased levels of lipids and Group III the least.⁵⁵ Silicone hydrogels have an increased level of lipid deposition (least on lotrafilcon A and B, moderate level with asmoofilcon A and most with galyfilcon A and balafilcon A).⁵⁶
2. Change lens care system: If the patient is not rubbing and rinsing their lenses on removal, instruct them on this procedure. Newer dual disinfecting multipurpose solutions contain ingredients to increase surface hydrophilicity, which should reduce deposition. The introduction of a peroxide system may also be effective.⁵⁷
3. Change frequency of replacement: Increasing the frequency of lens replacement will reduce the level of deposition, while daily disposable contact lenses do deposit the level of deposition is much reduced compared to 2-weekly or monthly replacement contact lenses.^{57,58}

5.14.5 Observation of lens removal

The point in the routine where the lenses need to be removed provides an opportunity for you to observe the patient's contact lens handling skills. It is also useful to ask the patient to demonstrate their lens cleaning technique at this point. Check:

1. Is their hand washing technique adequate?
2. Did the patient dry their hands sufficiently before handling the lenses?
3. Do they have a safe lens removal technique and are they confident, or do they need some pointers?
4. Do they have a good lens cleaning technique and was it undertaken for long enough?

5. Do they rinse the lenses thoroughly?
6. What is the condition of their lens case?
7. At the end of the examination, do they wash their hands before lens insertion?
8. Do they have a safe lens application technique and are they confident, or do they need some pointers?

Deficiencies should lead to re-education (section 5.14.7).

5.14.6 Check ocular health



Following removal of the lenses, perform a slit-lamp biomicroscope examination of the anterior segment (section 7.2), including staining with fluorescein sodium and lissamine green, lid eversion (see online video 5.22) and tear assessment.

Topography or keratometry (section 5.4) should be undertaken to assess the corneal shape to look for changes, particularly in terms of regularity. Unlike the days of hard polymethylmethacrylate lenses and thick hydrogel soft lenses, corneal warpage is now rare but it occasionally occurs with RGP and tight fitting, high modulus silicone hydrogel lenses.⁵⁹

Examine the posterior segment of the eye (section 7.10) unless it has been undertaken during a recent eye examination and nothing to raise suspicion, such as unexplained symptoms or visual acuity loss, has occurred since. Be mindful of the possibility of pathology in contact lens patients. For example, do not making protracted changes to a patient's contact lens specification over a period of weeks in response to a symptom like 'vision not quite right', without checking the whole eye for signs of pathology.

5.14.7 Summary of outcomes and re-education of patient

Finally, you need to create an action plan and discuss it with the patient. This summary must include the importance of regular aftercare visits and should cover the following:

1. The procedures that have been undertaken during the examination and what has been found if anything.
2. Any action required in light of what has been found.
3. Reinforce healthy lens wearing, good hygiene and lens care habits. Talking through a written check list and indicating to patients where they are doing well and where they could improve is a useful way of communicating such

information (www.bcla.org.uk and www.aoa.org/x8024.xml).

4. Give the patient a new, dated lens specification.
5. Ensure they have a new supply of lenses of the correct specification. They may wish to take the specification and buy the lenses online, in which case highlighting the importance of regular aftercare is particularly important.
6. Inform the patient when their next aftercare and eye examinations are due.
7. Remind the patient to remove their lenses and contact you if their eyes no longer 'see good, feel good, look good'.

REFERENCES

1. Pesudovs K, Garamendi E, Elliott DB. A quality of life comparison of people wearing spectacles or contact lenses or having undergone refractive surgery. *J Refract Surg* 2006;22:19–27.
2. Rumpakis J. New data on contact lens dropouts: an international perspective. Review of Optometry 2010. www.revoptom.com/content/d/contact_lenses_and_solutions/c/18929/.
3. Dumbleton KA, Woods CA, Jones LW, Fonn D. The relationship between compliance with lens replacement and contact lens-related problems in silicone hydrogel wearers. *Cont Lens Ant Eye* 2011;34:216–22.
4. Morgan PB, Woods CA, Tranoudis Y, et al. International contact lens prescribing in 2011. *Cont Lens Spect* 2012;26:26–31.
5. Bennett ES, Stulc S, Bassi CJ, et al. Effect of patient personality profile and verbal presentation on successful rigid contact lens adaptation, satisfaction and compliance. *Optom Vision Sci* 1998;75:500–5.
6. Gupta N, Naroo SA. Factors influencing patient choice of refractive surgery or contact lenses and choice of centre. *Cont Lens Ant Eye* 2006;29:17–23.
7. Young G. Why one million contact lens wearers dropped out. *Cont Lens Ant Eye* 2004;27:83–5.
8. Dumbleton K, Richter D, Woods CA, et al. Compliance with contact lens replacement in Canada and the United States. *Optom Vision Sci* 2010;87:131–9.
9. Efron SE, Efron N, Morgan PB, Morgan SL. A theoretical model for comparing UK costs of contact lens replacement modalities. *Cont Lens Ant Eye* 2012;34:28–34.
10. Stapleton F, Edwards K, Keay L, et al. Risk factors for moderate and severe microbial keratitis in daily wear contact lens users. *Ophthalmology* 2012;119:1516–21.

11. Patel S, Henderson R, Bradley L, et al. Effect of visual display unit use on blink rate and tear stability. *Optom Vision Sci* 1991;68:888–92.
12. Wu YT, Tran J, Truong M, et al. Do swimming goggles limit microbial contamination of contact lenses? *Optom Vision Sci* 2011;88:456–60.
13. Young G, Hunt C, Covey M. Clinical evaluation of factors influencing toric soft contact lens fit. *Optom Vision Sci* 2002;79:11–9.
14. Twa MD, Bailey MD, Hayes J, Bullimore M. Estimation of pupil size by digital photography. *J Cataract Refract Surg* 2004;30:381–9.
15. Martin DK, Holden BA. A new method for measuring the diameter of the in vivo human cornea. *Am J Optom Physiol Opt* 1982;59:436–41.
16. Young G. Ocular sagittal height and soft contact lens fit. *J Brit Cont Lens Assoc* 1992;15:45–9.
17. Hall LA, Young G, Wolffsohn JS, Riley C. The influence of corneoscleral topography on soft contact lens fit. *Invest Ophthalmol Vis Sci* 2011;52:6801–6.
18. Sabesan R, Jeong TM, Carvalho L, et al. Vision improvement by correcting higher-order aberrations with customized soft contact lenses in keratoconic eyes. *Opt Lett* 2007;32:1000–2.
19. Richdale K, Sinnott LT, Skadahl E, Nichols JJ. Frequency of and factors associated with contact lens dissatisfaction and discontinuation. *Cornea* 2007;26:168–74.
20. Simpson TL, Situ P, Jones LW, Fonn D. Dry eye symptoms assessed by four questionnaires. *Optom Vision Sci* 2008;85:692–9.
21. Chalmers RL, Begley CG, Moody K, Hickson-Curran SB. Contact lens dry eye questionnaire-8 (CLDEQ-8) and opinion of contact lens performance. *Optom Vision Sci* 2012;89:1435–42.
22. Pult H, Murphy PJ, Purslow C. A novel method to predict the dry eye symptoms in new contact lens wearers. *Optom Vision Sci* 2009;86:1042–50.
23. Efron N, Morgan P, Katasara S. Validation of grading scales for contact lens complications. *Ophthalmic Physiol Opt* 2001;21:17–29.
24. Maldonado-Codina C, Efron N. Impact of manufacturing technology and material composition on the clinical performance of hydrogel lenses. *Optom Vision Sci* 2004;81:442–54.
25. Wolffsohn JS, Hunt OA, Basra AK. Simplified recording of soft contact lens fit. *Cont Lens Ant Eye* 2009;32:37–42.
26. Young G. Evaluation of soft contact lens fitting characteristics. *Optom Vision Sci* 1996;73:247–54.
27. Maïssa C, Guillon M, Garofalo RJ. Contact lens-induced circumlimbal staining in silicone hydrogel contact lenses worn on a daily wear basis. *Eye Cont Lens* 2012;38:16–26.
28. Bandamwara KL, Garretta Q, Cheung D, et al. Onset time course of solution induced corneal staining. *Cont Lens Ant Eye* 2010;33:199–201.
29. Young G, Sulley A, Hunt C. Prevalence of astigmatism in relation to soft contact lens fitting. *Eye Cont Lens* 2011;37:20–5.
30. Richdale K, Berntsen D, Mack C, et al. Visual acuity with spherical and toric soft contact lenses in astigmatic eyes. *Optom Vision Sci* 2007;84:969–75.
31. Morgan PB, Efron N, Woods CA. An international survey of contact lens prescribing for presbyopia. *Clin Exp Optom* 2011;94:87–92.
32. Evans BJ. Monovision: a review. *Ophthalmic Physiol Opt* 2007;27:417–239.
33. Richdale K, Mitchell GL, Zadnik K. Comparison of multifocal and monovision soft contact lens corrections in patients with low-astigmatic presbyopia. *Optom Vision Sci* 2006;83:266–73.
34. Woods J, Woods CA, Fonn D. Early symptomatic presbyopes - what correction modality works best? *Eye Cont Lens* 2009;35:221–6.
35. Situ P, duToit R, Fonn D, Simpson T. Successful monovision contact lens wearers refitted with bifocal contact lenses. *Eye Cont Lens* 2003;29:181–4.
36. Gupta F, Naroo SA, Wolffsohn JS. Visual comparison of multifocal contact lens to monovision. *Optom Vision Sci* 2009;86:98–105.
37. Ezekiel DF. A 'genuinely' new bifocal lens design. *Optom Today* 2002;17:34–5.
38. Papas E, Decenzo-Verbeten T, Fonn D, et al. Utility of short-term evaluation of presbyopic contact lens performance. *Eye Cont Lens* 2009;35:144–8.
39. Robboy MW, Cox IG, Erickson P. Effects of sighting and sensory dominance on monovision high and low contrast visual acuity. *CLAO J* 1990;16:299–301.
40. Schor C, Erickson P. Patterns of binocular suppression and accommodation in monovision. *Am J Optom Physiol Opt* 1987;64:723–30.
41. Woods J, Woods CA, Fonn D. Fitting soft center-near design multifocal lenses. *Cont Lens Spect* 2010;24:44–6.
42. Edwards KH. The calculation and fitting of toric lenses. *Ophthalm Optician* 1982;22:106–14.
43. Yamane SJ. Are hard lenses superior to soft? The advantages of soft lenses. *Cornea* 1990;9:S12–4.
44. Meyler JG. Fitting and calculating toric corneal contact lenses. *J Brit Cont Lens Assoc* 1989;12:7–14.

45. Campbell D, Mann A, Hunt O, Santos LJR. The significance of hand wash compliance on the transfer of dermal lipids in contact lens wear. *Cont Lens Ant Eye* 2012;35:71–6.
46. McMonnies CW. Improving contact lens compliance by explaining the benefits of compliant procedures. *Cont Lens Ant Eye* 2011;34:49–52.
47. Rosenthal RA, Henry CL, Schlech BA. Contribution of regimen steps to disinfection of hydrophilic contact lenses. *Cont Lens Ant Eye* 2004;27:149–56.
48. Hickson-Curran S, Chalmers RL, Riley C. Patient attitudes and behaviour regarding hygiene and replacement of soft contact lenses and storage cases. *Cont Lens Ant Eye* 2011;34:207–15.
49. Cho P, Cheng SY, Chan WY, Yip WK. Soft contact lens cleaning: rub or no-rub? *Ophthalmic Physiol Opt* 2009;29:49–57.
50. Vesaluoma M, Kalso S, Jokipii L, et al. Microbiological quality in Finnish swimming pools and whirlpools with special reference to free living amoeba: a risk factor for contact lens wearers? *Br J Ophthalmol* 1995;79:178–81.
51. Bontempo AR, Rapp J. Protein and lipid deposition onto hydrogel contact lenses in vivo. *CLAO J* 2001;27:75–80.
52. Leahy CD, Mandell RB, Lin ST. Initial in vivo tear protein deposition on individual hydrogel contact lenses. *Optom Vision Sci* 1990;67:504–11.
53. Luensmann D, Jones L. Protein deposition on contact lenses: the past, the present, and the future. *Cont Lens Ant Eye* 2012;35:53–64.
54. Ng A, Heynen M, Luensmann D, Jones L. Impact of tear film components on lysozyme deposition to contact lenses. *Optom Vision Sci* 2012;89:392–40.
55. Lorentz H, Jones L. Lipid deposition on hydrogel contact lenses: how history can help us today. *Optom Vision Sci* 2007;84:286–95.
56. Teichroeb JH, Forrest JA, Ngai V, et al. Imaging protein deposits on contact lens materials. *Optom Vision Sci* 2008;85:1151–116.
57. Brennan NA, Coles ML. Deposits and symptomatology with soft contact lens wear. *Int Contact Lens Clin* 2000;27:75–100.
58. Maïssa C, Franklin V, Guillon M, Tighe B. Influence of contact lens material surface characteristics and replacement frequency on protein and lipid deposition. *Optom Vision Sci* 1998;75:697–705.
59. Alba-Bueno F, Beltran-Masgoret A, Sanjuan C, et al. Corneal shape changes induced by first and second generation silicone hydrogel contact lenses in daily wear. *Cont Lens Ant Eye* 2009;32:88–92.

ASSESSMENT OF BINOCULAR VISION AND ACCOMMODATION

BRENDAN T. BARRETT

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Tests that assess the binocular vision and accommodation systems are described in this chapter. Rather than group these tests in terms of preliminary/pre-refraction and post-refraction tests, tests are grouped together depending on the aspect of binocular vision or accommodation that they help to assess. This is because the organisation of the book is directed towards the assimilation of a problem-oriented approach (section 1.3.3).

Tests of accommodation and binocular vision are presented together here because it is frequently not obvious whether a patient's symptoms are primarily accommodative or binocular in origin and therefore, in a problem-oriented sense, it makes sense to consider these together.

Although the chapter contains a large number of tests that may at first appear independent of one another, a systematic, problem-oriented approach is advocated in which only the most appropriate tests are conducted. In the final section (section 6.18) a brief overview is provided of how the results from different tests can be considered in combination in order to aid diagnosis and thus inform management.

6.1 RELEVANT INFORMATION FROM CASE HISTORY AND ASSESSMENTS OF OTHER SYSTEMS

During a problem-oriented examination, a list(s) of tentative diagnoses is made during the case history and this is used to determine which particular tests are likely to be useful to help differential diagnosis. The tentative diagnosis list is then updated after consideration of the results from each test of the eye examination. A brief introduction to some of the relevant information in the case history and assessments of other systems to the assessment of binocular vision and accommodation is provided here.

6.1.1 Observations and symptoms

- Simple observation of the patient can highlight a strabismus or head turn or tilt. Parents or carers may also inform you that they have noticed that their child occasionally has an 'eye turn' or perhaps an abnormal head posture. Any suggestion of a strabismus requires a careful cover test and a stereopsis test in addition to looking for amblyopia and possible causes of the strabismus such as hyperopia.
- Symptoms of blurred vision, headaches or asthenopia at distance and/or near can indicate a decompensated heterophoria or accommodative insufficiency or excess at that distance.
- Complaints of 'double vision' could suggest a heterophoria breaking down into a heterotropia (typically horizontal diplopia, occurring especially when tired), a remote near point of convergence (section 6.6), the angle of strabismus changing so that the retinal image

falls out of the suppression area or an incomitant deviation (section 6.15). An appropriate line of questioning during the case history will help in this differential diagnosis. Beware that children sometimes complain of 'double vision' when they mean blurred vision. Note that cortical cataract and occasionally posterior subcapsular cataract can cause monocular diplopia (or polyopia) and should be considered in elderly patients by determining if the diplopia persists if one eye is covered.

- (d) Signs or symptoms of fluctuations in distance vision and, in particular, symptoms of distance blur after near work, suggest problems of accommodation and tests that assess accommodative function should be employed (sections 6.9–6.11).
- (e) No symptoms: It is worth remembering that a lack of symptoms does not, in itself, mean that the binocular system is normal. For example, patients with suppression or long-standing heterotropia almost certainly will not experience binocular vision symptoms.
- (f) Poor reading ability and poor progress at school could also be due to an accommodation or binocular vision problem. Children especially might not complain because they often think everyone sees the way they do.

6.1.2 Ocular history

The ocular history may indicate that the patient, or perhaps someone in the family, has a 'weak' or 'lazy' eye and/or strabismus. This should be followed up by asking if 'patching' or spectacles or any eye exercises have been prescribed or if 'eye muscle' surgery has taken place. Any positive response to these questions should lead to further questioning regarding the age when these interventions happened, when they stopped, their success and if the patient is still under any care for the amblyopia/strabismus, in which case a note should be made of who is providing the treatment and where it is being provided. If the latter is the case, you should be careful not to change an optical prescription or alter the current therapy in any way without permission/agreement from the other practitioner(s) currently treating the patient.

6.1.3 General medical history and family history

General health questions may indicate a systemic condition that can lead to an accommodation or

binocular vision problem, such as diabetes, or systemic medications that can affect accommodation or binocular vision. When examining young children with or without a binocular vision abnormality it is useful to ask whether any member of the patient's family has a strabismus or 'lazy eye' as there appears to be a hereditary link, particularly for esotropia.

6.1.4 Birth history

It is also useful to ask the child's parent/carer about the pregnancy and birth history. There is a high prevalence of ocular abnormality, in particular strabismus, in children born prematurely, those with low birth weight or disorders of the central nervous system, and in children with significant birth complications (e.g. forceps delivery).¹ It is, therefore, recommended that the following questions be posed to the parent/carer during the case history examination: Was the child a full-term baby or were they born prematurely? What was the birth weight? (Less than 2500 grams or 5.5 pounds is a significant risk factor for strabismus, in particular esotropia).² Were there significant complications at the child's birth? Is the child's current and past general health good? Since birth, has the child been investigated or received treatment for any medical condition?

6.1.5 Binocular visual acuity

In cases where the acuities in the right and left eyes are similar or identical, it is usual to find that binocular visual acuity (VA) is $\frac{1}{2}$ to one line better than monocular acuity.³ Of course, it is not possible to find this improvement if monocular VA equals the 'bottom line' of the Snellen chart you are using (section 3.2.2). When using a non-truncated chart, a binocular VA that is equal or worse than the monocular VA can indicate a binocular vision problem. A poor patient reaction to the restoration of binocular vision after an occluder has been removed following monocular subjective refraction can also indicate a binocular vision problem.

6.1.6 Retinoscopy and subjective refraction

Fluctuations in retinoscopy, retinoscopy results more than 1.00 D more positive than subjective refraction and/or fluctuations in subjective refraction suggest fluctuations in accommodation and/or latent hyperopia or pseudomyopia and should be investigated using assessments of accommodation (sections 6.9 to 6.11) and/or cycloplegic refraction (section 4.13).

6.1.7 Systemic and ocular health assessment

Previous or current systemic or ocular disease may explain signs or symptoms that are binocular or accommodative in nature. For example, diabetes or thyroid disease can lead to binocular vision problems. Similarly, particular signs or symptoms may prompt you to ask again about systemic health and/or to seek explanation within the eye/visual system. For example, a newly acquired divergent heterotropia and ptosis may be observed in a palsy of the 3rd cranial nerve and is suggestive of diabetes. Finally, cortical cataract and occasionally posterior sub-capsular cataract can generate diplopia that is monocular in origin (i.e. it persists even when one eye is covered).

6.2 THE COVER TEST

The cover test, in combination with the motility test (section 6.15), represents the corner-stone of the assessment of oculomotor alignment. The aim of the test is very simply to allow you to observe what happens when binocular vision is suspended by covering one eye whilst the patient has been instructed to view a near, intermediate or distant target. It is often important to determine the effect of any refractive error on the deviation, so an assessment of binocular status is often required in the unaided state, with the patient's own spectacles and with the optimal refractive error. While the cover test must always be carried out, it is usual for it to be conducted *prior* to the refraction. It is not generally repeated post-refraction (although it can be) because other tests of heterophoria are typically employed after the subjective refraction has been completed. These tests are described in section 6.4.

6.2.1 Comparison of tests

The cover/uncover test is the only method by which an ocular deviation can be distinguished as either a heterotropia (also called a 'tropia', 'strabismus' or a 'squint') or a heterophoria. The test has the advantage of being an objective test (i.e. one that requires co-operation but no response from the patient) although the subjective response of the patient while performing the test can provide valuable additional information. The cover test provides considerable information about a deviation including its direction and size. In addition, the pattern of movements observed may enable you to form an opinion about the stability, constancy, laterality or control of a deviation. The test is quick and simple to perform. One

disadvantage of the test is that even experienced practitioners cannot detect very small deviations (up to 2–3^Δ).⁴ Since even small vertical heterophorias can be clinically significant, it is likely that you would miss these if just using the objective cover test. However, small deviations of any variety may be identified using the subjective cover test. The only real disadvantage of the cover test is that it requires considerable practice before accurate observations can be made. In addition, it is vital to be systematic in your approach (Box 6.1). **FIRST:** Search for the presence of a heterotropia. If one exists, then by definition, a heterophoria cannot be present simultaneously. **SECOND:** If there is no heterotropia, search for a heterophoria using the alternating cover test and/or the cover/uncover test. **THIRD:** If no heterophoria is evident you should perform a subjective cover test.

An advantage for the alternating cover test in the assessment of heterophoria is that the deviation observed will normally be considerably larger (and therefore more obvious) than that which is apparent during the cover/uncover test. This is because binocular vision is suspended altogether during the alternating cover test whereas binocular vision is interrupted and then restored during the cover/uncover test. The deviation found on the alternating cover test is often referred to as the 'total angle of deviation' as compared to the 'habitual angle' that is measured during the cover/uncover test. It should also be noted that the alternating cover test can be used as a means of placing stress on the oculomotor system, and it can be useful to consider the total deviation as an indicator of the heterophoria when the patient is tired or at the end of the day. The alternating cover test can also be used to identify those heterophorias that can intermittently break down into a heterotropia. The alternating cover test cannot be used alone to evaluate whether a patient has a heterotropia as the pattern of eye movements observed during the alternating cover test in a patient with, for example, an exotropia will be indistinguishable from those observed in a patient with exophoria, etc. To detect a heterotropia, the cover/uncover test must be performed. However, the alternating cover test can be used to estimate the magnitude of any heterotropia found during the cover/uncover test.

6.2.2 Procedure

See online videos 6.1–6.13.

1. Keep the room lights on and, if necessary, use localised lighting so that the patient's eyes can be easily seen without shadows.



Box 6.1 Cover/uncover tests**Step 1: Check for tropia****Tropia present (Y/N)?****Procedure: Cover one eye whilst observing fellow eye**

RE moves when LE covered	LE moves when RE covered	RE moves when LE covered and LE moves when RE covered	Neither eye moves when fellow eye covered
Dx. RE tropia	Dx. LE tropia	Dx. Alternating tropia	Dx. No tropia is present, now check for phoria

Step 2: If no tropia present, check for phoria**Procedure: Alternating cover test****Observe each eye as it is uncovered**

Eyes move IN when cover switched to fellow eye Dx. EXOphoria	Eyes move OUT when cover switched to fellow eye Dx. ESOPhoria	No movement seen when cover switched but Px. reports shift in apparent target position. Dx. Phoria present (WITH in EXOphoria, AGAINST in ESOPhoria)	No movement seen when cover switched; Px. reports no shift in apparent target position. Dx. ORTHOphoria
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2. Explain the purpose of the test to the patient: 'I am now going to find out how well your eye muscles work together'.
3. The following targets should be used:
 - (a) For the distance cover test, isolate a single letter of a size one line larger than the patient's VA of the poorer eye. For example, if monocular VAs are 6/4.5 (20/15) and 6/9 (20/30), use a 6/12 letter (20/40) as a target for the distance cover test. The patient must be able to easily see the letter with both eyes, but it should be a target that requires accurate fixation and accommodation. If you are using a computer-based or projector chart, isolate a single letter on the appropriate line. If you are using a printed chart, then ask the patient to look at a letter at the end (or beginning) of a line, as it will be easier to locate after the eye has been uncovered and crowding effects are lower. If the monocular VA in either eye is 6/18 (20/60) or worse, a spotlight may be used for fixation.
 - (b) For the near cover test, a fixation stick should be used that contains letters or pictures of various sizes (Figure 6.1). A single letter of a size one line larger than



Fig. 6.1 Fixation sticks used for the near cover test and other tests requiring near fixation.

the patient's near VA of the poorer eye should be chosen. As most near VA charts are truncated to N5 or 0.4 M (20/20), this will tend to be N6 or 0.5 M (20/25). The fixation stick should be held at the patient's near working distance (this may be at an intermediate distance if you wish to assess their binocular status at a distance at which they view a computer screen).

4. Irrespective of whether you are carrying out a cover test during distance or near viewing, you should sit directly in front of the patient, at a distance of 25–40 cm away. This will place you close enough to be able to critically note eye movements. When performing the cover test for distance viewing, you should be very careful not to block the patient's view of the fixation target.
 - (a) For the distance cover test, the patient should have their head erect and eyes in the primary position of gaze.
 - (b) For the near cover test, the eyes should be in a slight downward gaze (similar to the position for reading).
5. Instruct the patient: 'I would like you to look at the letter * at the other end of the room (or the letter * on this stick). Please keep watching the letter as closely as you can. In a moment I will place this cover in front of your eye. If the letter appears to move please follow it with your eyes and keep it as clear as possible at all times'.
6. Before starting the cover test take the opportunity to observe the fixational stability of the patient's eyes as they view the letter. You can gain a good impression of the stability of their fixation simply by observing their eyes for a period of a few seconds (e.g. 5–10 seconds) as you remind them to keep looking closely at the letter.
7. Perform the cover/uncover (unilateral cover) test to look for a heterotropia ([Figure 6.2](#)):
 - (a) Place the cover before the left eye. As you do so, observe the response of the right eye that has not been covered. Repeat this procedure two or three times before you arrive at any decision. If the right eye moves when the left is covered, then a tropia is present in the right eye. The movement observed occurs to take up fixation. You should allow the eye time to take up fixation, which may be as long as 2–3 seconds. If the eye moves out to take up fixation, then in the binocular situation it must have been directed inwards and so an ESOTropia is present. If the eye moves in to take up fixation an EXOTropia is present. If the eye moves up to take up fixation, then in the binocular situation it must have been directed downwards and so a HYPOTropia is present. If the eye moves down to take up fixation, a HYPERTropia is present.

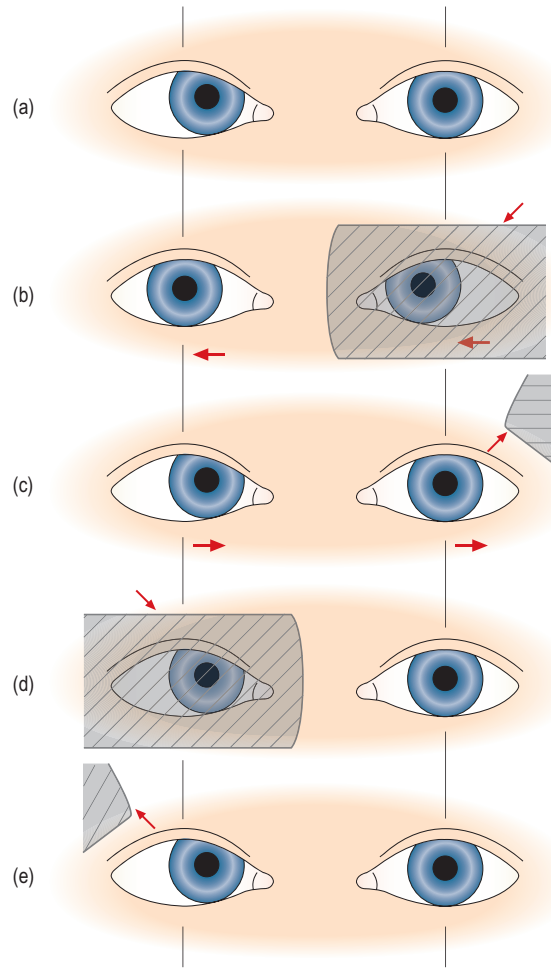


Fig. 6.2 Cover test in a patient with a right esotropia. (a) The right eye deviates inwards slightly, but this may not be obvious depending on its size and your experience. (b) As the left eye is covered, the right eye is seen to move out to take up fixation. Behind the cover, the left eye moves to the right, obeying Hering's law. (c) As the left eye is uncovered, it moves out to take up fixation as it is the non-strabismic eye. (d) When the right eye is covered, the left eye does not move. (e) When the right eye is uncovered, neither eye moves. Reprinted with permission from Pickwell D (1989). *Binocular vision anomalies*. Butterworth-Heinemann.

- (b) Repeat the cover/uncover test by placing the cover over the right eye and look for a heterotropia in the left eye. Once again, repeat the procedure two or three times. If neither eye moves when the other is

covered there is no heterotropia and you should go to step 8 below.

- (c) In a unilateral strabismus, when the deviating eye is covered and then uncovered, the non-tropic 'normal' eye will continue to fixate and will not move. If there is a unilateral heterotropia present, there is frequently amblyopia so that the visual acuity is reduced in that eye.
 - (d) Eyes with strabismus and amblyopia may not take up fixation immediately when the fellow eye is covered. Give them time to fixate and actively encourage them to do so. Note and record any fixation instability or tremor (nystagmus) when the patient attempts to fixate with the eye that normally deviates.
 - (e) Note that some heterotropias may be intermittent. Typically these are large heterophorias that sometimes break down into a heterotropia. If you suspect an intermittent tropia, use the alternating cover test to investigate whether the tropia is evident when the alternating cover test is concluded. If a tropia is now present, this indicates that the patient may develop a strabismus (i.e. and potentially therefore experience double vision) when tired or under stress.
 - (f) Repeat the test from the beginning to confirm your diagnosis.
 - (g) If a heterotropia is present there is no need to search for a heterophoria. You should record your result and move on to the next test (e.g. cover test in different refractive correction, or at a different viewing distance). Note that it is not meaningful to speak of 'recovery' movements in relation to tropia movements because there is no fusion reflex to bring the eyes back into alignment. When the cover is removed and habitual viewing is restored the movements that are seen have no diagnostic value in the way that recovery movements are valuable in patients with heterophoria (see 10(d) below).
8. If no heterotropia was found you should now begin the search for a heterophoria. There are two possible alternatives here and both have their advocates. Some practitioners will continue to use the cover/uncover test that was used for heterotropia investigation in the search for a heterophoria. If this is your preferred approach then go to step 9 below. An alternative approach is to switch now to the alternating cover test. If this is your preferred approach then go to step 10. Some practitioners use both techniques to evaluate heterophoria. There is no research to support one approach over the other.
9. If no heterotropia is present, perform the cover/uncover test to look for a heterophoria (Figure 6.3):
- (a) In heterophoria, the eye being covered will move out of alignment with the other eye because sensory fusion is being prevented. It will then retake up fixation when the cover is removed. Some practitioners attempt to observe both the movement of the eye that is under cover and the recovery movement of that eye when the cover is removed. This requires some dexterity on your part and care must be taken to ensure that the 'cover' is really covering the patient's view of the target. Other practitioners only attempt to observe the eye's recovery movement when the cover is removed. If you choose to do the latter, then go directly to step (c).
 - (b) Place the cover before the left eye in a manner that prevents the patient from viewing the target but allows you to continue viewing the covered eye. Observe the response of the left eye behind the occluder when it is first covered. If a heterophoria is present then the covered eye will drift outwards in EXOphoria, inwards in ESOPhoria, upwards in HYPERphoria and downwards in HYPOphoria.
 - (c) Observe the response of the covered eye as the cover is removed. Remove the cover in a manner that allows you to view the eye continuously as it is being uncovered. In other words don't move the occluder away from the patient's eye in a fashion that causes you to temporarily lose sight of it. For example, you can remove the cover from in front of the patient's right eye by moving the cover diagonally downwards and temporally. Note the recovery movement of the eye will be opposite to that which took place behind the cover. For example, in EXOphoria the eye moves back in when the cover is removed as it drifted out (away from the nose) behind the cover.

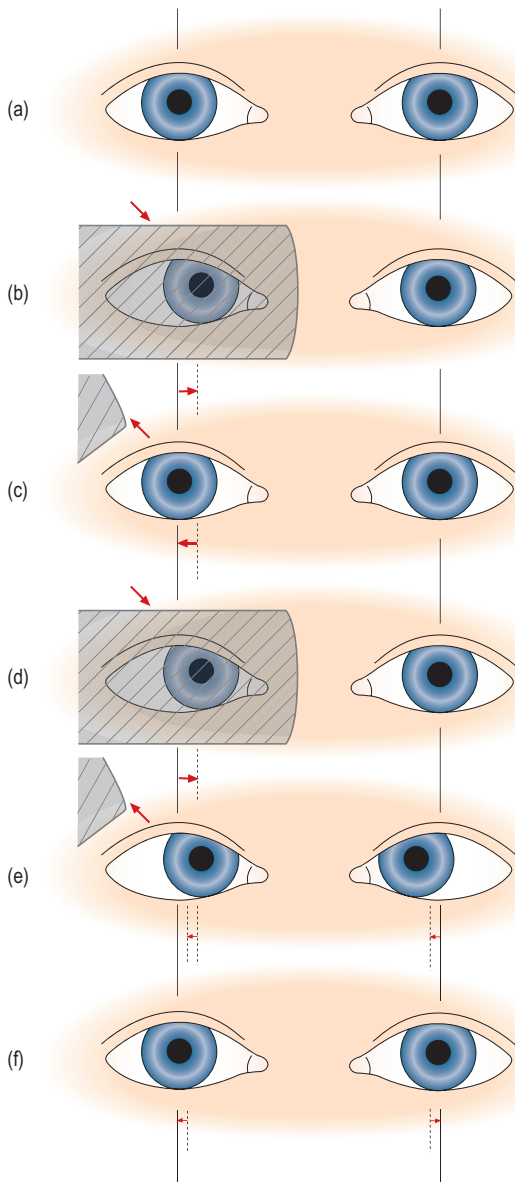


Fig. 6.3 Cover test in a patient with esophoria. (a) to (c) show the simple pattern of movements that are usually seen, and (d) to (f) show the more rare versional pattern of movements that can occur when one eye is dominant. (a) Both eyes look straight ahead. (b) The right eye is covered and the left eye does not move, indicating that there is no strabismus in the left eye. Behind the cover the right eye moves inwards. (c) The right eye is uncovered and the right eye moves out to resume fixation with the other eye. Note that during the movements of the right eye, the left eye has not moved, and disobeys Hering's law to maintain fixation. (d) The right eye is covered as before and it moves inwards behind the cover. (e) The right eye is uncovered and both eyes move right by the same amount, obeying Hering's law. (f) Both eyes diverge by the same amount, again obeying Hering's law, and take up fixation. Reprinted with permission from Pickwell D (1989). *Binocular vision anomalies*. Butterworth-Heinemann.

you should repeat this cycle several times, watching first one eye and then the other and comparing the movement of the two. However, you should leave several seconds between each cycle to avoid inadvertently performing an alternating cover test.

- (d) In a small number of patients, generally with large phorias or when a highly dominant eye is uncovered, the fixating eye undergoes a flick or wobble as the cover is removed from the other eye. This is due to the eyes more closely following Hering's law of equal innervation (Figure 6.3d-f).
- (e) Since it is not possible to observe the two eyes at once when the cover is removed,

- (f) Repeat the observations when covering and uncovering the right eye. If an esophoria was present in the left eye, it should be present and similarly sized in the right. It does not make sense to state that a patient has, for example, 'esophoria of the right eye' since esophoria of the same or very similar magnitude will almost always be present when the left eye is covered. There are some rare exceptions to this rule, such as in patients with uncorrected or residual anisometropia, where greater accommodative convergence in one eye influences the movements. Because the presence of a vertical heterophoria signals a tendency for the eyes to drift out of vertical alignment, a hypophoria evident in one eye will be evident as a hyperphoria in the fellow eye. Once again, however, the deviations will usually be of a similar size in the two eyes.
- (g) Estimate or measure the magnitude of the deviation. Deviations can be measured by placing prisms of increasing power in front of one eye until no movement is observed

during the cover/uncover test. The prism is normally placed in front of one eye only. Base-in prism power is used to measure EXOphorias/EXOtropias, and base-out to measure ESOPhorias/ESOTropias. A prism bar is most conveniently used for this purpose, although estimates made by experienced practitioners can be in good agreement with measurements made using prism bars.⁵

10. If no heterotropia is present, perform the alternating cover test.
 - (a) Place the occluder before one eye for 2–3 seconds and then transfer it quickly to the other eye, without pausing. Keep the occluder in front of the eye for 2–3 seconds, and allow the other eye to take up fixation, and then repeat the cycle. The patient must not view the target binocularly at any time and thus rapid movement of the cover between the eyes is required. For this reason, the occluder should be moved along a horizontal line between the eyes rather than in an arc-shaped pattern. In order to facilitate swift transfer of the cover between the eyes it is best if your hand that holds the cover is held close to the patient's forehead or alternatively, close to the tip of the patient's nose.
 - (b) If there is a deviation of the eyes, it will be seen as a re-fixation eye movement when the cover is transferred from one eye to the other. The eyes will move outwards in ESOPhoria/ESOTropia, and inwards in EXOPhoria/EXOTropia, etc.
 - (c) Estimate or measure the magnitude of the deviation. Deviations can be measured by placing prisms of increasing power in front of one eye until no movement is observed during the alternating cover test. The prism is normally placed in front of one eye only. Base-in prism power is used to measure EXOphorias and base-out to measure ESOPhorias. A prism bar is most conveniently used for this purpose, although estimates made by experienced practitioners can be in good agreement with measurements made using prism bars.⁵ To help you make better estimates of deviation sizes, ask your patient to look from the first to the last letter on the Snellen 6/12 (20/40) line at six metres (20 ft) with one eye occluded. The

movement observed is equivalent to 4 prism dioptres and using this as a guide provides a good way for you to estimate other deviation sizes.

- (d) Unlike in cases of heterotropia, observe the latency and the speed of the fusional recovery movement on uncovering, since this may give clues as to the strength of the fusion reflex. The movement should be smooth and fast. Poor fusion reflexes are slow and hesitant, with jerky movements.
11. If no heterophoric movements are seen *during the alternating cover test*, perform the subjective cover test.

If you cannot see any movement of the eyes during step 10 and the patient can provide good subjective responses, continue to perform the alternating cover test and ask the patient if the target appears to move when the occluder is switched from one eye to the other. Subjectively reported movements of the target are called 'phi' (pronounced as 'fy' as in 'why') movements. Small amounts of phoria (1–3^d) may be detected in this way. Any reported vertical phi movement should be further investigated using other tests, such as the modified Thorington technique ([section 6.4](#)). The type of deviation present can be inferred according to whether the target appears to move in the same or opposite direction as the cover. For example, esophoria will cause the target to move 'against' the movement of the occluder and an exophoria will cause the target to move 'with' it.

6.2.3 Adaptations to the standard procedure

1. **When examining children:** Pictures can be used to retain attention, but they should be of an appropriate size. Pictures (or letters) that are too large do not provide an accurate stimulus for fixation or accommodation and this is essential for an accurate cover test. In order to check compliance with your instructions, it is useful to occasionally move the stick a short distance to one side. If the eyes are seen to follow the target then you can be confident that your instructions are being followed.
2. **If a heterotropia is suspected in a patient with equal VA in the right and left eye:** (see online video 6.6). In such cases the possibility of an alternating heterotropia should be investigated.



Note that patients with a marked difference in VA between the eyes will not alternate. With an alternating heterotropia, the right eye will exhibit the tropia if the left eye fixates during the cover test and the left eye will exhibit the tropia if the right eye fixates during the cover test. The difficulty with diagnosing an alternating tropia is that the tropia movement only occurs during the first cover/uncover assessment. When the cover/uncover assessment is repeated a second and third time, the eye being observed does not now move as it has now become the fixating eye. The other eye has now become the deviating eye and the tropia will appear in the first cover/uncover assessment of the other eye. When asked to view binocularly after completion of the cover/uncover test, some patients with an alternating heterotropia will continue to fixate with the eye that fixated the target during the last iteration of the cover test procedure. In some cases, there is no preferred fixating eye. In other cases, there is a definite preference for fixation with one eye over the other and although the non-preferred eye might continue to fixate for a short period (e.g. a few seconds) after the cover had been removed, fixation then switches back to the preferred eye. Some patients with alternating tropia can switch eyes at will if you ask them to and some may even anticipate which eye is to be covered and switch eyes prior to you using the occluder. These tropias can be very confusing to diagnose.

3. **In patients with an abnormal head posture (head turn or tilt):** Ask the patient to straighten their head position before testing commences. If the abnormal head position is a permanent feature for a particular patient, the cover test should be carried out with the head in the habitual (i.e. turned/tilted) position and again when the head is straightened. If the deviation differs markedly with adjustment of the head position, it is possible that the head is being turned/tilted to address an underlying binocular vision issue. This can be further investigated if the head is tilted/turned in the opposite direction to the direction that the patient typically exhibits. If the deviation becomes even more pronounced, an incomitancy is certainly present and you can conclude that the abnormal head posture is linked to a binocular vision condition rather than to another, non-visual cause.

6.2.4 Adaptation for older patients

During the near cover test, it can sometimes be difficult to see an older patient's eyes due to drooping upper lids and the downward gaze needed to view the fixation target with multifocal spectacles. First, asking the patient to tilt their head back slightly may improve the visibility of their eyes. If the problem is due to drooping upper lids, they may need to be gently held up. In this case, you should ask the patient to hold the fixation stick. Finally, if it is otherwise not possible to see the patient's eyes sufficiently well, ask the patient to hold their multifocal spectacles up slightly and to view the fixation stick with their head erect and looking straight ahead with their eyes in the primary position of gaze. In this case, you should note that the near cover test has been performed in primary gaze rather than the preferred, slight downward gaze.

6.2.5 Recording

1. Record NMD (No Movement Detected) if this was the case and if no assessment of 'phi' movement was conducted. NMD is preferred to 'ortho' (i.e. orthophoria) or similar, as even experienced practitioners cannot detect very small eye movements (up to 2–3°).⁴ Hyperphorias of this size can be significant and cause the patient problems, so you must not assume that the patient does not have a significant phoria based on detecting 'no movement' using the cover test.
2. Record 'ortho' (orthophoria) or similar ($\ominus$ for horizontal orthophoria, Φ for vertical orthophoria and $\oplus$ for both vertical and horizontal orthophoria) only if no movement was detected using the cover test AND no phi movement was reported.
3. If heterotropia is detected, then record:
 - The constancy (if intermittent is not recorded, the tropia is assumed to be constant. If the deviation is intermittent, note the percentage of time that the eye deviates).
 - Which eye is deviated (right, left or alternating; abbreviated to R, L or Alt)?
 - The direction (exo, eso, R hyper or hypo, L hyper or hypo, excyclo, incyclo). Exo and Eso are abbreviated to XO and SO, respectively.
 - Add the suffix tropia (abbreviate to T, e.g., SOT, XOT).

- An indication of the size of the tropia, either measured with a prism bar or estimated (if estimated, precede your result with the symbol '~'), e.g. $\sim 20^\Delta$ L XOT. Remember that it is not meaningful to attach significance to (or record) 'recovery' movements in patients with a tropia.
- Heterotropias can also be defined as following an A- or V-pattern or other varieties of alphabet pattern (e.g. Y or inverted Y). By definition such deviations are of the incomitant variety and their presence will emerge during the motility test (section 6.15).

Examples are given in Table 6.1.

- If heterophoria is detected, then record:
 - The direction (exo, eso, R/L or L/R). Exo and Eso are abbreviated to XO and SO, respectively. R/L indicates a right hyperphoria, which is the same as a left hypophoria. L/R indicates a left hyperphoria/right hypophoria.
 - Add the suffix phoria (abbreviate to P, e.g., SOP, XOP).
 - An indication of the size of the phoria, either measured with a prism bar or estimated (if estimated, precede your result with the symbol '~').
 - Any recovery movements that were slow, hesitant and/or jerky. Normal, smooth and fast recovery movements are generally not recorded.

- Heterophorias that were found using the subjective cover test, but not seen by you, should be recorded in the usual manner and followed by the term 'phi'.
- A and V patterns may also be seen in patients with heterophorias and, as in the case of heterotropias, this also signifies the presence of an incomitant deviation (section 6.15).

Examples of appropriate test recordings are given in Table 6.1.

6.2.6 Interpretation

Hering's law states that the innervation to synergist muscles of the two eyes is equal. This would imply that the eyes would always move by equal amounts (in the same direction in version movements and in the opposite direction in vergence movements). The common cover test response, in which the fixating eye remains still and the uncovered eye moves to restore fusion thus contravenes Hering's law. Hering's law would predict that when one eye is uncovered, both eyes would make a version movement equal to half the deviation, and then both eyes would make an equal fusional (vergence) movement, to restore bifoveal fixation. This response does occur in some patients and should not be confused with heterotropic movements (Figure 6.3). Note that heterotropic cover test movements are in one direction and take place when the cover is *introduced* to the other eye whereas, when they occur, Hering's law

Table 6.1 Examples of recordings from the cover test

Abbreviation	Description
NMD	No movement detected (deviation $<2-3^\Delta$)
<3 SOP (Phi)	A small esophoria ($<3^\Delta$) not seen, but reported subjectively
~ 4 XOP	A small exophoria with good recovery, estimated to be 4^Δ
8 SOP, slow rec.	An esophoria with slow recovery, measured to be 8^Δ
~ 4 R/L	Right hyperphoria, estimated to be 4^Δ
Int (50%) ~ 10 RSOT	Intermittent right esotropia (tropia present about 50% of the time), estimated to be 10^Δ
8 R hyper T	Constant right hypertropia, measured with a prism bar to be 8^Δ
25 Alt XOT $\bar{c}$ 4 R/L	Constant alternating exotropia of 25^Δ with a vertical component. There is also an alternating right hypertropia of 4^Δ (measurements with a prism bar)

movements have the appearance of a ‘wobble’ and take place when the cover is *removed* from the other eye (see online videos 6.7 and 6.10).

Most children show no movement on the cover test at distance and either no movement or a just visible exophoria at near.⁶ There appears to be little information regarding cover test results for normal adults in the research literature. Textbooks suggest that the majority of adults will also show either no movement or a just visible exophoria or esophoria (up to about 4^Δ) on the distance cover test.⁷ At near, a small amount (3^Δ to 6^Δ) of exophoria is considered normal (physiological exophoria) and this is likely to increase with age (exophoria measured with the Maddox wing increased from a mean of zero at age 20 to 5^Δ at 65).⁸ As even experienced practitioners *cannot* detect very small eye movements (up to 2–3^Δ), small hyperphorias will be missed with the objective cover test, and any hyperphoria that is detected will be abnormal.⁴

The movements made by each eye are usually similar in heterophoria. In cases where the heterophoria movement is greater in one eye than the other, suspect poor technique (and re-assess), uncorrected or residual anisometropia or incomitancy (section 6.15).

6.2.7 Most common errors

1. Not positioning yourself appropriately to allow a clear and unimpeded view of the patient's eyes.
2. Blocking the patient's view of the target that you have instructed them to fixate upon. This is only a problem during the distance cover test.
3. Covering and uncovering the eyes so rapidly that the eyes do not have time to make the movements consistent with the deviation that is present. In the alternating cover test, you should leave the cover in place for at least 2–3 seconds before removing it or transferring it to the other eye.
4. Arriving at your diagnosis too quickly. Repeat the test two or three times in quick succession to confirm your diagnosis. Fixational instability can cause a misleading result on a single test.
5. Using a fixation target that is too large.
6. Using large, sweeping lateral movements of the occluder when covering/uncovering. This is distracting for the patient, and during an alternating cover test, may mean that binocular vision isn't being fully suspended. Small but swift movements with the occluder are required.
7. Diagnosing a heterotropia when there is a temporary loss, but then a quick recovery, of fixation of an eye when the fellow eye is uncovered (Figure 6.3e and f).
8. Failing to record information about the speed and/or smoothness of recovery in patients with a heterophoria in patients in whom the recovery is slow or jerky. Conversely, recording information about recovery in heterotropia patients.

6.3 OTHER TESTS FOR THE DETECTION AND MEASUREMENT OF HETEROTROPIA

In very young children, who may be unable to maintain fixation for long enough to allow the cover test to be performed, an objective assessment of binocular status in the primary position can provide useful information to indicate the presence or absence of heterotropia.

6.3.1 Comparison of tests

The Hirschberg test compares the position of the corneal reflexes (the first Purkinje images) of the two eyes that are formed by a pentorch. It is quick and easy to perform, and requires little co-operation on the part of the patient, but can really only be performed at near, the penlight target provides a poor stimulus to accommodation and it is relatively inaccurate. Choi and Kushner found that even experienced practitioners can obtain results that differ by up to 10 prism dioptres.⁹ This is because a deviation of just 1 mm is equivalent to ~22^Δ. The Krimsky test extends the Hirschberg test by using prisms to equalise the positions of the corneal reflexes in the two eyes. The Bruckner test relies upon a comparison of the brightness of the retinal reflex in the two eyes. In the presence of a strabismus the reflex can be brighter and whiter in the deviating eye as compared to the reflex from the fixing eye due to fundal reflections from a deviating eye being greater than from the darkly pigmented macular area of a normally fixating eye. The usefulness of the Bruckner test is, however, controversial.^{10,11} Given their limited accuracy, the cover test (section 6.2) should be used in preference to these tests as soon as the child can co-operate with the cover test requirements.

6.3.2 Procedure: Hirschberg and Krimsky

See online video 6.15.

1. Keep the room fully illuminated. Additional use of localised lighting is recommended so that the

patient's eyes can be easily seen without shadows.

2. Remove any spectacles that the patient may be wearing. However, if it is felt that the refractive correction will alter the result (e.g. in cases of significant hyperopia), the test should also be performed through the correction.
3. Hold a penlight horizontally 40 to 50 cm from the patient with the light aimed at the bridge of the patient's nose. The back of the penlight should be very close to the tip of your nose.
4. Ask the patient to look at the light with both eyes open. Young children will automatically tend to look toward the bright light but may need a little encouragement.
5. Note the location of the corneal reflex in each eye individually. In order to do this you should briefly cover each eye in turn; you can do this with the palm of your hand. Remember that the reflex is frequently decentred about 0.5 mm nasally with respect to the centre of the pupil because angle kappa is normally positive.
6. Now compare the location of the corneal reflexes as the patient views habitually (i.e. without any occlusion). The eye that has the same angle kappa as in the monocular test is the fixing eye. The location of that reflex should be considered the reference position.
7. If there is a heterotropia present, the corneal reflex of the other eye will have shifted in a direction opposite to that of the ocular deviation. For example, in the case of an ESOTropia, the corneal reflex will be displaced temporally on the patient's cornea relative to the position of the reflex in the fellow eye.
8. **Hirschberg:** Estimate the magnitude of the deviation from the displacement of the reflex in millimetres (mm) relative to the reference position using the approximation of $1 \text{ mm} = \sim 22^\Delta$.
9. **Krimsky:** Use a prism bar in front of the fixating eye in order to centre the corneal reflex in the deviated eye. Measures of the angle of heterotropia obtained using the Krimsky test rely upon the assumption that the deviating eye fixates centrally rather than eccentrically. While this assumption may not be valid in many instances, the error it introduces is likely to be small in relation to the overall size of the deviation.

6.3.3 Procedure: Bruckner test

See online video 6.14.



1. Turn down the lights so the room is dimly lit.
2. Remove any spectacles that the patient may be wearing. However, if it is felt that the refractive correction will alter the result (e.g. in cases of significant hyperopia), the test should also be performed through the correction.
3. Hold a penlight horizontally 1 m from the patient with the light aimed at the bridge of the patient's nose. The back of the penlight should be very close to the tip of your nose.
4. Ask the patient to look at the light with both eyes open. Young children will automatically tend to look toward the bright light but may need a little encouragement.
5. Compare the colour and brightness of the fundus reflexes.

6.3.4 Recording

Record the eye that deviates, along with the direction of the deviation. In your recording, make it clear that the observation was made using the Hirschberg, Krimsky or Bruckner techniques. For the Hirschberg and Krimsky tests, equal nasal displacement of the corneal reflexes in each eye indicates a non-strabismic patient. For example:

Hirschberg: No Strab; Hirschberg: $\sim 11^\Delta$ RSOT; Krimsky: 15^Δ L XOT. Bruckner: L SOT.

6.3.5 Interpretation

For the Krimsky and Hirschberg tests, a reflex located nasally to the reference point suggests an exotropia, a reflex located temporally to the reference point suggests an esotropia. Superior displacement of the reflex suggests a hypotropia, and inferior displacement suggests a hypertropia. It is important to realise that, in most patients, the corneal reflections will be displaced slightly nasally relative to the pupil centres. This displacement arises because a separation exists between the pupillary and visual axes. The angle between these axes is referred to as the angle kappa, which is given a positive value if the reflexes are nasally displaced. It is important to remember that a large angle kappa may result in the misdiagnosis of heterotropia or failure to detect a heterotropia. For example, a large positive angle kappa will simulate the presence of an exotropia. Similarly, an existing exotropia will appear larger than it actually is and small esotropias may escape detection.

For the Bruckner tests, any brightness difference indicates the presence of at least a moderate sized strabismus, although the brightness difference gives no indication of its type or size. Also, when interpreting the results of the Bruckner test, remember that differences in brightness can be caused by factors other than strabismus including anisometropia and media opacities.

6.3.6 Most common errors

1. Hirschberg and Krimsky: Basing your decision upon the absolute position of a single reflex relative to the pupil centre rather than on a comparison of the relative locations of the corneal reflexes in the two pupils.
2. Not viewing the patient's eyes from a position which is directly behind the penlight for the Hirschberg and Bruckner tests or from directly in front of the deviating eye in the case of the Krimsky test.
3. Placing too much emphasis on the accuracy of the estimates provided by these tests.
4. Not realising that these tests may fail to detect a small angle heterotropia.

6.4 OTHER TESTS FOR THE DETECTION AND MEASUREMENT OF HETEROPHORIA

While the cover test must always be carried out, it is usual for this to be conducted prior to refraction and for other tests of oculo-motor alignment to be employed after the subjective refraction has been completed. The assessment of heterophoria requires that fusion is suspended and the eyes dissociated. This is achieved using vertical prism power which is too high for the eyes to overcome (von Graefe and Howell-card methods); viewing dissimilar images (a streak in one eye, a spotlight in the other as in the Maddox rod and modified Thorington tests) or using a septum (Maddox wing). Heterophoria tests are more repeatable with a trial frame than with a phoropter.¹² In addition, since the use of a phoropter will limit the patient's ability to adopt a habitually abnormal head position, the measurement of vertical phorias is best performed using a trial frame or a hand-held rod in free space.

6.4.1 Comparison of tests

Because the cover test can be difficult to perform when using a phoropter or reduced aperture trial case lenses,

all of the techniques described in this section offer advantages over the cover test for assessment of oculomotor alignment post-refractive correction. Also since the objective cover test can't reveal small eye movements below about 2–3^Δ, the subjective tests are useful for checking for small vertical heterophorias that may be clinically significant.⁴

The Maddox rod test can be easily performed with a phoropter, trial frame or the patient's own spectacles and with any test chart that contains a spotlight. It is widely used, easy for patients to understand, and can be performed relatively quickly. One drawback is that a spotlight represents a poor stimulus for accommodation and some clinicians consider that this limits the usefulness of the Maddox rod to the measurement of vertical heterophorias, which are assumed to be unaffected by accommodative changes. However, the Maddox rod should produce reliable assessments of horizontal heterophoria when used in patients with no accommodation, such as patients over the age of 60 or pseudophakes. The test should be carried out with the head held in the habitual fashion.

The modified Thorington technique is a very simple and quick technique that can be used in a phoropter, trial frame or free space. It produces the most repeatable results of the most commonly used techniques.^{12–14} The modified Thorington overcomes the Maddox rod's problem of lacking an accommodative target by using a target of small letters or numbers (Figure 6.4).

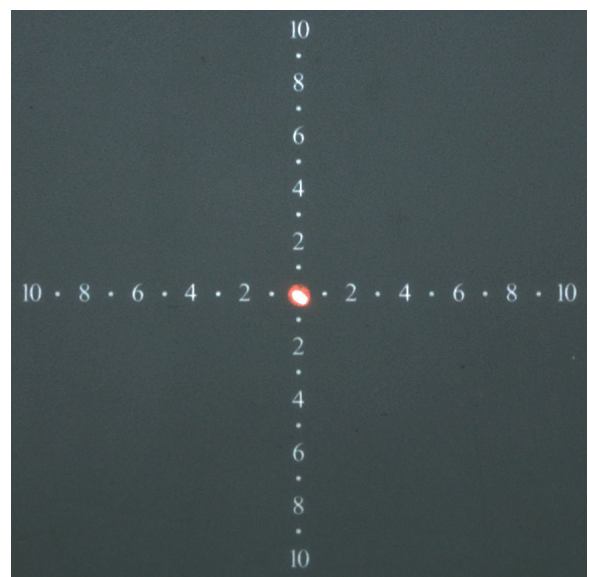


Fig. 6.4 A Thorington card.

It is principally used at near, but Thorington cards are available for both distance and near. In view of its many advantages it is somewhat surprising that it is not more widely used at present. Normative data from large study populations of children have been published.¹⁵

The Maddox wing provides a simple and relatively fast technique for the measurement of heterophoria at near. However, the figures used on the scale are relatively large with the result that accommodation does not need to be precisely controlled. This may lead to overestimation of an exo-deviation, to underestimation of an eso-deviation or to variable results. There are claims that changing to smaller letters improves test reliability.¹⁶ In addition, the eyes may not be fully dissociated because the septum may allow peripheral fusion to occur. Finally, the instrument uses a standard, fixed centration distance between the lenses and a fixed testing distance of 25 cm and it would be very difficult to use with a phoropter.

The von Graefe technique is widely used and can be easily performed in a phoropter with a projector chart and no additional equipment. Unfortunately, it is the least reliable technique of those commonly available and its results correlate poorly with the cover test, especially in the case of horizontal phoria measures.^{12–14,17,18} This may result from variable amounts of prism adaptation, phoropter-induced proximal accommodation, a head tilt behind the phoropter leading to an induced vertical deviation or a reduction in peripheral fusion.¹² In addition, it is a relatively lengthy procedure, can be difficult for patients to understand and cannot easily be used with a trial frame. The technique does not appear to warrant its widespread use and other more reliable techniques such as the modified-Thorington or Howell card methods should ideally replace it.^{12–14,17}

The Howell card method provides a simple and quick technique that can be used in a phoropter, trial frame or free space and it can be used for measurement of horizontal phorias at distance or near. It cannot be used to measure vertical phorias. Although it appears to be popular, the method has not been subjected to many comparisons with other techniques but a study by Wong et al. suggests that the Howell phoria card method has a better inter-examiner repeatability than the von Graefe method.¹⁷

6.4.2 Initial procedure for all tests

1. Inform the patient about the test: 'This test is to check how your eye muscles work together with the new prescription'.

2. Measure near phorias immediately after the distance heterophoria measurements in pre-presbyopic patients and after inclusion of the required reading addition in presbyopes.
3. For near phoria measurement, adjust the trial frame/phoropter to the near centration distance.

6.4.3 Procedure: Modified Thorington test

Horizontal near heterophoria

Ensure the patient is wearing their optimal near refractive correction and adjust the phoropter/trial frame to the near centration distance.

1. Place the Maddox rod in front of one eye making sure that the 'grooves' are horizontal. Note that it is conventional to place the Maddox rod before the right eye. Dim the room lights.
2. Shine the light from a penlight through the central aperture of the Thorington near card. The near cards are usually calibrated for 40 cm and because the cards feature a tangent scale it is vital that the viewing distance is correct.
3. Direct the patient to look at the letters and keep them clear. Ask them to then look at the spotlight, and tell you whether the vertical red line is seen to the right, left or straight through the spotlight.
4. Some patients have difficulty seeing the red line initially. If they cannot see the red line, cover each eye in turn to demonstrate that one eye sees the spotlight, letters and numbers and the other sees the red line. Once they are aware of the test format they are often able to see the red line and spotlight, letters and numbers simultaneously. Placing a green filter before the eye viewing the spotlight can also help the patient to perform the test. If difficulty is still experienced, place the Maddox rod in front of the left eye and try again. If the spotlight and red line cannot be seen together then suppression may be present and follow up tests should be performed ([section 6.13](#)).
5. With the Maddox rod in front of the right eye the following responses may be given:
 - (a) If the line is seen to pass through the spotlight the patient has no horizontal phoria.
 - (b) If the line is to the left of the spotlight (crossed images) the patient has an exophoria. If the line is to the right of the

spotlight (uncrossed images) the patient has an esophoria.

- (c) Determine the size of the deviation by asking the patient which number on the horizontal series of letters on the Thorington card the line passes through. This is the number of prism dioptres of horizontal heterophoria.

Vertical near heterophoria

1. Rotate the Maddox rod so that the 'grooves' are vertical.
2. Ask the patient if the red line is seen above, below or straight through the spot.
3. With the Maddox rod in front of the right eye the following responses may occur:
 - (a) If the line is seen to pass through the spotlight the patient has no vertical phoria.
 - (b) If the line is above the spotlight the patient has a right hypophoria. It is possible to specify vertical heterophorias with respect to the right or left eye. Thus, a right hypophoria can also be called a left hyperphoria. As above, the size of the deviation is determined by asking the patient which number on the vertical series (number or letters) of letters on the Thorington card that the line passes through.

Distance lateral and vertical phorias

These can be similarly measured using a distance Thorington card and a penlight. The distance cards are normally calibrated for use at 3 metres (10 feet).

6.4.4 Procedure: Howell cards

Horizontal near heterophoria

1. Ensure the patient is wearing their optimal near refractive correction and adjust the phoropter/trial frame to the near centration distance.
2. Ensure the card (Figure 6.5) is 33 cm away from the patient's eyes. This is important because the tangent scale is calibrated for this exact distance. A piece of string of the appropriate length provides a simple means to establish that the viewing distance is correct.
3. Hold the stick-mounted or loose vertical prism in front of the right eye. This will generate vertical diplopia so the patient should see two

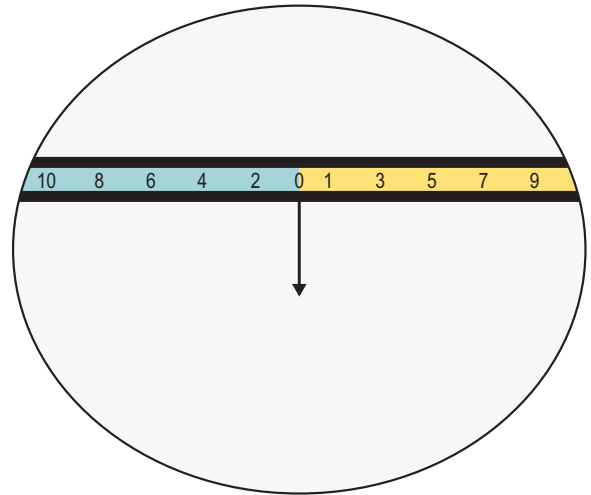


Fig. 6.5 A representation of a typical Howell card.

scales and two arrows. The prism power used is 6^Δ and it is introduced with base direction vertically oriented.

4. Ask the patient 'Do you see two arrows and two sets of numbers?'
5. Next ask the patient to do the following: 'Please look at the top arrow and you will see it points downwards from the '0' on the top set of numbers. Please follow it down with your eyes, and tell me which number on the lower set of numbers it points to. If it points between two numbers, please tell me between which two numbers it seems to point'.
6. Since the scale is a tangent scale, the number corresponds to the magnitude of the phoria.
7. Assuming the prism is placed base UP in front of the right eye, if the arrow points down towards an odd number, the patient is EXOphoric. If it points to an even number the patient is ESOPhoric. Since the patient may extrapolate between two numbers, you should ask if the numbers appear on the yellow or blue part of the scale. Numbers on yellow are odd and those on the blue part of the scale are even.

Distance horizontal phoria measurement

The Howell distance card is calibrated for use at 3 m (10 feet). Otherwise the procedure is identical as for near phoria measurement. Note that the Howell card method cannot be used for assessment of vertical heterophorias.

6.4.5 Procedure: Maddox rod

Horizontal distance heterophoria

1. Place the Maddox rod in front of the right eye making sure that the 'grooves' are horizontal.
2. Provide a spotlight target at distance using the wall/projector chart and then dim the room lights.
3. Ask the patient to look at the spotlight, and to indicate if the vertical (red) line is seen to the right, left or straight through the spotlight.
4. Some patients have difficulty seeing the red line initially. If this occurs, try the following:
 - (a) Make sure that there are not other sources of light that will each produce a line image.
 - (b) Cover each eye in turn to demonstrate to the patient that one eye sees the spotlight while the other sees the line. Once they are aware of the test format they are often able to see the line and spotlight simultaneously.
 - (c) Placing a green filter before the eye viewing the spotlight may also help the patient perform the test, presumably because the brightness difference between the spot and streak is reduced relative to the normal white/red condition.
- (d) If the patient continues to see only the line or spot, transfer the Maddox rod to the left eye and try again.
- (e) If the spotlight and red line cannot be seen together then suppression may be present and follow-up tests should be performed (section 6.13).
5. With the Maddox rod in front of the right eye the following responses can occur:
 - (a) If the line is seen to pass through the spotlight the patient has no horizontal heterophoria.
 - (b) If the line is seen to the left of the spotlight (crossed images) the patient has an exophoria. If the line is to the right of the spotlight (uncrossed images) the patient has an esophoria.
 - (c) If the line is seen to be continuously in motion, ask the patient to concentrate on seeing the spotlight as clearly as possible.
6. To measure the size of the phoria, place prism in front of either eye. The following approach can be adopted:
 - (a) When using a phoropter, use the Risley prism (Figure 6.6) and increase the power of the appropriately-oriented prism (base in for exophoria, base-out for esophoria). Ask the patient to say when the line is seen to overlap the spot and record the prism power at this instant.
 - (b) When using a trial frame, use loose prisms or a prism bar and increase the power of the appropriately oriented prism (base in for exophoria, base-out for esophoria) until the patient indicates that the line runs through the spot or until the line is reported to have crossed to the other side of the spot. In the latter case use an interpolated score. For example, if the patient has exophoria and with 2^Δ IN the line is still to the left of the spot, but with 3^Δ IN it switches across to the right, record 2.5^Δ.
 - (c) Some practitioners adopt a screening approach when using the test with a trial frame and place a 2^Δ prism with appropriately oriented base in front of one eye. If the line moves to the opposite side, the heterophoria can be recorded as <2^Δ.

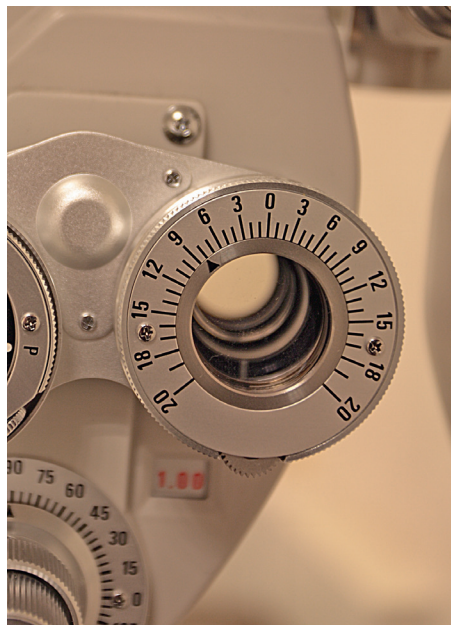


Fig. 6.6 A Risley prism in position to provide prism base in or base-out.

Vertical distance heterophoria

1. Rotate the Maddox rod so that the 'grooves' are vertical.
2. Ask the patient if the red line is seen above, below or straight through the spot.
3. With the Maddox rod in front of the right eye the following responses can occur.
 - (a) If the line is seen to pass through the spotlight the patient has no vertical heterophoria.
 - (b) If the line is above the spotlight the patient has a right hypophoria. It is possible to specify vertical heterophorias with respect to the right or left eye. Thus, a right hypophoria can also be called a left hyperphoria. The size of the deviation is determined using base down prisms before the left eye (or base up prism power before the right eye) until the red line and spotlight are overlapping (Figure 6.7).
 - (c) If the line is below the spotlight the patient has a right hyperphoria (or left hypophoria). The size of the deviation is determined using base up prisms before the left eye (or base down prism power

before the right eye) until the red line and spotlight are coincident.

4. As a screening technique when used with a trial frame, place a $\frac{1}{2}^\Delta$ prism with appropriate base in front of one eye. If the line moves to the opposite side, the phoria can be recorded as $< \frac{1}{2}^\Delta$.

Horizontal and vertical phorias at near measured using Maddox rod

These can be similarly measured, although the near horizontal phoria measurements are considered unreliable in young patients due to the lack of a good accommodative stimulus. A penlight held at 40 cm or the patient's near working distance can be used as the spotlight. The measurement technique is otherwise exactly the same as for distance phoria measurement. Some units designed to be used at near contain a spotlight and a tangent scale to allow near phorias to be measured with the Maddox rod in precisely the same manner as for distance. However, the Maddox wing is the normal accompaniment at near to the Maddox rod for distance.

6.4.6 Procedure: Maddox wing

1. The test is carried out with the room lights on. Ensure there is sufficient lighting to allow the scale on the Maddox wing to be seen with ease (Figure 6.8).
2. Direct the patient to look through the horizontal slits to view the chart, which comprises horizontal and vertical scales, and horizontal and vertical arrows. The right eye sees only the arrows whilst the left eye sees only the scales. The arrows are positioned at zero on the scales but through the dissociation, any departure from orthophoria will be indicated by an apparent movement of the arrow along the scale.
3. Some patients have difficulty seeing the arrows and the scales simultaneously and require help to position the instrument correctly. If necessary demonstrate to the patient, by covering the aperture in front of each eye in turn, that one eye views the arrows and the other eye views the scales. If the arrows and scales cannot be seen together then suppression may be present and follow-up tests should be performed (section 6.13).
4. Firstly ask the patient to say whether the arrow is to the right or left of the zero on the scale.

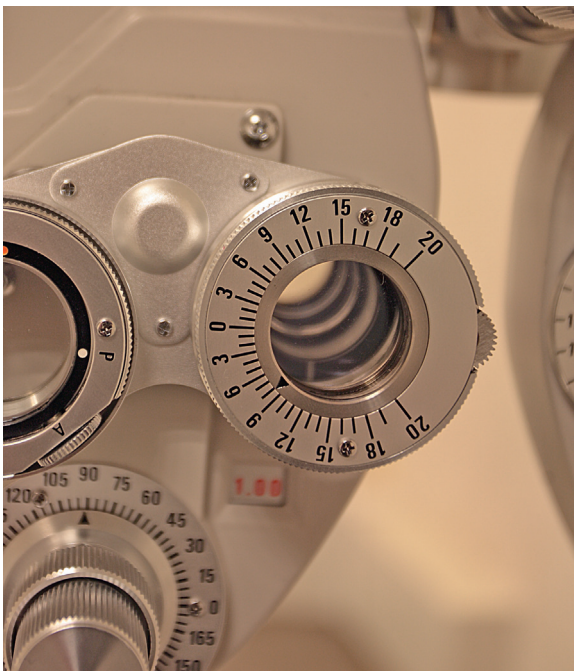


Fig. 6.7 A Risley prism in position to provide prism base up or base down (8^Δ base down in this case).

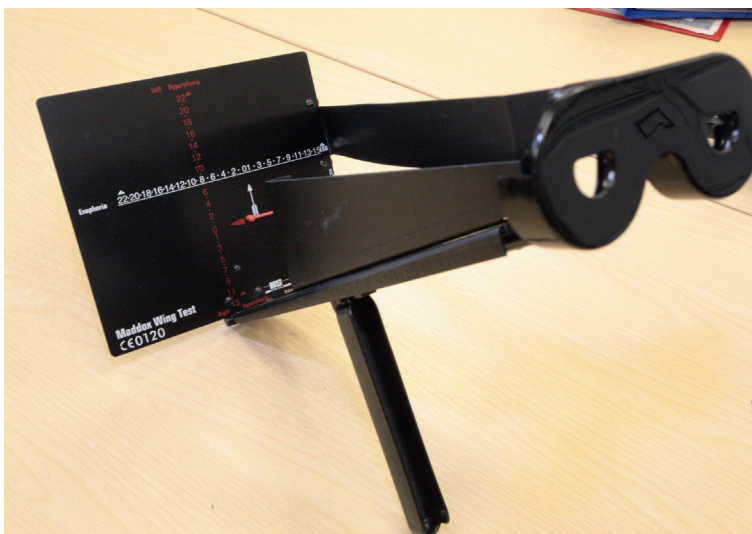


Fig. 6.8 A Maddox wing

This will inform you as to whether there is exophoria or esophoria present. Allow the patient plenty of time before asking 'Which white number does the white arrow point to?' The number on the scale indicates the magnitude of the deviation in prism dioptres and the direction (even numbers correspond to exophoria, odd numbers to esophoria). If, over time, the arrow moves to higher and higher numbers on the scale, wait until the arrow has stopped moving before taking the reading. If the arrow is varying between a maximum and a minimum value, record the value of the midpoint between the extremes. The arrow position will be more stable if you remind the patient to focus on the tip of the arrow and ensure that it is kept as clear as possible.

5. To measure a vertical heterophoria ask the patient 'Which red number does the red arrow point to?' The number on the scale indicates the magnitude of the deviation and the direction.

6.4.7 Procedure: Von Graefe's method

Distance lateral phoria

1. Using the projector chart, isolate a letter or a vertical column of letters one line larger than the visual acuity of the poorer eye. This ensures that both eyes can easily see the letters. As the patient is asked to keep the letter(s) clear, this also helps to control accommodation. Direct the patient's attention to the letter(s).
2. Inform the patient: 'Please close your eyes while I make the letters go double.' Patients are asked to briefly close their eyes because some patients do not react well when the letters are seen to move as the prism is being introduced. Using the Risley prisms, place 6^Δ base up (BU) in front of the left eye. This is the dissociating prism. Place 10^Δ base in (BI) in front of the right eye. This is the measuring prism.
3. Ask the patient whether they see double. If they do not, there are a number of changes you can make to ensure diplopia is seen:
 - (a) Check the phoropter as one eye may be occluded.
 - (b) Ask the patient to look around. The patient may simply not have noticed the second image.
 - (c) Alternately occlude the eyes so that each eye's target is shown. This can help the patient find the targets and can help to eliminate slight suppression.
 - (d) Increase the base up prism to 8–10^Δ BU. They may have a very large vertical vergence range or large prism adaptation.
 - (e) Change the prism to 6^Δ base down (BD). The patient may have a vertical deviation that the original 6^Δ BU is correcting/partly correcting.
 - (f) Check the patient is holding their head straight so that both eyes are looking through the phoropter.

4. Explain to the patient that you want them to look at the bottom letter and that you are going to line up the two letters/columns of letters 'like buttons on a shirt'. To minimise accommodative (and accompanying vergence) changes, ask the patient to keep the bottom letter clear. This is the letter viewed through the dissociating prism.
5. To ensure that prism adaptation has minimal effect, the letters should only be made visible to the patient for brief periods of about 1 second ('flashing'). Briefly occlude the right eye with a hand-held occluder, then remove the occluder and ask the patient if the top letter is seen initially to the right or left of the bottom one.
6. Given the prism used in step 2, the bottom letter is seen by the left eye and the top letter by the right eye. If the top letter is initially seen to the right of the bottom, this is uncrossed diplopia, and the deviation is less than the 10^{Δ} measuring prism, so this should be reduced. If the top letter initially appears to be to the left of the bottom, this is crossed diplopia, and the deviation is greater than the 10^{Δ} measuring prism, so this should be increased.
7. Repeat the occlusion and change the base in measuring prism accordingly. Initially use about 4^{Δ} steps and progressively reduce the step size to 2^{Δ} as the alignment position is first passed and then use a step size of 1^{Δ} as you approach alignment.
8. Use a bracketing technique to determine the amount of measuring prism required to make the letters line up 'like buttons on a shirt'.
9. Some clinicians get close to the end-result by asking the patient when the letters are lined up as they move the prism in the appropriate direction. They then 'fine-tune' the result using a flashing technique. There is a greater risk of prism adaptation with this technique, and it is less repeatable than the 'flashing' procedure.¹³

Distance vertical phorias

1. This is usually measured after the distance lateral phoria measurement.
2. Occlude one eye and change the prism before the right eye to 15^{Δ} BI. Leave the prism before the left eye (6^{Δ} BU). In this case, the base in prism is the dissociating prism and the base up prism is the measuring prism.
3. Adjust the base up prism in front of the left eye until the patient reports that the two letters line

up like 'the headlights on a car'. Use a similar technique as for the lateral phoria measurement: 'flash' the letters for 1 second only, change the prism power when the left eye is occluded, ask the patient to keep the letter to the right clear (this is the letter viewed through the dissociating prism) and use a bracketing technique to determine the required prism. Use an initial step size of 2^{Δ} , then subsequent step sizes of 1^{Δ} and finally 0.5^{Δ} as you approach alignment. Accuracy is especially important for the vertical phoria measurement as small phorias frequently give rise to symptoms.

Near lateral and vertical phorias

These can be similarly measured. The near point card should be attached to the near point rod in good illumination. The near card is traditionally set at 40 cm, but could be set at the patient's typical near working distance if this differs considerably from 40 cm. The target should be a column/row or small block of letters that are approximately one line larger than the near acuity in the poorer eye. In patients with normal visual acuity, this is usually about 0.5 M or 20/30 equivalent Snellen. The measurement technique is otherwise exactly the same as for distance heterophoria measurement with the von Graefe technique.

6.4.8 Recording

1. The technique used to measure heterophoria should be included.
2. Record 'ortho H and V' (i.e. orthophoria) if there is no horizontal or vertical phoria. Another way to record orthophoria is to use the symbol Φ to record that there is no horizontal phoria, Θ to record that there is no vertical phoria or Φ to signal that there is no horizontal or vertical phoria.
3. Record the amount of deviation in prism dioptres ($^{\Delta}$) and the direction of the phoria, e.g., 3^{Δ} SOP, 5^{Δ} XOP. Vertical phorias can be recorded in a variety of ways, such as: $2^{\Delta R/L}$ (or 2^{Δ} R hyper or 2^{Δ} L hypo), $1^{\Delta L/R}$ (or 1^{Δ} L hyper or 1^{Δ} R hypo). Record the test distance corresponding to each heterophoria measurement.
4. Note if any suppression took place during the test, for example if the patient could not simultaneously perceive the line (streak) and spot during Maddox rod or modified-Thorington methods.

- Also record if the result was variable, for example if the arrow in the Maddox wing or Howell card methods is not stable on the tangent scale.

6.4.9 Interpretation

Most people with normal binocular vision have some slight degree of heterophoria. Lyon et al. reported 25th to 75th percentiles for distance and near phorias of 0 to 1^Δ esophoria and 2^Δ exophoria to 1^Δ esophoria, respectively, in a large sample of first-grade children (aged ~5 years).¹⁵ In older children (4th grade, aged ~8 years), distance and near phorias measured with the modified Thorington method were of 0 to 1^Δ esophoria (distance) and 2^Δ exophoria to 2^Δ esophoria (near). Mean distance heterophoria in children and young adults is 1^Δ exophoria $\pm$ 1^Δ and mean near heterophoria is 3^Δ exophoria $\pm$ 3^Δ.¹⁹ In older adults, there is a tendency towards greater amounts of exophoria (physiological exophoria) and up to 6^Δ of exophoria is not uncommon.⁷ In adults and children, only about 0.5^Δ of vertical phoria may be considered normal, and in some patients even this amount can give rise to symptoms. Significant vertical phorias should be checked to make sure they are not due to a head tilt (unseen behind a phoropter) or abnormal head posture or a non-level trial frame or phoropter.

The heterophoria determined using the subjective tests and measured with the optimal refractive correction, should be compared with the corresponding cover test result measured using the patient's spectacles. If there is no significant change in refractive error, the horizontal heterophoria measurements post-refraction should be similar to that found with the cover test. Vertical heterophorias would not be expected to differ pre- versus post-refraction, even if there is a substantial change in refractive correction. If a change in refractive correction has occurred this should lead to a predictable change in the horizontal heterophoria so that if the optimal correction shows an increase in plus/decrease in minus power from the patient's spectacles, then an increase in exophoria or a decrease in esophoria should be expected. Similarly, an increase in minus/decrease in plus power could lead to a decrease in exophoria or increase in esophoria. The amount of change will depend upon the accommodative convergence/accommodation ratio (AC/A ratio, [section 6.12](#)). This can be particularly useful to students as it can help to monitor the accuracy of their cover test results, particularly when estimates of the heterophoria are made, rather than measurements with a prism bar.

6.4.10 Most common errors

- Attempting to determine the presence of heterophoria in a patient with strabismus.
- Failing to distinguish between lens-induced deviations and true heterophorias, particularly with vertical phorias and commonly caused by a head tilt behind the phoropter or the trial frame or phoropter not being level.
- Believing that the results from different heterophoria tests are inter-changeable when research evidence shows that this is often not the case.¹⁴

Modified-Thorington

Not attempting the various procedures that may be necessary to enable the patient to simultaneously perceive the red line and spot. This also applies to the Maddox rod technique.

Maddox wing

- Not allowing the patient sufficient time for the arrow to stop moving with horizontal phoria measurement. Also, not encouraging the patient to keep the arrow-head in sharp focus to help reduce its apparent movement on the scale.
- Mistaking the direction of horizontal heterophoria present because the patient has interpolated between the numbers on the scale. For example, if the arrow is seen to be between the 11 and 13 scale positions (esophoria), the patient may state that 'the arrow is pointing to 12'. You may mistakenly record this result as 12^Δ of exophoria because even numbers are employed on the test for exo deviations. The way to avoid this problem is to initially ask whether the line is seen to the left or right of the zero position. This is also a potential issue with the Howell card method.

von Graefe

- Allowing continual viewing of both letters, which may induce prism (vergence) adaptation.
- Not reminding the patient to keep one of the letters clear.

6.5 FIXATION DISPARITY

During binocular viewing the visual axes are directed at the object of regard so that an image falls on each fovea. However, it is possible to fixate an object without the visual axes intersecting precisely on the object and still have binocular single vision, providing the

misalignment is within Panum's areas. Since Panum's areas are small, fixation disparities represent small (typically less than 10 minutes of arc) misalignments.^{20,21} The advocates of fixation disparity maintain that a fixation disparity arises when the visual system is under stress; indeed the presence of fixation disparity is considered by some to represent that part of the heterophoria that is decompensated.

Unlike in heterophoria assessments (section 6.4), the eyes are only partially dissociated during fixation disparity assessment. Thus, most of the target is seen by both eyes; these elements are known as the binocular locks. A small portion of the target, however, is visible to only one eye; these elements are called the monocular markers and the relative position of these markers indicates whether or not a fixation disparity is present.

Some clinical assessments of fixation disparity do not provide a direct measure of the magnitude of the disparity but rather provide a measure of the amount of prism required to eliminate a fixation disparity. This prism power is called the 'aligning prism'. Fixation disparity measures that are given in prism dioptres are sometimes referred to as the 'associated heterophoria' or 'associated phoria', although these terms are not universally popular.⁷ Similarly, though less commonly practised, the presence of a fixation disparity can be eliminated using spherical lens power placed before both eyes.

6.5.1 Comparison of tests

The assessment of fixation disparity with the Mallett unit is quick and simple and gives the prism or spherical lens power that can be used as the starting point for correction of binocular problems. Jenkins et al. found that 1^Δ and 2^Δ of fixation disparity was associated with symptoms in pre-presbyopes and presbyopes, respectively, and it may be the best indicator that a heterophoria is decompensated.^{22,23} Mallett reported that the aligning prism corresponded to the decompensated portion of the heterophoria, and fixation disparity has also been shown to increase under binocular stress, such as working under inadequate illumination or too close a working distance, and at the end of a working day.^{23,24}

The Saladin and Wesson cards provide a means for establishing the shape of the fixation disparity curve, something that was originally possible only with the Sheedy Disparometer, a device that is no longer commercially available.^{25,26} As opposed to the aligning prism measure (which corresponds to just one point on the fixation disparity curve) provided by the Mallett

unit, the Saladin and Wesson cards provide estimates of fixation disparity when different amounts of prism are introduced and from these measures the key components of fixation disparity curves (e.g. slope in central region, as well as the x- and y-intercepts) can be deduced.^{25,26} The Saladin card is reported to have good test-retest reliability.²⁷

The fixation disparity approach has a number of significant disadvantages. One is that fixation disparity measures seem to be critically dependent on the method used to measure them. For example, results obtained with the Wesson and Saladin cards are not comparable, raising the possibility that the measures indicate more about the equipment than about the visual system they are testing.²⁵ The size and position of the binocular lock and monocular markers appear to exert an influence on the magnitude of the fixation disparity.²⁸ This is a problem given that many computer-based programmes offer different formats of the fixation disparity test. For this and other reasons, many remain unconvinced about the clinical relevance of fixation disparity and view it instead as a physiological phenomenon.²⁹ For example, if fixation disparity does reflect the decompensated portion of the heterophoria, the type of fixation disparity present should always match the direction of heterophoric deviation (e.g. an exo fixation disparity should only be present in a patient with exophoria). However, this is not always the case and it is estimated that one quarter to one third of individuals may have so-called 'paradoxical fixation disparity'.^{30,31} Nevertheless, others place much greater emphasis on its clinical significance and claim that fixation disparities have strong diagnostic significance. There are claims, for example, that the magnitude of fixation disparity is linked to the level of stereopsis that can be achieved by the patient and that the size of the aligning prism at near is inversely correlated with the fusional reserves, supporting the view that both measures may be indicators of decompensation of heterophoria.^{32,33} Proponents of fixation disparity also argue that since the eyes are only minimally dissociated, the conditions of testing mimic those in habitual viewing to a much greater extent than is the case in heterophoria measurement.

In the UK, the Mallett unit is typically used to measure the fixation disparity at distance and near. The distance Mallett unit uses red monocular strips and a central fixation lock (OXO), but does not have a peripheral fusion lock (Figure 6.9). The near Mallett unit uses green monocular strips, as green is usually more sharply focused at near due to a slight lag of accommodation, a central fixation lock (OXO) and a surrounding paragraph of print providing a



Fig. 6.9 A distance Mallett fixation disparity target.

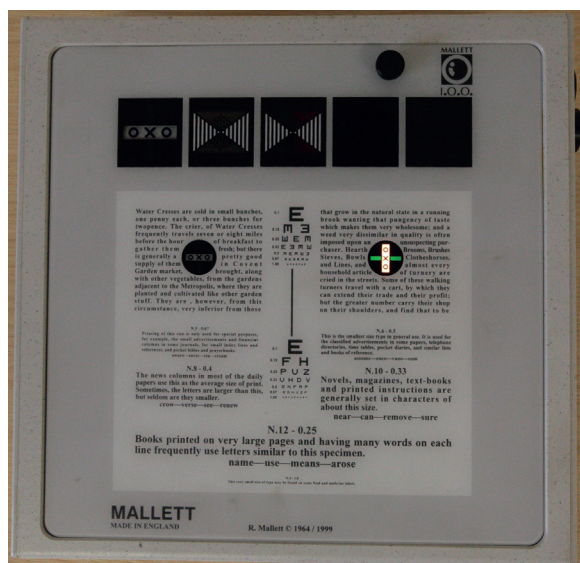


Fig. 6.10 A near Mallett unit.

peripheral fusion lock. The near Mallett unit (Figure 6.10) also contains paragraphs of text of various sizes (typically N5 to N10), a retractable ruler, a near duochrome and targets that allow investigation of stereopsis and suppression.

Like the Mallett unit, the Wesson Fixation Disparity card and the Saladin Near Point Balance card use a polarisation method to render the monocular markers visible to the right or left eye. In the newer Saladin card, a penlight is held behind the card and is used to illuminate each circle. The practitioner asks the patient to identify the circle that contains the vertical lines which appear in horizontal alignment (horizontal fixation disparity) and the circle containing the horizontal

lines which appear in vertical alignment (vertical fixation disparity). In the Wesson chart, the patient sees an arrow with one eye and the lines above it with the other eye; the task is simply to say to which line the arrow points.

6.5.2 Procedure: Mallett unit

1. Explain the test to the patient: 'This is a test that will help to determine whether your symptoms could be due to a problem of your eye muscles not working together properly.'
2. Fixation disparity is usually assessed when the appropriate refractive correction is in place for the viewing distance.

Fixation disparity at distance

3. Orient the OXO in a horizontal position with the red strips vertical. Keep the room lights on to illuminate the unit's surroundings; this provides paramacular and peripheral fusion stimuli.
4. Prior to placing the polaroid visor in front of the patient's eyes, ask the patient to 'Look at the X in the middle of the OXO; do you see two red strips, one above and one below the OXO? Are the two strips exactly in line with each other and in line with the middle of the X?' This ensures that the patient is aware of what alignment looks like (Figure 6.11a), so that any subsequent misalignment is more easily noticed.
5. Place the polaroid visor in front of the patient's eyes and check that the top red

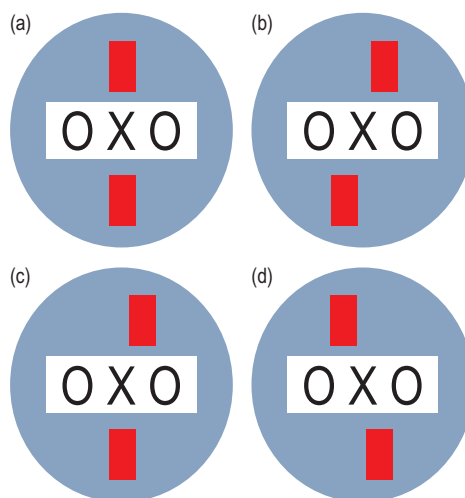


Fig. 6.11 Diagram illustrating the possible patient responses to the Mallett fixation disparity test.

strip is seen by the left eye, and the lower strip by the right eye.

6. Ask the patient 'Can you still see the two red strips?' If only one strip is seen, show the patient the two individual strips by covering each eye in turn. If only one strip is still seen, deep central suppression may be present, and no further measurement is possible. Most patients, however, should see both strips without difficulty.
7. Ask the patient 'Are the strips in line with the middle of the X?'
8. If both of the strips are seen to be aligned with X, no fixation disparity is present (Figure 6.11a).
9. Several results could be reported:
 - (a) If the lower red strip (RE) is to the left of the X and the upper strip (LE) is to the right, an EXO fixation disparity is present in both eyes (Figure 6.11b).
 - (b) If the lower strip (RE) remains below the X but the upper strip (LE) moves to the right, an EXO fixation disparity is present in the left eye only (Figure 6.11c). When the disparity is unilateral, it is usually the non-dominant eye that demonstrates the deviation. Unilateral fixation disparity is most common in vertical imbalance, whereas horizontal fixation disparities are usually bilateral.
 - (c) If an ESO fixation disparity is present, the lower strip (RE) will be to the right of the upper strip (LE) (Figure 6.11d).
10. The fixation disparity should be neutralised using the lowest prism power (or in some cases of esophoria, the weakest spherical lens) that eliminates the fixation disparity. With a unilateral fixation disparity, it is suggested that prism should be added to the eye demonstrating the slip. Note, however, that in the case of a bilateral slip it is not necessary to introduce prism before both eyes when neutralising the disparity. Between changes of prism, instruct the patient to read a few Snellen letters from the distance chart. Remember that the Mallett unit is designed to allow you to determine the minimum power of prism necessary to eliminate the fixation disparity.
11. Rotate the OXO through 90 degrees. The OXO letters now appear in a vertical line with the red strips horizontal. Repeat the assessment. If both a horizontal and vertical fixation disparity exists together, the horizontal fixation disparity should be corrected before the vertical is measured.

Fixation disparity at near

1. The measures obtained using the near Mallett unit are likely to be changed by previous heterophoria measurement, particularly if von Graefe's technique was employed. It is recommended, therefore, that the near Mallett unit should be used before the dissociated heterophoria is measured in patients regarded as having unstable binocular vision, past or present.³⁴
2. For near assessment, the procedure is similar, except that the patient's normal reading spectacles or optimal near correction should be worn in the trial frame. Also, the near centration distance should be adjusted for near.
3. A paragraph of small text must be read prior to any fixation disparity assessment to ensure accurate accommodation on the target.

6.5.3 Procedure: Wesson card

1. The Wesson chart can be used at 40 cm or at 25 cm. Appropriate refractive correction should be worn and the card should be properly illuminated.
2. Wearing the polarising goggles, the patient reports which line the arrow is pointing towards when no prism is introduced and then when 3 BI, 3 BO, 6 BI, 6 BO, etc., in 3 prism dioptre increments up to 24 BI and 24 BO, or up to the prism power where non-transient diplopia is reported. In so far as possible, the prism should be split evenly between the eyes.
3. Because of the risks of prism adaptation it is recommended that the prism should not be in place for more than 15 seconds and that the patient should close their eyes for at least 15 seconds between measurements with successive prism powers.²⁶
4. Note the magnitude of fixation disparity from the card for each prism and plot the fixation disparity curve using the data that are gathered.
5. To obtain vertical fixation disparity measures, the card is turned through 90 degrees. Vertical fixation disparity measures are taken without any prism in place.

6.5.4 Procedure: Saladin card

1. The Saladin chart is used at 40 cm and appropriate refractive correction should be worn to enable the card to be seen clearly at this

distance. The card should be properly illuminated.

2. Wearing the polarising goggles, the patient reports which circle contains the vertically-oriented lines that are in alignment. The physical misalignment of the lines in these circles provides the measure of horizontal fixation disparity.
3. The above procedure is carried out when no prism is introduced and then when 3 BI, 3 BO, 6 BI, 6 BO, etc., in 3 prism dioptre increments up to 24 BI and 24 BO, or up to the prism power where non-transient diplopia is reported. In so far as possible, the prism should be split equally between the eyes.
4. Because of the risks of prism adaptation it is recommended that the prism should not be in place for more than 15 seconds and that the patient should close their eyes for at least 15 seconds between measurements with successive prism power.²⁶ Similarly if the patient fails to achieve fusion with the new prism power within 5 seconds of its introduction, it is suggested that no fixation disparity be recorded for that prism power and that no higher prism power with the same base direction be offered.²⁶
5. Note the magnitude of fixation disparity from the card for each prism and plot the fixation disparity curve using the data that are gathered.
6. Using the circles with horizontally oriented lines, the vertical fixation disparity can be measured. Vertical fixation disparity measures are taken without any prism in place.

6.5.5 Recording

If the monocular markers of the Mallett unit are not simultaneously visible to both eyes, record the eye that was being suppressed and whether the suppression was intermittent or constant.

If a fixation disparity was present, record the lowest amount of prism or spherical lens required to align the strips. If the fixation disparity was found in one eye only, this should be recorded. For example, 'Mallett: No Fixation Disparity (FD) D or N; 'Mallett, Dist: 2^A BI; Near: 1^A BI LE'.

For the Saladin and Wesson cards, the recording consists of each fixation disparity in minutes of arc corresponding to the prism power that was introduced. If one of the targets disappears during measurement, this indicates suppression and the eye that is being suppressed should be recorded.

6.5.6 Interpretation

Most patients will be able to simultaneously perceive the monocular markers on the distance and near Mallett unit, and usually they are aligned without the need for any prisms. It is important to remember that the prism power required to align the markers is not predictable from the magnitude of the fixation disparity (e.g. small fixation disparities are not always eliminated by low prism powers) and two patients exhibiting the same amount of fixation disparity may require very different prism powers to perceive the lines as aligned. Owing to prism adaptation it is advisable to leave the lowest prism power that neutralises the fixation disparity in place for a period of time (several minutes). If a slip re-appears after a period of time when the same prism power had initially neutralised the fixation disparity, you can be much less certain that prescribing this prism will prove beneficial. On the other hand, it is claimed that most patients with abnormal binocular vision which gives rise to symptoms do not adapt, or only partially adapt, to prisms.³⁵ The prism power that neutralises any vertical fixation disparities can be used to prescribe vertical prism.

For the Wesson and Saladin card, the horizontal fixation disparity data gathered are used to plot fixation disparity curves and from these curves four key characteristics are identified; they are the type (I, II, III or IV), the slope, and the x- and y-intercepts. A discussion of fixation disparity curves is beyond the scope of this chapter except to say that most asymptomatic patients have type I curves that feature shallow slopes in the central region, and most show low numerical values for the x- (aligning prism) and y- (fixation disparity in minutes of arc) intercepts. Scheiman and Wick maintain that fixation disparity curve method provides the best means for determining the amount of prism to prescribe.¹⁹

6.5.7 Most common errors

1. Decentration errors due to poorly fitting trial frame/phoropter or badly centred lenses.
2. Mallett:
 - (a) Not starting with the lowest possible prism.
 - (b) Making a decision to prescribe prism before checking whether the patient's visual system will adapt to the prism and thus rendering the prism less useful, or perhaps of no use at all.

3. Wesson/Saladin card:
 - (a) Assuming that the results obtained with these cards are interchangeable.²⁵
 - (b) Leaving the prism in place for too long before measures are taken.
 - (c) Not allowing enough time between the introduction of new prism powers.

6.6 CONVERGENCE ABILITY: NEAR POINT OF CONVERGENCE (NPC) AND JUMP CONVERGENCE

When we wish to view a near target, three processes take place and collectively they are referred to as the near triad of responses. The eyes converge, they accommodate and there is pupillary constriction. The near point of convergence (NPC) is the point where the visual axes intersect under the maximum effort of convergence whilst maintaining binocular single vision. It is a measure of pursuit convergence. Jump convergence, a qualitative assessment of the quality of convergence as fixation jumps from a distant or mid-distant target to a near target, can also be measured.³⁶

Convergence insufficiency is typically described as a syndrome of exophoria that is greater at near than at distance, a remote near point of convergence and poor positive fusional reserves together with the presence of asthenopia.³⁷ Tests of jump convergence are not normally included in the diagnosis of convergence insufficiency, perhaps because it provides qualitative rather than quantitative data. Convergence insufficiency is an important binocular vision problem due to its high prevalence; in population-based studies it has been reported to have a prevalence of up to 8.3%.³⁸ It is also important because there is considerable evidence available to show that it is a treatable condition.^{38–40} It is not appropriate to assess convergence ability in a patient with heterotropia at near; unless the strabismus is of recent-onset they will almost certainly not experience diplopia because of suppression of the strabismic eye. Also, convergence is not tested in these patients because the eyes do not converge to the same point in habitual viewing at near.

6.6.1 Comparison of tests

The near point of convergence is a quick and easy test to perform. It requires no special equipment and it provides a very repeatable result.⁴¹ It is the standard test for convergence ability. The Jump Convergence test has the advantage that it more closely reflects typical near viewing situations where fixation is

continually switching between near targets; it is seldom in the real world that we would encounter a target that moves slowly and predictably towards us along the midline as with the NPC task. Early research suggested poor jump convergence was more closely linked to visual difficulties at near by comparison with a remote NPC.³⁶ The test is relatively easy to perform and can be used as an additional assessment in patients who show signs of convergence insufficiency, and in patients who show a normal NPC but whose symptoms suggest possible convergence difficulties. The disadvantage of the jump convergence test is that it has not been subjected to the same research evaluation as NPC. Consequently there is a lack of normative values for the test and a lack of evidence that the test can discriminate symptomatic from asymptomatic individuals.⁴²

The issue of whether NPC should be measured with an accommodative (e.g. a letter) or a non-accommodative (e.g. spotlight) target has received considerable attention. In presbyopic patients the choice of target does not seem important but in presbyopes there may be a difference in NPCs measured with accommodative and non-accommodative targets.^{42–44} Although such differences may not be substantial in visual normals, Scheiman et al. suggest that individuals with convergence insufficiency show more remote break and recovery NPCs with a penlight compared to when an accommodative target is used.⁴²

6.6.2 Procedure: NPC

See online video 6.11.



1. Seat the patient comfortably with their head erect and eyes in slightly downward gaze. Make sure the patient is wearing their near correction because this relates to the situation in which any symptoms are being noticed. There is also merit in assessing convergence without any correction, although the patient will need to be reminded that it is doubling, not blurring of the near target that is of interest. Sit directly in front of the patient so that you have a clear view of the two eyes.
2. Keep the room lights on. If necessary, position additional lighting to illuminate the patient's eyes and/or the target.
3. Explain the measurement to the patient: 'This test determines how well your eyes can turn in to follow a close object'.
4. Position the target at a distance of 50 cm directly in front of the patient slightly below the midline. A target with fine detail should

be avoided as otherwise patients often confuse blur with diplopia. In adults, the tip of a pen can be used. A medium sized, coloured picture on a fixation stick can be used with children.

5. Instruct the patient: 'Please keep looking at the pen/picture as I move it towards your eyes. Let me know as soon as it becomes doubled – not blurred but doubled. Try really hard to keep it single. Don't worry if you feel your eyes pulling'.
6. Make sure that the patient is looking at the target with both eyes.
7. Slowly but steadily move the target toward the bridge of the patient's nose. The speed should be such that it takes approximately 10 s to move the target from 50 cm to the bridge of the patient's nose. To keep the patients attention, it can be useful to move the target from side to side slightly, particularly at the beginning of the measurement, and check that the patient maintains fixation.
8. Observe the patient's eyes for loss of convergence. Measure the distance the target is from the eyes when one of the eyes loses fixation by flicking outwards (objective NPC) and/or the patient reports diplopia (subjective NPC).
9. If the target becomes doubled (subjective NPC) before it is more than 10 cm from the bridge of the nose encourage the patient to make an extra effort to make the target single again. Moving it away slightly will help this. If single binocular vision can be re-established, advance the target again towards the patient.
10. If a patient exhibits a remote NPC and both eyes appear to be converging to the target, they may be confusing diplopia with blur. Check this by covering one eye and asking the patient if the target is still double. Continue to move the target in until the objective NPC is found.
11. Once the NPC has been reached, slowly move the target away from the patient's eyes and ask when the target becomes single again. Measure this point and record it as the recovery NPC point. Repeat the test. If the patient can keep the target single to their nose, this is recorded as 'to nose' and a recovery point is not measured.
12. If the history indicates that the patient requires prolonged and/or excessive convergence in a specific position of gaze then repeat the procedure in that specific gaze position.
13. If the NPC appears remote (10 cm or above) in a pre-presbyopic patient, repeat the test using

an accommodative target rather than the tip of the pen.

6.6.3 Adaptation for older patients

For older presbyopes the target will typically blur (due to loss of accommodation) before the NPC is reached. Patients often report this blur as 'doubling', so a remote *subjective* NPC cannot be relied upon in older patients. It is better therefore to rely upon the objective NPC. Use of a non-accommodative target (e.g. tip of a pen) is preferred in older patients because blurring may not be as noticeable as with an accommodative target (e.g. letter).

6.6.4 Procedure: Jump convergence

1. Seat the patient comfortably with their head erect and eyes in slightly downward gaze. The patient should wear their refractive correction for distance viewing. Sit directly in front of the patient so that both eyes can be viewed simultaneously, but ensure that distance fixation is not obscured.
2. Keep the room lights on. If necessary, position additional lighting to illuminate the patient's eyes and/or the target thus avoiding shadows.
3. Indicate clearly to the patient both a distant single letter of a size one line larger than the patient's VA of the poorer eye (e.g. if the patient's VAs are 6/4 and 6/9, use a 6/12 letter as a target) and near (fixation rule) target. Position the near target about 20 cm in front of the patient. In another version of the test, the patient may be asked to switch fixation between a target at, say, 60 cm and another at, say, 30 cm.
4. Ask the patient to alternate fixation from the near target to the more distant target and back again.
5. Observe the eyes as they converge and diverge in order to gain an impression of the speed and accuracy in switching between the two target locations.
6. The number of cycles (switching from the first target to the second target and then back to the first) that can be completed in a minute (cycles per minute, cpm) may be counted. Alternatively, comment on the speed and accuracy of eye movements between the near and more distant targets observed over a shorter period of time (e.g. 5 or 6 cycles of change in target being viewed).

Table 6.2 Examples of recordings of the near point of convergence

Abbreviation	Description
NPC: 6 cm/9 cm	A break point of 6 cm and recovery point of 9 cm (normal convergence)
(Obj.) NPC: 5 cm/8 cm	Objective NPC recording of a 5 cm break point and 8 cm recovery point
NPC: to nose	Normal convergence to the nose
NPC: 12 cm/16 cm, RE diverges	Abnormal convergence, with 12 cm break and 16 cm recovery points. The right eye moves out at the break point
NPC: 14 cm/18 cm, LE diverges, suppression?	Abnormal convergence with likely suppression. The break point is 14 cm and the recovery point is 18 cm. The left eye moves out at the break point, but no diplopia is reported

6.6.5 Recording

1. **NPC:** The break and recovery NPC points should be recorded in centimetres from the bridge of the nose. Record the break point first, followed by the recovery point. Examples are given in Table 6.2. If the subjective NPC is much larger than the objective NPC, it is likely that the patient has confused blurring with diplopia and the objective NPC should be recorded. If the patient reports that the target is still seen singly when the eyes are seen to be misaligned, suppression should be suspected and investigated further.
2. **Jump:** Record whether the jump convergence is smooth and fast or whether there are any jerky movements or an inability of one eye to converge adequately to the target. For example:
Jump convergence (80 to 30 cm): jerky, RE slower to converge.
Jump convergence: (D to 30 cm): 20 cpm, smooth and fast.

6.6.6 Interpretation

Normative NPC values show considerable variation between studies. Scheiman et al. suggest a clinical cut-off value of 5 cm for the near-point of convergence break and 7 cm for the near-point of convergence recovery with either an accommodative target or a penlight in children and adults.⁴² Children and adults should certainly be able to converge to within about 7.5 cm and recovery should return within 10.5 cm.³⁷ An NPC larger than these figures suggests possible convergence insufficiency and should be investigated further. This investigation should include jump

convergence, distance and near heterophoria, near fusional reserves and near fixation disparity. Given the reported high prevalence of accommodative insufficiency in children with convergence insufficiency, tests of accommodation should also be conducted in these patients.³⁷ The effect of any new refractive error or refractive change on these measurements should be assessed.

Instead of a failure of one eye to converge it is possible that diplopia will be reported and/or that both eyes are seen to no longer view the target because of over-convergence. This is rarely encountered but when it does arise it suggests that the patient may have an abnormally high AC/A ratio (section 6.12). This should be recorded and additional investigations should be carried out. Good, fast, smooth jump convergence should be observed to 10–15 cm.

6.6.7 Most common errors (NPC)

1. Relying upon *subjective* NPC measures. Objective estimates should also be gained from careful observation of the eyes as they converge.
2. Carrying out the test once only; the test should be carried out at least twice to gain an impression of sustained and repeated convergence ability.
3. Moving the target too rapidly can lead to over-estimation of convergence ability. Moving the target too slowly could cause the patient to lose interest. This is particularly true in children.
4. Not encouraging the patient enough to keep the NPC target single (particularly children).
5. Testing the eyes in upward or primary gaze instead of slight downward gaze.

6. Carrying out the tests in patients who have a heterotropia at near.

6.7 FUSIONAL RESERVES

There are several names attached to tests that involve determining the prism power that leads to a breakdown in fusion and the perception of diplopia. The names in common use include Fusional Reserves, Fusional Amplitudes, Fusional Vergences, Prism Fusion Range, Vergence Amplitudes and Prism Vergences! The term 'fusional reserves' will be used here as it provides a clear indication of the clinical information provided by the measurement.

6.7.1 Fusional reserves

The measurement of fusional reserves is an important clinical test in the assessment of binocular vision status. Heterophorias are latent deviations that are corrected by the sensory fusion reflex. It is useful to know what proportion of the fusional reserves are required to correct the heterophoria.⁴⁵ It is thought that between one-third and two-thirds of the fusional reserves may be used without placing the system under undue stress. Positive and negative fusional reserves can be measured at distance and near by placing appropriate prisms before the eyes. Prism is introduced before the eyes until fusion breaks down and diplopia results.⁴⁶ Placing base-out prism before the eyes stimulates convergence and the amount required to produce diplopia is called the positive fusional reserve (PFR). Because the eyes are forced to converge, accommodation is stimulated (convergence accommodation) but cannot be maintained at the correct level for the target distance and therefore the target usually blurs before diplopia occurs.⁴⁷

Placing base-in prism before the eyes stimulates divergence and the amount required to produce diplopia is called the negative fusional reserve (NFR). When measuring NFR at near distance, a blur point is usually reported prior to diplopia as accommodation relaxes when the eyes are forced to diverge. However, it is unusual to obtain a blur point when measuring NFR at distance as accommodation is already at a minimum (provided the eyes are emmetropic or appropriate distance correction is worn) and cannot relax beyond this point.

6.7.2 Comparison of techniques

Risley or rotary prisms are an ideal method of changing the amount of prism before the eyes in a smooth

manner and they provide repeatable results in young adults, although the results are reported to be less repeatable in children.^{41,46} Although phoropters typically feature rotary prisms, they have the disadvantage that they do not allow a view of the patient's eyes. Fusional reserve tests in free space, typically using prism bars, more closely mimic natural viewing conditions and are particularly useful with young children as the eyes can be seen and an objective assessment of the fusional reserves can also be obtained. Objective fusional reserve estimates are very important, particularly in individuals in whom subjective estimates are often unreliable (e.g. young children).

6.7.3 Procedure

See online videos 6.16-6.17. NOTE: This description is for the measurement at 6 m. The technique can be applied for near by adjusting the trial frame/phoropter to the near centration distance and locating a fixation target at the appropriate distance.



1. Explain the test to the patient: 'This test measures the range over which your eye muscles can keep objects clear and single.' The patient should wear their distance refractive correction. Keep the room lights on.
2. Position yourself in front of the patient so that you can view the patient's eyes easily without obstructing their view of the target.
3. To ensure accurate fixation and accommodation, isolate a single letter of a size that is equal to or slightly larger than the patient's visual acuity of the poorer eye (alternatively, a small block or a vertical line of letters can be used). For young children, a small, isolated picture may be better for holding their attention.
4. Instruct the patient: 'I would like you to look at the letter * at the other end of the room (or 'the letter * on this stick' for near reserves). I am going to make the picture want to go double and I would like you to try as hard as you can to keep it both clear and single. Please tell me as soon as the letter/target becomes blurred or doubled but remember to try to keep it clear and single for as long as you can even it takes a big effort to achieve this.'

Horizontal fusional reserves

5. Measure horizontal fusional reserves first. You should first measure the fusional reserve that opposes the heterophoria: e.g. if the patient has exophoria, measure the positive fusional reserve first. This is to ensure that an accurate

measurement of the key reserve is obtained, as fusional reserves that are measured subsequently may be modified by vergence adaptation and fatigue.⁴⁸

6. If you are using a phoropter, ask the patient to close their eyes and introduce the Risley prisms (set at zero) in front of both eyes. If you are using a prism bar, position it so that horizontal prism will be introduced from a zero starting point over one eye.
 7. Let us take the example of measuring PFR (measured with base-out prism): Slowly increase the amount of base-out prism at a rate of around $2/3 \Delta$ /second. If you are using a phoropter, increase the prism in both eyes at an equal rate. In this case, remember that the amount of prism being added is the sum of the powers introduced before each eye.
 8. Instruct the patient to report the first perceptible blur. As soon as the blur is reported, stop increasing the base-out prism and instruct the patient to attempt to clear the letter. If the letter can be cleared, continue to slowly increase the base-out prism power until the patient reports a blur that cannot be cleared. This is the sustained *blur point* and it indicates that the prism power has caused the patient's accommodation response to be over-exerted (base-out prism) or under-exerted (base-in prism) for the viewing distance in question. In other words, the error in accommodation response just exceeds the depth-of-focus at the blur point. Make a mental note of the prism amount before the patient's eye(s) at this point. If the patient does not report a blur but instead reports diplopia first, then there is no blur point.
 9. Ask the patient to report when the letter now doubles. Increase the amount of prism until the patient reports sustained double vision. This is the *break point* and it corresponds to the situation where the eyes can no longer make the motor response that is needed to overcome the prism power and the image of the target no longer falls on the fovea of the right and left eyes. Make a mental note of the prism before the eye(s) at this point.
 10. Throughout the procedure watch the patient's eyes carefully. As the base-out prism power is increased, the eye receiving the prism power should be seen to converge to overcome the prism. This is difficult to observe initially when small amounts of base-out prism power are introduced and when the increments in prism power are small. However, when substantial amounts of prism power (e.g. 6^Δ and above) have been introduced, the eye (or both eyes if prism is simultaneously introduced to both eyes) receiving the prism should be seen to converge and when the prism power is further increased, further convergent movements should be observed. Thus you should be on the look out for the objective break-point. When the break point is reached, the eye receiving the base-out prism will be seen to make a swift, large outwards movement (so as to make the visual axes parallel again) or the eye not receiving the base-out prism will make a swift and large outwards movement which leaves the visual axes more parallel.
 11. It is important to note that in some cases the patient will not report diplopia even though the break point has been passed. When questioned, such patients will usually notice that there is another target 'away to the side'. Because the two images are widely separated it can be ignored by the patient. Careful observation of the patient's eyes will alert you to the possibility that this may have happened. For example, despite the presence of large prism power the visual axes of the eyes will look aligned whereas the appropriate response of the visual system in these circumstances is that the eye receiving the prism should have converged (base-out prism) or diverged (base-in) so as to overcome the prism to restore single binocular vision.
 12. Slowly reduce the amount of prism until the patient reports that the two images have moved together again to form a single image. This is the *recovery point*. Make a mental note of the amount of prism in front of the patient's eye(s) and remove the prism bar.
 13. If you are using a phoropter, ask the patient to close their eyes and return the Risley prism power to zero.
 14. Repeat the measurement for the other horizontal fusional reserve (steps 6–12). In the example above base-out prisms were used to measure the PFR, so base-in prisms should now be used to measure the NFR. Remember that with NFR measurement at distance there is usually no blur point.
- Vertical fusional reserves**
15. If you are using a phoropter, ask the patient to close their eyes and introduce a Risley prism in

front of one eye only (e.g., base-up BU RE). If you are using a prism bar, position it so that vertical prism will be introduced from a zero starting point over one eye.

- 16. To measure vertical fusional reserves, slowly increase the amount of prism placed before the eye(s). Note that vertical fusional reserves are considerably less in magnitude than the horizontal reserves and the increase of the prism power should be slower than used for measuring horizontal vergences (at about 0.5–1^Δ/second).
- 17. Measure the break and recovery points for right supravergence (base-up before right eye) and infravergence (base-down before right eye). Vertical fusional reserves do not have a blur point.

6.7.4 Recording

- 1. If there is no blur point, record ‘X’.
- 2. Examples of test results include: e.g. NFR @ 6 m: X/14/10; PFR @ 6 m: 12/18/10; R(OD) infra @ 40 cm: 3/1; R(OD) supra @ 40 cm: 3/1.
- 3. A recovery point that requires prism of the opposite base to that used to initially produce the diplopia (such as a base in prism being needed for recovery from diplopia when using base-out prisms to produce diplopia and measure PFR) is recorded as a minus value. For example, PFR @ 6 m: 3/5/–1 indicates that 1^Δ base in was required to achieve recovery from the diplopia that resulted when 5^Δ base-out had produced diplopia and 3^Δ base-out had produced the first sustained blur.
- 4. If the limit of the prism power is exceeded, record as >40^Δ (or the maximum prism value) provided you are certain that the break-point has not been exceeded and that the patient simply failed to report diplopia.

6.7.5 Interpretation

Fusional reserves can be compared to normal data (Table 6.3) and several tables of comparison have been published in adults and children.^{15,19,49} It is clear from these comparisons that a wide variety of ‘normal’ data has been published over the years. While you should have some awareness of values that can be expected at distance and near for the various measures (base in, out, etc.), it is desirable that each clinician obtain their own impression of the normative values (average and

Table 6.3 Approximate range of normal fusional reserves

	Distance (range, ^Δ)	Near (range, ^Δ)
Positive fusional reserves		
Blur	8–12	16–22
Break	15–22	20–28
Recovery	8–12	16–22
Negative fusional reserves		
Blur	Not applicable	10–16
Break	6–10	16–24
Recovery	4–8	8–14

range) that they can expect using their own equipment and their own technique. The value of fusional reserve measures is greatest when considered not in isolation but when compared to the heterophoria measurements. A patient with an exophoria will use part of their PFR to correct the deviation. The measured PFR therefore represents the amount of fusional vergence in reserve to maintain single binocular vision. Similarly, a patient with esophoria will use part of their NFR to correct the deviation. Knowledge of the heterophoria size and of the magnitude of the opposing fusional reserves can be useful in the assessment of a patient’s binocular status specifically in relation to whether the heterophoria is likely to be giving rise to the patient’s symptoms. The proportion of the total fusional vergence used to correct the phoria can be determined. For example:

Distance phoria	9 ^Δ exophoria
Measured positive fusional reserves (PFR)	18 ^Δ
Total positive fusional reserves	18 ^Δ + 9 ^Δ = 27 ^Δ

Therefore, 1/3 (9^Δ) of the total positive fusional reserves (27^Δ) are used to correct the phoria, which is within normal limits. This approach has been formalised in Sheard’s and Percival’s rules, which are used to compare the fusional reserves with the heterophoria and to indicate whether the phoria is likely to be decompensated now or to decompensate in the future under conditions of stress (e.g. around examination time in the case of students).

Sheard’s rule proposes that the fusional reserve blur point should be at least twice the size of the phoria. Sheard’s criterion works best for exophoric cases so

that the PFR to blur should be at least twice the size of the exophoria in order for it to be compensated.⁵⁰ Sheard's criterion further suggests that the prism required to correct a decompensated exophoria is:

Prism required = $2/3$ exophoria – $1/3$ PFR. Thus, for example if the exophoria is 6^Δ and the PFR is also 6^Δ . Sheard's criterion suggests that a prism of 2^Δ base-in should be prescribed. Percival's rule suggests that a patient should operate in the middle third of their binocular vergence range. Percival's rule should only be used for near phorias as normal distance PFR and NFR are typically very unbalanced and Percival's rule tends to work best for near esophoric cases.⁵⁰ Percival's rule suggests that the PFR and NFR should be balanced and that one should not be more than double the other. Percival's criterion suggests:

Prism required for esophoria = $1/3$ total range – NFR. For example, if the PFR is 11^Δ and the NFR is 4^Δ , the prism required is $15/3 - 4 = 1^\Delta$ BO.

6.7.6 Most common errors

1. Not explaining the test properly to the patient and not pushing the patient to make maximum effort to keep the target clear and single for as long as possible.
2. Not observing the eyes carefully as the prism power is increased so as to gain an objective estimate of the break-point.
3. Increasing the prism power too quickly or too slowly.
4. Carrying out the test in those patients who do not have binocular vision at the test distance. In patients with suppression (e.g. strabismic patients) diplopia will probably never be reported no matter what prism power is introduced.
5. Providing an inappropriate stimulus to accommodation through poor choice of target.

6.7.7 Acceptable alternative technique: 20^Δ base-out test



See online video 6.18.

This technique is suitable for use in those patients who may not be able to co-operate with fusional reserve measurement (e.g. young children). Rather than introduce variable prism power and obtain responses from the patient regarding the blurring or doubling of images, this test relies upon qualitative judgements made by the practitioner in response to the introduction of a high-powered prism. Typically, a 20^Δ base-out is used (though in theory any prism power or

direction can be employed) and the practitioner examines whether the eye behind the prism makes a swift and smooth movement in order to restore the image of the object of regard on the fovea and a swift recovery movement in the opposite direction when the base-out prism is removed. The test is repeated with the prism in front of the other eye. In principle the test is similar to 4 prism base-out test (section 6.13) but it is qualitatively much easier for the practitioner to establish whether the appropriate motor fusion response has taken place following the introduction of this high powered prism. A normal response on this test can allow the practitioner to generalise about the effectiveness of the motor fusion system and thus the ability of the visual system to maintain fusion throughout the day. A normal response on this test may be recorded in the following fashion: ' 20^Δ base-out overcome with either eye, and good recovery'. A positive response on this test (i.e. an appropriate motor fusion response) is a very strong indicator that peripheral fusion exists and thus the 20^Δ base-out test can prove useful in children who are too young to undergo formal sensory testing.⁵¹ Unfortunately the same is not true in reverse, because a negative result on the 20^Δ base-out does not guarantee that peripheral fusion is poor or absent.

6.8 VERGENCE FACILITY: PRISM FLIPPERS

Measures of vergence facility may be useful alongside measures of fusional reserves (section 6.7) in diagnosing binocular vision problems in symptomatic patients in the same way that measures of accommodative facility can provide additional information beyond that provided by measures of accommodative amplitude.⁵² Base-out prism forces the eyes to converge and thus the patient is forced to employ their positive fusional reserves to restore bifoveal fixation following the introduction of base-out prism pair. No change in accommodation is needed, and any accommodation that accompanies the positive fusional effort may blur the target. Similarly, the patient needs to employ their negative fusional reserves without relaxing accommodation to overcome the presence of base-in prism. Different prism powers can be used in prism flippers. For example, 3BI/12BO and 8BI/8BO represent common combinations.¹⁹

6.8.1 Comparison of tests

This test requires little additional equipment and is straightforward to perform. The results of the test may

explain symptoms not readily explained by other tests.⁵² Gall and colleagues reported that the combination of 3^Δ base-in and 12^Δ base-out prism flippers provides good repeatability and the best discrimination between symptomatic and non-symptomatic patients.⁵³ However, normative values have also been published for 8BO/8BI prism flippers.^{49,53}

6.8.2 Procedure



See online video 6.19.

The test can be carried out at any test distance, although it is normally carried out at near. If, however, symptoms are reported at a non-reading test distance, testing should be carried out at that distance. The patient should view a single isolated letter/target or a vertical line of letters; the letter/target should be ~1 line bigger than the smallest letters that can be read at the test distance. The patient should wear the habitual near correction for the test. You should sit down during the test so that you can observe the patient's eyes as the prisms are flipped.⁵⁴

1. Instruct the patient as follows: 'I am now going to test how well your eyes can maintain clear and single vision when I introduce some lenses'.
2. First demonstrate the task required of the patient by introducing the prisms and asking the patient to appreciate that it can take some time for the letters to become clear and single after the introduction of the prism flippers. Remind the patient that they will be required to let you know as soon as the letters are clear and single, and also that they should attempt to make them clear and single as quickly as possible.
3. Once the patient has understood the test, start a watch and introduce the 12^Δ base-out prism power. When the patient reports 'clear', flip the handle to introduce the 3^Δ base-in prism power. When the patient again reports 'clear' this represents one cycle.
4. Observing the patient's eyes as the prisms are introduced provides very useful objective confirmation that the patient understands what is required in the test, that they are complying with your instructions and therefore that the result is valid. When base-out prism power is introduced, expect to see the eyes converge and when the prisms are flipped to provide base in power the eyes should be seen to diverge. The ease with which this pattern of eye movements can be seen naturally depends on the prism powers but except in the case of very low

powers (e.g. 2BI/2BO), careful observation should reveal the expected pattern if the test is proceeding properly.

5. As the eyes are being observed, count the number of cycles achieved by the patient in a 60 second period.

6.8.3 Results

Record the number of cycles achieved in the following format:

Vergence facility at 40 cm: 10 cycles/minute (12BO/3BI).

6.8.4 Interpretation

Normal values for this test (using 12 BO/3BI) are in the region of 15 cycles/minute.¹⁹

6.8.5 Most common errors

1. Using an inappropriately sized target for the test (e.g. letters that are too large) or using a target that is surrounded horizontally by other targets so that appreciation of diplopia is made difficult for the patient.
2. Counting the recovery from each prism introduction as a cycle and thus over-estimating the test performance by a factor of two.
3. Not observing the eyes closely during the test and therefore failing to check that the eyes move in the expected fashion when base-in and base-out prism powers are added.
4. Not recording the power of prisms in the flippers used to test the vergence facility and/or the test distance.

6.9 AMPLITUDE OF ACCOMMODATION

Accommodation or focusing allows targets to be made clear over a large range of distances. The amplitude of accommodation measures the full range of accommodation: from the far point, where accommodation is fully relaxed, to the near point, with maximum accommodation exerted. If the far point is at infinity (as in the case of emmetropes and those wearing optimal refractive correction for distance vision), then measurement of the near point allows the amplitude of accommodation to be determined with ease. The amplitude is calculated simply by taking the inverse of the near point of accommodation, which is expressed

in metres. For example, if the near point was 10 cm, the amplitude of accommodation is $1/0.10 = 10\text{D}$. The amplitude of accommodation gradually falls with age, and causes patients over the age of about 45 years to have difficulty with near work and require reading glasses. Measurement of the amplitude of accommodation can help to identify the appropriate reading add required to alleviate the patient's near visual problems (section 4.14). The amplitude of accommodation becomes zero at age 55–60.⁵⁵ If you obtain a measure for amplitude of accommodation in patients over 60 years of age, you are measuring their depth of focus and not accommodative amplitude.

6.9.1 Comparison of tests

There are a variety of ways in which the amplitude of accommodation can be measured.^{56,57} One is to bring a target closer and closer to the patient's eyes until it first blurs; this is called the push-up amplitude. Another is to start with the target directly in front of the eyes and move it away until it first becomes clear; this is the pull-away method. Some practitioners take an average of the push-up and pull-away values as the amplitude of accommodation because it provides a useful compromise between the slight overestimate of the push-up technique and the slight underestimate of the pull-away technique.⁵⁸ However, the subjective element that is a feature of push-up methods (where the patient reports first sustained blur) is best avoided altogether because of differences between patients in their understanding of 'blur' or in their interpretation of these instructions and because the letters get progressively bigger in angular size (and thus easier to see) as they are moved closer to the eyes.⁵⁹ The technique advocated here is the pull-away method. The advantage of the pull-away method is that the patient responds by naming the letter/target as soon as they can identify it rather than when they first notice the subjective impression of blur (as in the push-up method). In the pull-away method, you hold the fixation stick and place your thumb beneath an isolated 20/30 letter (or use an RAF rule, [Figure 6.12](#); or an appropriately sized picture target in the case of young children). The patient should not know the identity of the target/letter before the test starts. There is a modification to the pull-away method which involves inserting a -4 D lens before the eye before the test is carried out. This modification has some advantages and is described below in [section 6.9.6](#).

Another alternative involves using increasing amounts of minus spherical lens power until distance

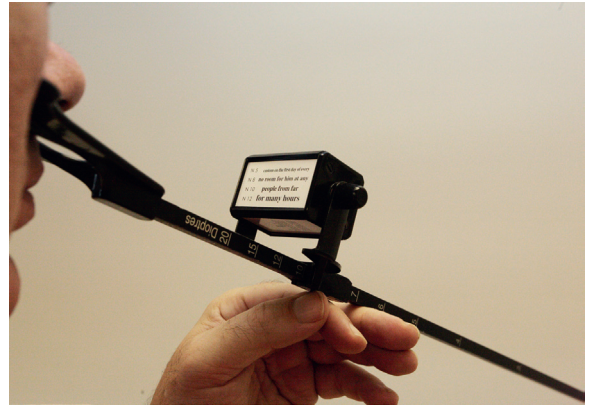


Fig. 6.12 A Royal Air Force (RAF) rule being used to measure amplitude of accommodation. It can also be used to measure the near point of convergence.

vision blurs ('Sheard's technique'). This method typically provides lower estimates of amplitude of accommodation than those provided by the push-up method and it can only be satisfactorily measured using a phoropter.⁶⁰ In addition, the minus lens method provides a less clinically relevant measure than the push-up or pull-away techniques, which provide direct measurements of the near point of clear vision.⁵⁹

6.9.2 Procedure: Pull-away amplitude of accommodation

1. Explain the test to the patient: 'I am going to measure the focusing power of your eyes.'
2. The test is usually performed with the patient wearing their optimal distance correction, but can be performed with the patient's spectacles as a screening test. If the test is to be performed on older presbyopes they should wear a partial addition ($\sim +1.00$ for 45–55 years) to ensure they can see the stimulus at the end of the near point rule. You should sit directly in front of the patient to allow a simultaneous, unobstructed view of the two eyes. In young children with very high amplitudes, slight linear differences of the near point produce large dioptric differences, and it is useful to add a -3.00 D lens to place the near point further from the spectacle plane. This also ensures that depth-of-focus errors are minimised.⁵⁹
3. Direct additional lighting over the patient's shoulder to illuminate the reading card without shadows.

4. The test is usually performed monocularly (right and left) followed by a binocular measure of accommodation amplitude. The procedure is common for all viewing conditions. For monocular measures occlude one eye.
5. Instructions: 'In a moment I am going to ask you to close your eyes. When you open them there will be a letter/target right in front of your eye(s). At the start it will be too close for you to name but I will start to move it away from your eye. It is very important that you tell me what the letter/target is as soon as you can see it'.
6. With the patient's eyes closed, place the fixation stick so that it is almost touching the eyelid (monocular measures) or tip of the nose (binocular measures). When you instruct the patient to open their eyes, begin to move the target slowly away from the patient. Remind the patient to tell you as soon as they know what the letter/target is. In the case of children this can take the form of a game to try to optimise compliance and engagement.
7. When the patient correctly identifies the target/letter, stop the movement and measure the distance to the spectacle plane and convert this distance to dioptres by taking the inverse of the distance (in metres). For example, if the target was first identified correctly at 10 cm, the amplitude of accommodation as assessed using this method is 10 D (i.e. $1 \div 0.1$ m).
8. Add the effect of any additional lenses to the measured dioptric near point to obtain the true amplitude. For example, if a +1.00 DS lens was added and the measured amplitude was 4.50 D, the actual amplitude of accommodation is 3.50 D as the additional lens provided 1.00 D. If a -3.00 DS lens was added and the measure indicates an amplitude of 7.50 D, the true amplitude is 10.50 D. Repeat at least once, or twice if the values obtained from the first and second tests are significantly different from each other (e.g. ≥ 1.5 D difference) or from what would be expected on the basis of the patient's age. In young adults, differences of less than 1.50 D between recorded and age-matched values, or between recordings on two separate occasions, are not usually clinically significant.⁵⁶
9. Repeat for the left eye.
10. Repeat binocularly.

6.9.3 Recording

Record the number of dioptres of accommodation for each eye. Examples:

Amp. of Accom. (pull-away) R(OD) 8.50 D, L(OS) 8.50 D, BE(OU) 10.00 D.

6.9.4 Interpretation

Pull-away values tend to be lower than push-up values for the amplitude of accommodation. Normal values of monocular spectacle accommodation are shown in Table 6.4. If the measured amplitude is significantly (>1.50 D) lower than the age-matched normal values the patient may have accommodative insufficiency.⁵⁶ Binocular values of amplitude of accommodation are usually a little higher (1–2 D) than the monocular values as the convergence response helps to induce additional accommodation (convergence accommodation).⁶¹ If amplitude of accommodation is reduced to a level below 5.00 D in a patient aged over 40 years wearing optimal distance correction but who has difficulty reading, the patient is presbyopic. In children aged 4 to 11 years, Adler et al. found large

Table 6.4 Monocular expected accommodation levels as a function of age

Age (years)	Accommodation (D)		
	Donders	Duane	Sheard
10	14.00	11.00	–
15	12.00	10.50	11.00
20	10.00	9.50	9.00
25	8.50	8.50	7.50
30	7.00	7.50	6.50
35	5.50	6.50	5.00
40	4.50	5.50	3.75
45	3.50	3.50	–
50	2.50	–	–
55	1.75	–	–
<i>Duane–Hoffstetter formula for probable amplitude of accommodation:</i> <i>Maximum amplitude = $25.0 - 0.40 \times \text{age}$.</i> <i>Average amplitude = $18.5 - 0.30 \times \text{age}$.</i> <i>Minimum amplitude = $15.0 - 0.25 \times \text{age}$.</i>			

intra-individual variation in measures of amplitude of accommodation and suggested that, in this age-group, the test may prove useful mainly as a pass/fail check for substantially reduced accommodative amplitude of less than 8 D.⁶¹

Anomalies of accommodation may be associated with a wide variety of conditions including various systemic and ocular medication (probably the most common cause), trauma, inflammatory disease, metabolic disorders such as diabetes and other systemic diseases.⁵⁸ Reduced amplitudes of accommodation have also been reported in children with Down's syndrome and cerebral palsy.^{62,63} Wick and Hall found that a battery of tests (amplitude, lead/lag of accommodation, accommodative facility and a cycloplegic refraction) was required to detect accommodative dysfunction, and that just because a patient had an adequate amplitude of accommodation did not mean that accommodative function was normal.⁶⁴

6.9.5 Most common errors

1. Not stressing to the patient to report the identity of the letter/target as soon as it becomes known.
2. Carrying out the test without optimal distance correction in place. This will have the effect of overestimating the amplitude in myopes and underestimating the accommodative amplitude in hyperopic individuals.
3. Moving the fixation stick away too slowly or too quickly from the patient. The latter will lead to an underestimation of the accommodative amplitude while the former is less of an issue.

6.9.6 Acceptable alternative technique: Modified pull-away method

This is carried out precisely as described above except that a -4 D lens (or pair of -4 D lenses in binocular measurements) is placed in front of the eye before the test is started.⁵⁷ This has the effect of moving the point at which the letter/target is identified away from the eyes. Measurements are more repeatable because of the non-linear relationship between the distance (metres) and dioptric scales. Once the distance has been converted to dioptres, 4 D is then added to obtain the final result.

6.10 ACCOMMODATIVE FACILITY

Accommodative facility is the ability of a patient to rapidly change accommodation. A reduced

accommodative facility has been shown to be related to symptoms experienced in near viewing and it may exist even when other accommodative measures, such as the amplitude of accommodation, are at normal levels.⁶⁴ There is growing evidence from clinical studies that the responsiveness of accommodation is amenable to treatment and evidence of objectively-measured improvement in accommodation responsiveness following training is also beginning to emerge from laboratory studies.⁶⁵⁻⁶⁷

6.10.1 Comparison of techniques

The ± 2.00 DS flippers test of accommodative facility can be performed rapidly with minimal additional equipment. Measures of accommodative facility may be useful in diagnosing binocular vision problems in symptomatic patients whose phorias and visual acuity are normal.⁵² It appears to have diagnostic value in that a reduced facility correlates with near symptoms and facility increases as symptoms are alleviated through treatment. Indeed, flippers can be part of the treatment. There is little justification for the use of the ± 2.00 DS flippers other than they are the power traditionally used. Indeed, it may be that what is required is a range of flipper powers that relate to the patient's amplitude of accommodation.⁶⁸ For example, for a young patient with an amplitude of 12.00 D, the ± 2.00 DS represent only a 33% range of the amplitude, whereas they represent a 67% range of the amplitude in an older patient with an amplitude of 6.00 D. Yothers et al. suggest using an amplitude-scaled test for adults, which uses a test distance that requires 45% of the amplitude of accommodation to be exerted and a lens flipper range that is 30% of the amplitude.⁶⁹ For example, a patient with 7.00 D of accommodation would indicate the use of an approximate working distance of 32 cm (1/3.15, i.e. 45% of 7.00) and a flipper range of 2.10 (30% of 7.00) giving a flipper power of ± 1.00 D.

Many authors recommend measuring the binocular accommodative facility with a suppression check (typically using polaroid glasses with the Bernell No. 9 vectogram). For appropriate comparison, the monocular measurements should be made with the same set-up except that one eye is now fully occluded. Alternatively, accommodative facility can be measured using standard near charts with binocular facility measured only if other tests indicate that the patient does not suppress at near. In this case, the clinical 'pass' values obtained using the polaroid system cannot be used for comparison. Some authors just test binocularly first and only measure monocular facility if the

binocular results are reduced. If the binocular facility is reduced, but monocular facility values are within normal limits, then this suggests a dysfunction of the vergence system rather than of accommodation.

6.10.2 Procedure



See online video 6.20.

1. If testing monocularly, occlude one eye. Keep the room lights on and, if necessary, use localised lighting so that the patient's eyes can be easily seen without shadows.
2. Explain the measurement to the patient: 'I am now going to test how quickly your focusing can change.'
3. Ask the patient to hold a near chart at 40 cm. Maintaining a stable viewing distance is crucial because viewing distance affects the results obtained and because published normative data are generally based upon a 40 cm test distance.^{19,70} Ask the patient to look at a letter on a line that is one line bigger than the binocular near visual acuity. This would typically be about N6 (0.4 M, 20/30).
4. Explain the test to the patient: 'I want you to keep looking at the word/letter *. I am going to place a lens in front of your eye that may make the word appear blurred. I want you to focus and make the print clear again as soon as you can. As soon as it becomes clear, say 'clear'. I will then flip another lens in front of the eye that may make the word appear blurred again. As before, I want you to refocus quickly and make the word clear again, and then say 'clear'. We will repeat this for 60 seconds.' Demonstrate the procedure to the patient so that they understand what is required before the test is started.
5. Start a watch as soon as you place the +2.00 D lens in the lens flippers (twirls) in front of the patient's right eye and ask the patient to tell you as soon as they get it clear by saying 'clear'.
6. As soon as the patient reports that the word is clear, quickly flip the lens flippers to the -2.00 lens and ask the patient to inform you as soon as the letters become clear again.
7. Count the number of times the patient utters 'clear' in 60 seconds. One cycle consists of clearing both the plus and the minus lenses.
8. Repeat for the left eye.
9. Repeat the test binocularly if the patient does not suppress at near. Some practitioners use a

polaroid bar reader placed over the near chart while the patient wears polaroid glasses. This provides a check on suppression because the patient will only be able to see half of the text if suppression is present.

6.10.3 Recording

Record the number of cycles/minute for each eye and then for the binocular viewing condition; e.g. 'accomm. facility: 10 cycles/min. binocularly (+2 D/-2 D)'

One cycle consists of clearing both the plus and the minus lenses. Record the lens powers that were used to measure accommodative facility because facility may need to be measured with lower lens powers (e.g. +1 D/-1 D) if the patient is a presbyopic adult or if +2 D/-2 D lenses can't be cleared by the patient. If the patient can't clear one of the two lenses, the recording should note this. For example, 'accomm. facility: 5 cycles/min, fast initially, failed to clear +lens power after 30 secs)'.

6.10.4 Interpretation

The normative data reported in the literature are variable, possibly because data were gathered across a range of ages but reported as a grand average or because they were collected from unselected samples (e.g. samples may have included patients with symptoms and accommodative or vergence dysfunctions). For these reasons, published normative data cannot be completely relied upon and you are encouraged to have an impression of normative data for a range of age groups based upon your own measurements.⁶⁸ Suggested 'clinical pass' criteria in young adults are 11 cycles/minute (monocular). The task becomes more difficult with the polaroid system, so that a clinical pass binocularly is 8 cycles/minute.⁷¹ For children aged between 8 and 12 years, 'clinical pass' criteria are 7 cycles/minute (monocular) and 5 cycles/minute (binocular polaroids).⁷² A major disadvantage of the accommodative facility test is that there is no objective information available to you. In other words from observing the eyes, it is not possible for you to ensure that the patient understands and is complying with the test requirements. This is because changes in accommodation do not produce a change in the appearance of the eyes in the way that changes in vergence (e.g. during vergence facility test with prism flippers) do. You are therefore forced to rely exclusively on the subjective impressions of the patient during this test.

6.10.5 Most common errors

1. Holding the flippers so that the patient cannot see the target.
2. Not allowing the patient to practice before starting the test or not explaining in sufficient detail to the patient as to what is expected.
3. Not turning the flippers fast enough so that the cycles/minute result reflects the hand-speed of the examiner instead of a measure of accommodative facility.
4. Not recording an abnormal test result in sufficient detail; e.g. not indicating whether it was negative or positive lens powers (or both) that the patient struggled to clear.
5. Not recording the powers of the lens flippers and/or the testing distance.
6. Overestimating the facility by a factor of two because each 'clear' was counted as a cycle.

6.11 ACCOMMODATION ACCURACY

Accommodation accuracy measurements are valued because they indicate the behaviour of the patient's accommodation system when an actual near task is being carried out. Accommodative lag and lead indicate whether a patient's accommodation level to a target is less (lag) or more (lead) than expected. These measures provide information about the patient's accommodation that may be more directly applicable than that provided by amplitude (section 6.9) or facility (section 6.10) measures.

6.11.1 Comparison of tests

Accommodative lag and lead can be measured objectively using various dynamic retinoscopy techniques or subjectively using relative accommodation measurements or the binocular crossed-cylinder method. The latter two subjective measurements are more often used in the assessment of accommodation to help determine the tentative reading addition and are discussed elsewhere (section 4.14). Dynamic retinoscopy offers a quick, repeatable and valid means for establishing the accuracy of the patient's accommodation system and it requires minimal extra equipment.⁷³ Both dynamic retinoscopy tests provide results that are less variable than the crossed-cylinder or near duochrome techniques.⁷⁴ As with most clinical techniques, practice is required in order to develop proficiency in carrying out the tests, especially in relation to the short time in which to make retinoscopy judgements. One study has suggested that the Nott technique provides

more accurate estimates of the accommodative response as it does not require the introduction of supplementary lenses.⁷⁴

6.11.2 Procedure: Nott dynamic retinoscopy

1. The patient should wear their optimal distance refractive correction in the trial frame, or their existing spectacles if lens powers are not significantly different from the optimal refraction result. The phoropter should not be used for this test because of the risk of inducing proximal accommodation.
2. Explain the test to the patient: 'I am going to check the focusing ability of your eyes using this torch that will shine a light into your eye.'
3. The test should be carried out in conditions that approximate, in so far as possible, normal reading conditions and the card to be viewed by the patient needs to be located close to the patient's typical reading distance (e.g. 30 cm). The card should contain letters (or pictures for young children) in a position that permits you to perform retinoscopy close to the patient's visual axis (Figure 6.13). A near chart with a central aperture works well. If letters are being used they should be bigger (by one line) than the binocular near visual acuity (typically N6, 0.5 M, 20/30).

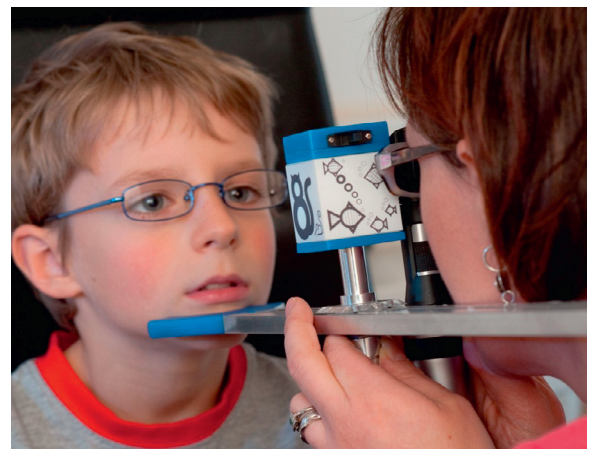


Fig. 6.13 The Ulster-Cardiff Accommodation Cube enables distances to be accurately measured during dynamic retinoscopy. Photograph courtesy of Dr. KJ Saunders, University of Ulster.

4. The room lights can be left on and use additional lighting if necessary to ensure that the near chart is well illuminated.
5. Ask the patient to focus on the letters/targets.
6. Perform retinoscopy on the right eye from 40 cm (typically 10 cm behind the near point card) along the horizontal meridian (with the streak vertical). Perform retinoscopy as quickly as possible as the retinoscope light will interfere with binocularity.
7. If neutrality is not observed at 40 cm, change the working distance (further away if 'with' movements are seen at 40 cm, and closer if 'against' movements are seen) until the neutral point is seen. Note the distance of your retinoscope when the neutral point is obtained. To establish the result you need to know the distance at which the target was presented and the distance from the patient's eyes at which the retinoscope was positioned when reversal was observed. To help to measure these two distances, a convenient new measurement scale and target has been developed and validated (Figure 6.13).^{73,75}
8. Repeat the procedure on the left eye.

6.11.3 Procedure: MEM dynamic retinoscopy

1. Attach a MEM card or hold a fixation stick to the front of your retinoscope. The card should contain letters or pictures around a central aperture, through which retinoscopy is performed.
2. The room lights can be left on and use additional lighting if necessary to ensure that the near chart is well illuminated.
3. Ask the patient to focus on the letters/targets. To maintain appropriate fixation and accommodation, you may need to ask children to read some of the letters out aloud or to name details in the picture.
4. Perform retinoscopy on the right eye from the patient's typical working distance (usually around 30 cm) along the horizontal meridian (with the streak vertical). Retinoscopy should be performed in the usual manner, but the lenses should only be placed in front of the patient's eyes for the least amount of time possible. This is to maintain binocularity, which is interrupted by the retinoscope's light. Try to ensure that the accommodative system does not change in response to any added lenses. To ensure the latter does not occur, you need to place the

lens in front of the eye for 0.50 seconds or less.

5. Record the dioptric power of the lens that provides neutrality.
6. Repeat the procedure on the left eye.

6.11.4 Recording

For the Nott technique, record the dioptric difference between the near chart and the position of the retinoscope when neutrality is observed. If the neutrality point is behind the near chart position, then there is a lag of accommodation. If the neutrality point is in front of the near chart position, then there is accommodative lead. For example, if the near chart is at 40cm and neutrality is observed at 57cm, then the accommodative lag is $+2.50\text{ D} - 1.75\text{ D} = +0.75\text{ D}$. It is useful to learn corresponding distances and dioptric values, such as 80 cm (1.25 D), 67 cm (1.50 D), 57 cm (1.75 D), 50 cm (2.00 D), 44 cm (2.25 D) and 40 cm (2.50 D).

For the MEM technique, record the dioptric value of the lens that produces neutrality. Positive lenses indicate a lag of accommodation and negative lenses indicate a lead of accommodation).

6.11.5 Interpretation

Typically the accommodative response to a target is slightly less than the accommodative stimulus. For example, a target positioned at 40 cm provides an accommodative stimulus of 2.50 D, but the normal accommodative response is slightly less, at about 2.00 D. The target remains clear due to depth of focus. Accommodative lags of 1.00 D or greater could be due to uncorrected (or insufficiently corrected) presbyopia and/or hyperopia or it can indicate a lack of accommodative amplitude or reduced accommodative facility in a pre-presbyopic patient. The lack of an accommodative lag or an accommodative lead can indicate pseudomyopia or accommodative spasm. It has been claimed that the MEM technique provides lags which are on average twice those found using the Nott method but most studies find results that are similar.^{58,76} In children with low- to moderate hyperopia for whom it is not clear whether they would benefit from refractive correction, there is a growing belief that assessment of accommodative accuracy using dynamic retinoscopy offers a means of identifying those who are likely to benefit from spectacle correction.⁷⁷ Specifically those with a large lag of accommodation are predicted to benefit more than those with smaller lags.

6.11.6 Most common errors

1. Not realising that a small of accommodation is normal.
2. Taking too long to make a judgement as to whether the reflex is moving 'with' or 'against'.
3. Nott method: inaccurate measurement of the distance of the target to the patient and the retinoscope distance from the patient that gives reversal.
4. MEM method: leaving the lens in place for too long. This lens can alter the accommodation of the eye.

6.12 ACCOMMODATIVE CONVERGENCE/ACCOMMODATION (AC/A) RATIO

The coupling of accommodation and vergence allows clear stable single binocular vision across a range of viewing distances. A change in accommodation (A) is usually accompanied by a change in vergence known as accommodative convergence (AC). When accommodation is exerted the eyes are induced to converge. When accommodation is relaxed the eyes diverge. The amount of accommodative convergence in prism dioptres (Δ) evoked by 1 D of accommodation is known as the AC/A ratio. As the actual accommodation response is difficult to measure in clinical practice, it is usual to measure the change in vergence obtained with a fixed change in the stimulus to accommodation. This is formally known as the stimulus AC/A ratio but clinically it is usually just called the 'AC/A ratio'. AC/A ratios that are abnormally high or low can give rise to binocular vision problems.⁷⁸ The AC/A ratio remains fairly constant throughout life until the onset of presbyopia. Measurements of AC/A after the age of 45 years are of little value.⁷⁹

6.12.1 Comparison of tests

The modified gradient test allows a quick and reliable measure of the AC/A ratio using standard clinical equipment. This procedure allows proximal components of the response to be controlled as the test is performed at a fixed distance.⁸⁰ The modified gradient AC/A depends on heterophoria measures at only two points, which can lead to errors.⁸¹ The full gradient test overcomes this problem by measuring heterophorias with additional powers from +3 D to -3 D in 1.00 D steps and plotting a graph of lens power against induced phoria. The gradient of this line gives the

AC/A ratio in Δ /D. The AC/A ratio can also be calculated from the information that is already available during a routine eye examination, specifically by comparing the distance heterophoria and near heterophoria (see [section 6.12.6](#) below). This method has the disadvantage that proximal accommodation is present in one heterophoria measure (near) but not the other (distance). Also, the result is subject to error because only two measures of heterophoria are used in the calculation. Irrespective of the method used, the target viewed by the patient should require controlled accommodation as the ratio obtained has been shown to depend upon the fixation target.⁸²

6.12.2 Procedure: Modified gradient AC/A ratio

1. Ensure the patient is wearing an appropriate refractive correction, either their own spectacles or, preferably, the optimal correction determined during the eye examination.
2. Measure the horizontal near heterophoria using the modified Thorington or Howell card method ([section 6.4](#)) or some other method that carefully controls accommodation.
3. Add -2.00 DS to the refractive correction in both eyes and measure the new horizontal phoria (any pair of minus lenses can be used but -2.00 DS provides a reasonable accommodative stimulus for most patients).
4. The above procedure is normally carried out at near. However it is just as valid to determine the AC/A ratio by comparing the horizontal heterophoria at 6 m when viewing with optimal refractive correction to the heterophoria that exists when the patient looks through a pair of -2 D lenses.

6.12.3 Recording

Use the following formula to calculate the AC/A ratio. Use positive numbers for esophoria and negative numbers for exophoria.

$$\text{AC/A} = \frac{\text{Phoria with additional minus lenses} - \text{Baseline phoria}}{\text{Absolute power of additional minus lenses}}$$

The calculation required to determine the AC/A ratio is the same irrespective of whether the heterophoria measurements were taken during near or distance viewing. For example, if a patient exhibits 6 Δ esophoria during distance viewing when -2.00 D lenses are added to his/her normal refractive correction but 2 Δ

exophoria with the normal refractive correction in place, the AC/A ratio is calculated as:

$$AC/A = 6 - (-2)/2 = 8/2 = 4^A : 1 D$$

6.12.4 Interpretation

Normally the AC/A is $3-5^A/D$. A low AC/A ratio may, depending upon the distance heterophoria, result in convergence insufficiency exophoria. Similarly, a high AC/A ratio may lead to a problem of convergence excess esophoria. Knowledge of the AC/A ratio can be useful when determining plus lens power for the correction of decompensated esophoria. As the amount of convergence induced by 1.00 D stimulus to accommodation is known, it is possible to calculate the extra plus lens power required to reduce the esophoria to an acceptable level.

6.12.5 Most common error

Using a method of heterophoria assessment to determine the AC/A ratio, which is less reliable than other available methods (section 6.4).

6.12.6 Alternative technique: Calculated AC/A

The calculated $AC/A = PD_{cms} + (n - d)/D$, where PD = interpupillary distance measured in cm; n = near phoria; d = distance phoria; D = accommodation. Exophorias are negative and esophorias are positive;

e.g., PD = 6 and D = 2.5 (accommodation required at 40 cm), distance phoria is ortho and near phoria is 5 exo, $AC/A = 6 + (-5/2.5) = 4^A : 1 D$.

Without using the above formula, it is of course possible to get an impression of whether the AC/A ratio is normal or not by comparing the near and distance heterophorias. For example, an exophoria that is much greater at near than at distance will be found in a patient with a low AC/A ratio. Similarly, esophoria that is greater at near than at distance suggests either a high AC/A ratio or significant uncorrected hyperopia. In cases where the near and distance phorias are the same, the formula above indicates that the AC/A ratio is given by the patient's PD (in cm).

6.13 SUPPRESSION TESTS

A properly functioning oculo-motor system is a requirement for binocular vision, but it does not guarantee that binocular vision exists. Suppression testing provides an indication of whether the patient is capable

of fusing the images from the right and left eyes, thus providing the conditions that are necessary if the highest level of binocularity (stereopsis, see section 6.14) is to be achieved. When the retinal images differ in size as in aniseikonia, or in clarity as in uncorrected anisometropia, amblyopia or unilateral eye disease, it is possible that the images from the two eyes are not fused because one eye is suppressed. An inability to appreciate diplopia in some of the motor system assessments, such as the near point of convergence, may already have suggested suppression.

6.13.1 Comparison of tests

The Worth 4-dot test is widely available, relatively cheap, easy to use and can be used to assess fusion or reveal suppression at distance and near. It provides a rather coarse indication of suppression in the sense that other tests may reveal the presence of suppression when the 4-dot test suggests that none is present. This is particularly true for near 4-dot testing because of the relatively large angular size of the lights when viewed at near compared to distance viewing. Conversely, the rivalry produced by the red/green goggles may lead to dissociation even in a patient with useful or normal binocular vision so that the test can suggest the existence of suppression when none is present under habitual viewing conditions. The major disadvantage of the test is that luminance of the red and green targets can vary widely between tests as can the transmission characteristics of the red and green goggles with the result that the test outcome can vary depending on whether the goggles are used in the standard format (red goggle in front of the right eye) or reversed.⁸³ Another disadvantage of the test is that a patient with constant strabismus and abnormal retinal correspondence may achieve a normal result. A positive test result does not therefore guarantee the presence of normal binocular vision.

An advantage of the Bagolini lens test is that it creates minimal dissociation between the eyes and thus allows you to assess binocular status in conditions that very closely resemble the patient's habitual viewing conditions. This is a particular advantage over the Worth 4-dot test which may provide results that do not apply in habitual viewing. Bagolini lenses offer the only method that is likely to be available to practitioners wishing to investigate retinal correspondence. The disadvantages are that, for whatever purpose the Bagolini lenses are used, the test is quite subjective and therefore there is a danger that the patient will be led to give the answer you expect. Also, the method offers a qualitative rather than a

quantitative method for assessing suppression and retinal correspondence.

The 4^A base-out test is used as a test of suppression in the specific case of a suspected microtropia. Indeed, it is used in combination with tests of visual acuity, refraction, eccentric fixation, abnormal retinal correspondence (ARC) and stereopsis to confirm a diagnosis of microtropia. It differs from the Worth 4-dot and Bagolini lens tests in that it is entirely objective; the result does not rely upon a verbal response from the patient but rather is determined by a comparison of the pattern of eye movements that result when the 4^A (base-out) is introduced in front of one eye and then the other. This test thus requires little additional equipment and is quick and straightforward to perform. However, its repeatability is relatively poor and visually normal children can show atypical responses.⁸⁴ Other assessments of suppression are also available on the Mallett unit (section 6.5) and with some stereopsis tests (section 6.14).

6.13.2 Procedure: Worth 4-dot

1. Explain the test to the patient: 'This test checks whether you are using both eyes at the same time to see'.
2. Do not allow the patient to see the 4-dot stimulus before putting the red–green spectacles on. Place the red–green spectacles on the patient (over their spectacles if worn for that particular test distance). Except in cases where the test is presented on a computer screen, the eye with the red filter in front of it (usually the right eye) will see the red dots and the eye with the green filter in front of it (usually the left eye) will see the green dots. When presented on a computer screen, the eye wearing the red filter will see the green dots, and vice versa. You need to be aware which eye is seeing which dots in order to be able to interpret an abnormal test result (see below).
 - (a) For testing at 6 m: Ensure that the patient is wearing their distance spectacles/contact lenses.
 - (b) For testing at 40 cm: Hold the Worth 4-dot torch/flashlight at the patient's reading position, so that the patient looks slightly downward at it. In the case of presbyopic patients, ensure that the patient wears appropriate refractive correction for the near test distance. The torch is usually held with the red light at the top and white light at the bottom (Figure 6.14).
3. Keeping the room lights on, now turn on the Worth 4-dot instrument.
4. Ask the patient: 'How many dots do you see?'
5. There are four possible responses (Figure 6.14).
 - (i) '4 dots seen': This generally indicates that the patient has normal flat fusion and no suppression. The response can be checked by asking 'How many red dots do you see? How many green ones?' Normally, patients will see one red, two green and one yellow dot. The white dot may appear yellow, or alternate between red and green due to retinal rivalry.
 - (ii) '2 dots seen'. These will be the red and white, seen by the patient as two red dots. This indicates suppression of the eye with the green filter in front of it (usually the left). To detect alternating and/or intermittent suppression ask: 'Are the number of dots changing as you look at them?' If the number of dots seen is constant, check to see if fusion can be achieved by briefly occluding the non-suppressed eye.
 - (iii) '3 dots seen'. These will be the two green dots and the white dot, seen by the patient as three green dots. This indicates suppression of the eye with the red filter in front of it (usually the right). To detect alternating and/or intermittent suppression ask: 'Are the number of dots changing as you look at them?' If the number of dots seen is constant, check to see if fusion can be achieved by briefly occluding the non-suppressed eye.

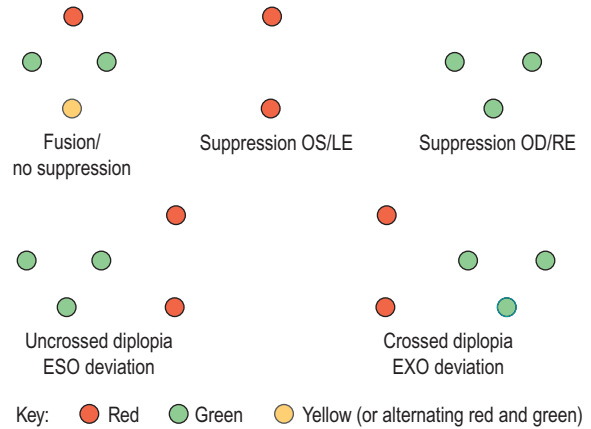


Fig. 6.14 Possible patient responses to the Worth 4-dot test.

- (iv) '5 dots seen': This indicates diplopia. The right eye (usually with the red filter) will see two red dots. The left eye (with the green filter) will see three green dots. Ask the patient to indicate where the red dots are in relation to the green ones. If the red dots (usually seen by the right eye) are to the right of the green dots, this indicates uncrossed diplopia and an eso deviation. If the red dots are to the left of the green dots, this indicates crossed diplopia and an exo deviation. If the red dots are below the green dots, this indicates an R/L deviation. If the red dots are above the green dots, this indicates an L/R deviation.
- 6. If suppression or diplopia is found, repeat the testing with the room lights off.
- 7. If suppression is found at distance but not at near, measure the extent of the suppression scotoma by moving the near target away from the patient and, based upon what they say, deducing when suppression does and does not occur.
- 8. In patients who show suppression, it can be useful to repeat the test with the red–green goggles reversed to ensure an accurate assessment.⁸³

Children who cannot respond verbally can be asked to touch the dots to indicate the number seen, and 'touching four' indicates normal flat fusion. There is some evidence to indicate that although the test will reliably detect suppression in this way, it is unlikely to differentiate between normal fusion and alternating suppression.⁸⁵

6.13.3 Procedure: Bagolini lenses

1. Ensure the patient is wearing appropriate refractive correction. The test is normally conducted with the patient viewing a spotlight in the distance but a hand-held pentorch allows the test to be carried out at closer viewing distances. The room lights should be turned off;

aside from the spotlight or pentorch there should be little or no other lighting.

2. Place one Bagolini lens in front of each eye. The lenses are oriented so that they will generate streaks of light that are mutually perpendicular when a spot of light is viewed. Typically the lenses generate streaks oriented at 45 and 135 degrees.
3. Explain the test to the patient: 'This test assesses how well your eyes are working together as a team'.
4. The patient should be instructed to report on what they see when they have been made aware of the streak of light in each eye. It may be necessary to cover one eye and say to the patient 'When you look at the spot of light, can you see a faint streak of light extending either side of the light?' Once you have established that the patient understands and perceives the streaks you then ask 'What do you see when you look at the spotlight with both eyes open?' (Figure 6.15).
5. To be able to interpret the patient's description of what they see it is necessary to know whether the right eye sees the 45 or 135 degree line. Covering one eye and asking the patient allows this information to be gained very simply and quickly.
6. Bagolini lenses can also be used to assess retinal correspondence and the approach to testing is identical whether the lenses are being used to assess suppression of retinal correspondence. When used as a test for suppression, the patient is asked about the presence and completeness of the lines. When used to investigate retinal correspondence the patient also reports on the relative location of the lines and on the location of their intersection.

6.13.4 Procedure: 4^A base-out (BO) test

1. Seat the patient comfortably. Keep the room lights on and, if necessary, use additional

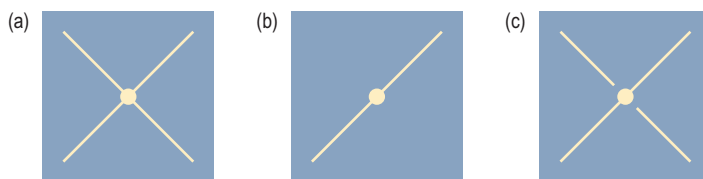


Fig. 6.15 Possible patient responses to the Bagolini lens test. The right eye sees the line oriented at 135 degrees while the left eye sees the line oriented at 45 degrees. (a) No suppression; (b) Right eye suppression; (c) Central suppression of the right eye.

lighting so that the patient's eyes can be easily seen without shadows. The test cannot be performed using a phoropter and a trial frame with the optimal distance refractive correction (or the patient's spectacles) should therefore be used.

2. Explain the measurement to the patient: 'I am going to perform a test to see how if and how your eyes move when I introduce this lens'.
3. Provide a single letter on a featureless background for the patient to view. The letter should be one line larger than the distance VA of the weaker eye.
4. Ask the patient to keep looking at the letter, even if it appears to move.
5. This test is normally carried out in cases of suspected microtropia in which there is an interocular difference in visual acuity. First place the 4^A BO prism over the eye with the better VA (Figure 6.16). The eye should make a swift movement inwards due to the prism. The fellow eye, which is likely to have slightly reduced VA (due to amblyopia and/or eccentric fixation if the patient has microtropia), should make a conjugate, versional movement (i.e. in the same direction as the sound eye) due to Hering's law. You should repeat this several times to confirm your result.
6. Now place the 4^A BO prism over the eye with reduced VA (Figure 6.16). In a microtropia (which is generally of the esotropic type) the 4^A BO prism will merely shift the retinal image within the suppression scotoma of the amblyopic eye. In such cases, neither eye will move. Again, you should repeat this several times to confirm your result. Obtaining the expected pattern of eye movements when the fellow eye views through the prism but the absence of eye movements when the amblyopic eye views is confirmation of an abnormal ('fail') result.

6.13.5 Recording

1. **Worth 4-dot.** Record the normal perception of four dots at 6 m and 40 cm as: 'W 4-dot: 4-dots seen, DV and NV' or similar. If suppression is found, indicate which eye was being suppressed. Indicate whether suppression was found at both distance and/or near in both the light and dark. Indicate whether the condition was intermittent or constant. If diplopia is found, indicate the direction of deviation suggested. Indicate whether diplopia

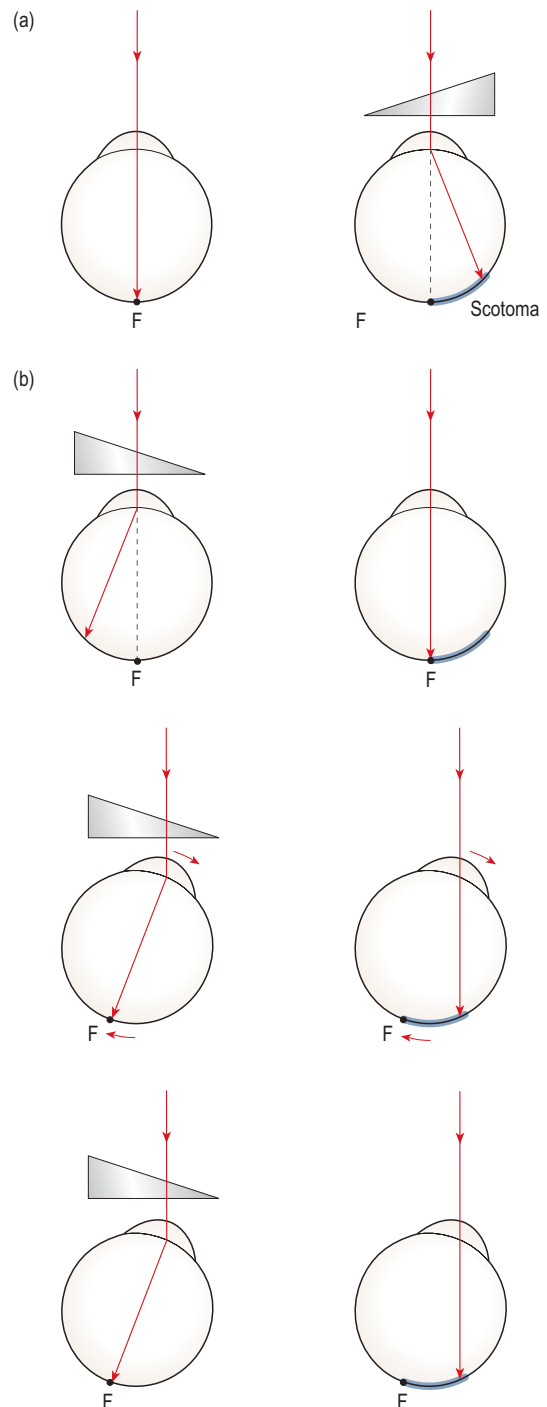


Fig. 6.16 Diagram illustrating the eye movements that should occur during a 4-prism dioptre test when the prism is placed in front of (a) a microtropic eye (there are no eye movements) and (b) the fellow normal eye.

was found at both distance and/or near in the light and/or dark.

2. **Bagolini lenses.** Record what the patient describes in words or using a simple diagram. For example, 'no suppression' or 'RE suppressed centrally' may appear on the patient's record. A cross may also be drawn by yourself or even by the patient if they are struggling to put into words what they saw.
3. **4^A BO test.** Record 'fail' if there is no movement of the weaker eye when the 4^A base-out prism is placed before the weaker eye (note that in this case, the fellow eye will also not move, as described above). This indicates suppression. For example, 4^A BO test: fail LE (OS). Record 'normal' if the expected pattern of eye movements was seen when the 4^A BO prism was introduced before each eye in turn.

6.13.6 Interpretation

If a patient without strabismus sees all four dots on the Worth dot test, this is a normal test result. Note that absence of suppression does not mean that binocularity is necessarily normal. If a patient with strabismus sees four dots with the test, then this indicates that they have abnormal retinal correspondence (ARC). If the response is suppression of the right eye (i.e. the response is "three green dots") or suppression of the left eye (i.e. the response is "two red dots") (Figure 6.14) then there is a suppression scotoma larger than the angular subtense of one of the four dots. The dots on the distance target have a smaller angular subtense than those on the near target. Because suppression is more common for targets imaged in central vision, suppression is therefore found more frequently for distance viewing than for near. The size of the suppression scotoma can be estimated by moving the near target further away from the patient than the standard 40 cm until a response consistent with suppression is noted. The distance that the target is from the patient should be recorded. If the patient achieves fusion in the dark but not in the light, this indicates a shallower level of suppression as compared to the situation where suppression is present in both the dark- and light-room conditions.

If neither eye moves when the 4^A base-out prism is introduced before the eye with reduced VA but the expected pattern of movement is observed when the prism is placed before the fellow eye, this confirms the presence of suppression in the weaker eye. Along with reduced visual acuity, anisometropia, the

presence of eccentric fixation, and degraded but measurable stereopsis, this result on the 4^A BO test confirms a diagnosis of microtropia.

If the patient reports seeing two orthogonal, continuous lines which intersect at the spotlight when using the Bagolini lenses, then there is no suppression. If one line is missing when the spotlight is viewed with both eyes open, one eye is being suppressed. You can establish which eye is being suppressed from the orientation of the line that is seen. Instead of a line being completely absent, part of a line may be missing. Typically, if part of a line is missing, it will be in the vicinity of the spotlight. Thus the patient might, for example, report a continuous line oriented at 45 degrees but a line oriented at 135 degrees which has a gap on either side of the centre (Figure 6.15) but which appears further away from the spotlight. If the 45 degree line should have been generated in the right eye, this report would be interpreted as evidence for central suppression in the right eye. If the left eye is now covered and the patient reports that the vertical line now runs continuously through the spotlight, this is powerful evidence that the right eye is being suppressed by the left eye in habitual viewing.

6.13.7 Most common errors

1. Not performing the tests with the patient's optimal refractive correction in place.
2. Assuming that the absence of suppression confirms the presence of stereopsis.
3. Worth 4-dot: Asking the patient the leading question 'Can you see four dots?'
4. 4^A BO test: (a) Providing a target that is inappropriately sized or crowded by other letters/targets; (b) Making a decision on the test result on the basis of the first introduction of the prism; (c) Not comparing the pattern of eye movements in the two eyes in response to the introduction of the prism.

6.14 STEREOPSIS

The fundamental characteristic of binocular vision in humans is stereoscopic vision. The two eyes receive slightly disparate views of objects due to being separated horizontally by around 6 cm and this disparity can be used to signal the relative depth of objects. There are three main requirements for stereoscopic vision: a large binocular overlap of the visual fields, partial decussation of the afferent visual fibres and co-ordinated conjugate eye movements. Any obstacle to normal visual development early in life

will have consequences for the level of stereoacuity attained. For example, stereoscopic vision is typically not measurable in patients with strabismus and is either poor or absent in patients with amblyopia. Consequently, stereoacuity measures feature prominently in examinations of children in the clinic but stereo-testing has an important role to play in the visual assessment of all age-groups.⁸⁶ There is growing evidence, for example, that stereoacuity levels are linked to the level of fine motor skills.⁸⁷

6.14.1 Comparison of stereopsis tests

The main advantage of the TNO test is that monocular cues are completely eliminated. The patient is required to describe the shape of the raised figure and since this shape is only seen if stereopsis is present there is no possibility of 'cheating'. You can be certain that stereopsis is present if the correct answers are given. The same is not necessarily true for the other tests because monocular cues (e.g. Titmus Fly, Randot Circles test) are present in some of the test stimuli and/or because head tilts or viewing from an oblique angle (e.g. Frisby) can help the patient to achieve a result that is not reflective of the genuine presence of stereopsis. However, with careful attention to following the correct procedure, this drawback should not be critical for the non-TNO stereotests. A drawback of the TNO test is that, like the polaroid based tests discussed later, it may not be possible to perform this test with young children as they may not be happy to wear the red-green goggles; however, there is evidence that children aged from 3 years can perform the test.⁸⁸ Another disadvantage of the TNO is that the transmission

characteristics of the red and green lenses may lead to different contrast levels being experienced by the patient.⁸³ In some patients this can lead to a different test result depending upon which way the goggles are worn (i.e. red before right eye or green before right eye).⁸³

The Stereo Fly test is popular with children, although the Fly can frighten nervous or timid patients. The Randot graded-circles and Randot Pre-school tests operate on the same principle as the Fly test in that they use polaroid spectacles and they are increasingly used because of disadvantages associated with the Fly test. One such disadvantage is that it contains monocular cues which are particularly evident if the test is viewed without the polaroid goggles but are still present to some extent (for the initially viewed circles and cartoon characters) even when the goggles are worn; a monocular, alert patient could identify which is the 'odd one out' by observing which of the circles is slightly displaced from the centre (see Figure 6.17).⁸⁹ This disadvantage can be overcome to some extent by asking the patient what is odd about the target they selected or whether the target seen in depth lies in front or behind the other animals/circles. The target seen in depth is usually seen in front of the others, but by turning the book upside-down the target in depth is seen behind the other animals/circles. Other more recent versions of polaroid-based stereo tests include the Randot graded-circles and the Randot Pre-school tests.⁹⁰ These tests have the advantage that they feature at least some material which, like the TNO, is constructed on a random dot principle, and thus which requires stereopsis in order to be able to detect the depth effects. The newer Randot Pre-school test has



Fig. 6.17 The Titmus stereopsis test. Notice that monocular cues provide the correct answers for some of the tests (compare this to other stereotests in Figures 6.18–6.21).

the added advantage that it has been validated on large sample sizes.⁹⁰

The TNO, Fly, Randot graded-circles and Randot Pre-school tests may be difficult to use with young children as they may not be happy to wear goggles, although children from the age of about 3 years can usually be tested.⁸⁸ For younger children (6 months to 4 years) it is best to use tests that do not require goggles to be worn such as the Frisby test, or if this can't be used, the Lang test.⁹¹ Because it gives only an indication of whether stereopsis may be present and doesn't measure it as such, the Lang should not be used if any of the other tests can be used. The Frisby test has the advantage that provides the only test of real depth; all of the others create depth effects by artificial means, and for this reason the Frisby is popular amongst many clinicians. Its drawback (monocular clues) can be minimised with careful administration of the test.

6.14.2 Procedure: TNO stereo test

This test works using a random-dot principle and red green goggles.

1. Explain the test to the patient: 'I am now going to test your 3-D vision.' Place the red-green goggles over the patient's habitual correction. For presbyopic patients, the test should be properly positioned for near-point viewing and appropriate near correction should be worn.
2. Hold the booklet at about 40 cm, angled so that it is parallel to the plane of the patient's face.
3. Keep the room lights on. Additional lighting over the patient's shoulder can be used to illuminate the booklet if required.
4. For a general screening test, the first four plates are useful as the disparity is large and provides a qualitative assessment of stereopsis. If the patient has a short attention span it is advisable to present Plate III alone as this gives a good early qualitative indication if stereopsis is present. Find out if the following images can be seen:

Plate I: In this plate there are two butterflies, one can be seen monocularly, whereas the other can only be seen if stereopsis is present ([Figure 6.18](#)). Ask the patient: 'How many butterflies can you find on this page? Can you point to them?'

Plate II: There are four discs. Two may be seen without stereopsis. Ask the patient: 'How many circles? Which is the biggest?'

Plate III: Four 'hidden' shapes (circle, square, triangle, and diamond) are arranged around a



Fig. 6.18 The butterfly plate from the TNO stereo test. One butterfly is shown in the figure and is seen monocularly. There is another butterfly that can only be seen with stereopsis through the red and green goggles.

central cross that is visible without stereopsis. Ask the patient: 'Can you find a cross/square/triangle/circle/diamond? Can you point to it?' This plate is very useful with children, as they like to find and name shapes. You will need to remember the correct locations of the shapes in order to verify the accuracy of the responses. Plate IV: This is a suppression test. There are three discs. When viewed through the goggles, one disc is seen only with the right eye, one is seen only by the left eye, and one seen binocularly. Ask the patient: 'How many circles can you see on this page? Can you point to them?'

To quantitatively measure stereopsis, proceed to plates V to VII.

5. Plates V to VII: These plates present images that present disparities from 480 to 15 seconds of arc. At each disparity level, two discs with a sector missing are presented in different orientations ([Figure 6.19](#)). Using the demonstration on the left of the display, ask the patient: 'In each of these squares there is a cake with a piece missing. Can you find the cake and point to the piece that is missing?'

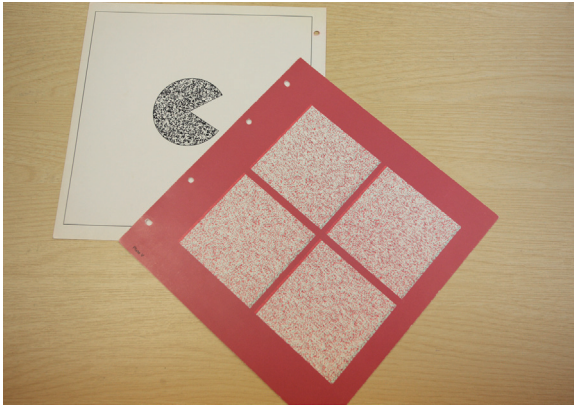


Fig. 6.19 TNO stereo plates in which the patient has to indicate whether the 'missing pizza slice', 'missing cake slice' or 'pac-man mouth' is pointing up, down or to the right or left. The disparities range from 15" to 480".

6. If the patient is hesitant about an answer, allow them plenty of time to view the test plate. If only one of the two tests for each stereo level is called correctly, allow them a second attempt at the incorrect one, but if called incorrectly again, or if the patient does not volunteer an answer, record the result as the previous correctly identified stereo level.
7. Record the patient's stereoacuity in seconds of arc using the information provided with the test. It is important to record the name of the test used (TNO, etc.), as performance on different stereotests will vary.
8. In patients achieving a poor test result, it can be useful to repeat the test with the red-green goggles reversed to ensure an accurate assessment of stereoacuity.⁸³

6.14.3 Procedure: The Frisby test

The Frisby test provides a test of sensitivity to real depth using perspex sheets containing contoured figures (Figure 6.20). One element of the contour that is the shape of a circle is printed on one side of the sheet whereas the remainder is printed on the opposite side. The thickness of the plate thus generates the real depth effect. No goggles are needed and the patient has to select the square that contains the circle in depth.

1. Explain the test to the patient: 'I am now going to test your 3-D vision.' In the case of younger



Fig. 6.20 One of the Frisby plates. The faint dark areas in the background are shadows produced by the photographic flash.

- children you could say 'We are going to play a game where you have to find the ball'.
2. In presbyopic patients, the test should be properly positioned for near-point viewing and appropriate near correction should be worn.
3. Keep the room lights on. Additional lighting over the patient's shoulder can be used to illuminate the test if required but make sure there are no reflections from overhead or any additional light sources from the perspex plates as these could interfere with the visibility of the target.
4. Hold the thickest of the three perspex plates (6 mm) a distance of 40 cm from the patient and angled so that it is parallel to the plane of the patient's face. The sheet should be held against the white background card that is part of the box provided with the test. Because monocular cues can be provided with movement of the plate or patient's head it is very important that the plate is displayed squarely and the patient's head kept still to minimise parallax effects.
5. Ask the patient to point to the square that is the 'odd one out' (older children and adults) or 'to point to the square that contains the ball'. If the patient answers correctly you could ask why it's the odd one out; the patient may volunteer at this point, they can see a 'shape' or a 'ball' or a

'circle' and that it's in front or behind the rest of the 'pattern' or 'background' or 'picture'. All of this additional information, if provided, is very positive and strongly suggests that the patient is seeing real depth.

6. You can tell which is the correct plate by using your sense of touch. One of the buttons at the four corners has a flat top and this signals the location of the circle, and the side (front/back) of the Perspex on which the circle is printed. This avoids having to look at the sheet to tell if the response was correct. Encouraging the patient (especially children) is a useful way of ensuring continued co-operation and a reliable measure of the stereoacuity.⁹²
7. Repeat step 5 whether or not the response was correct. With the thickest plate, next turn and flip the plate so that the target circle now occupies a new position. Sometimes patients will get the answer correct the second time because they are more sensitive to crossed versus uncrossed disparities, or vice versa. This would manifest itself when the patient shows that they can detect the location of the circle more easily when it is, for example, in front rather than behind the surrounding contours.
8. If the patient is correct on two successive occasions, move to the intermediate plate (3 mm) and repeat steps 5 to 7.
9. If, using the intermediate plate, the patient is correct on two successive occasions, move to the thinnest plate (1.5 mm) and again repeat steps 5 to 7.
10. From 40 cm, the best level of stereoacuity that can be assessed for using the Frisby test is 85 seconds of arc. If you wish to measure the stereopsis (as opposed to just establishing that it's 85" or better), a longer viewing distance is used in combination with the thinnest plate. The lid of the box presents a table which can be used to determine the stereoacuity for different test distances.

6.14.4 Procedure: Stereo Fly test/ Stereo Butterfly test/Randot graded-circles test/Randot Pre-school test/Random dot 'E' test

These tests operate on similar principles to one another in that they use crossed polaroid filters to present slightly different aspects of the same object to each eye. The vectograph consists of two superimposed, similar

patterns that are polarised at right angles to each other. Some aspects of each pattern are identical, whilst for others, small crossed and uncrossed disparities are introduced.⁸⁸ When the patterns are viewed with polaroid goggles, the patterns are seen in depth if stereopsis is present. Although these tests are all different to one another they contain many similar aspects and are run procedurally in an identical fashion. The following is a description for the Fly test. After this some additional points relating to the other tests are listed.

1. Explain the test to the patient: 'I am now going to test your 3-D vision.'
2. Ask the patient to hold the booklet at about 40 cm angled so that it is parallel to the plane of the patient's face.
3. Keep the room lights on. Additional lighting over the patient's shoulder can be used to illuminate the booklet if necessary.
4. If you are measuring stereopsis in children, first show them the fly (Figure 6.17). Ask the patient to wear the polaroid goggles (you could refer to these as 'magic glasses' to younger children to make the test more of a game). Note the patient's reaction and ask them to pinch the wings of the fly. A positive test result is indicated if in attempting to touch the wings, the child pinches the air a few centimetres above the chart.
5. Cartoon animals: Ask the patient to look at the top row of animals (Figure 6.17) and tell you which is the odd one out. Then ask the patient why this one appears different to the others. If the patient volunteers that it's different because it's closer to them (or because it stands out) this is a strong indication that stereopsis is present. If there is any doubt that the patient may know the answer that was expected (e.g. sibling tested previously when the child was present), turn the test upside down and the figure that appeared in front should now appear behind. Repeat this for the two lower rows of animals.
6. Circle patterns (also known as the Wirt test, Figure 6.17): Starting at the top array of circles, ask the patient which one of the circles is the odd one out. Check the test card to ensure that they gave the correct answer and, as with the cartoon figures, ask why it appears different. Continue with this process until the patient cannot tell which is the unique circle ('odd one out') or until they give a wrong answer. The stereo level measured with the test is the smallest disparity that could be correctly detected.

7. Record the result in seconds of arc.
8. For the Randot graded-circles test, the graded circles element works in a similar fashion to the Wirt circle test described above in 6, except that there are 10 versions of a 3-circles test and one of the three contains depth. This test features disparities from 400" to 20". The cartoon figures are identical to those in the Stereo Fly test (400" to 100"). This test differs from the Stereo Fly test mainly in that it offers six geometric forms created using the random dot principle (500" to 20"). This element of the test can be administered by asking the patient to name the shapes that they see or, in the case of younger children, to perform a matching task where the same shapes are made available on a separate, printed sheet.
9. For the Stereo Butterfly test, the same Wirt circle and animal cartoon tests as in the Fly test are presented. The only difference is that the butterfly is created using random dots and offers a test of gross stereopsis (2500" to 1200").
10. The Randot Pre-school test is designed for children from the age of two. All of the figures in depth are generated using the random dot principle and the test takes the form of a matching test in which the child matches the 2-D pictures on the left side of the booklet with the 3-D/random-dot figures on the right hand side. The disparity range is 800" to 40".
11. The Random dot 'E' test. In this test, which is suitable for children aged 3 years and above, the patient is asked to distinguish between a raised E and a non-stereo target.

6.14.5 Procedure: Lang stereotest

This test was designed to simplify stereopsis screening in children. The test is a single card that can be held easily by yourself or the patient. It only assesses gross stereopsis and provides targets of a moon arc (200"), star (200"), car (400") and an elephant (600") (Figure 6.21).

1. Hold the card at a distance of 40 cm from the child who sits on the parent/carer's lap.
2. The star can be seen monocularly to help attract the attention of young children.
3. Ask the child what they can see.
4. Pre-verbal children should be encouraged to respond by reaching for the images and this action can be used to indicate that some stereopsis is present. The test can become a matching game; if the child cannot name the

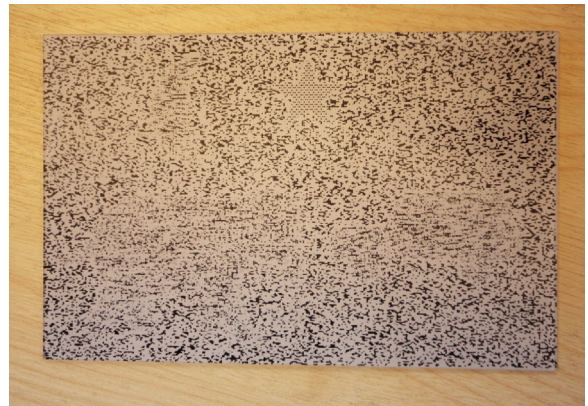


Fig. 6.21 The Lang stereotest II showing the monocularly visible star. Other figures (elephant, car and moon) can only be seen binocularly with stereopsis.

- targets they see but can match them with the same targets shown on paper this is a good indication that stereopsis is present.
5. A preferential-looking procedure can also be adopted in pre-verbal children: this involves comparing the child's fixation when the card is held in the normal fashion as compared to when it is rotated by 90 degrees. This is a useful test to have available as it is easy to use, does not require goggles, provides valuable information and is relatively inexpensive.⁹³

6.14.6 Recording

1. Always record the test used to measure the stereopsis.
2. TNO: If the stereo shapes are identified in Plates I–III but not V–VII, record 'Gross Stereopsis; TNO Plates I–III correct'. If Plate IV is incorrect, record which eye is being suppressed. For Plates V–VII, record the stereoacuity as 'at least' the highest level where both responses were correct, e.g., 'TNO stereoacuity ≤ 15 ".
3. Fly-Test: If the patient's reaction and pinching of the fly's wings indicates they could see the fly in depth, record 'Gross Stereopsis (Titmus Fly)'. Record the stereoacuity as 'at least' the highest level where a response was correct, e.g., Titmus Fly ≤ 40 ". The disparities of the animals range from 400" to 100" and the disparities of the circles range from 800" to 40". Record the smallest disparity that was correctly identified for this and the other tests, and indicate which

element of the test this result is based on, e.g. graded-circles 50", cartoon 200", etc.

4. Frisby: Again record the stereoacuity as 'at least' the highest level if testing was at 40 cms and the responses were all correct, e.g., Frisby $\leq 85''$.
5. For the Lang test, record as positive or negative the responses to the shapes. For example, if the elephant (600") was seen/pointed to but not the car (400"), record as: Lang 400"–600" (Elephant +ve, car –ve).

6.14.7 Interpretation

If stereoacuity is recorded as $\leq 40''$ you can assume that any ocular misalignments cannot be larger than Panum's fusional area. Stereoacuity of less than 60" can be normal but most adults and very many young (e.g. 5-year-old) children will achieve better (i.e. lower) thresholds.^{88,90} In young children, an abnormal test result should prompt you to repeat the test on another occasion as there is evidence that there is a strong likelihood that children exhibiting an abnormal result on the first occasion of testing will achieve a normal test result when the test is repeated.⁹⁴ Constant strabismus, amblyopia or other causes of visual loss (in particular monocular visual loss) usually leads to a seriously degraded or complete loss of stereoacuity.⁹⁵ In addition, small amounts of blur (binocular or monocular) and/or aniseikonia can reduce stereoacuity so that a patient's optimal stereo threshold is only obtained with their optimal refractive correction, i.e. reduced stereopsis when viewing with the patient's existing spectacles could be due to refractive blur if the correction is not optimal.^{96,97} In addition, fixation disparity may lead to reductions in stereopsis.³² If performance is poor on one stereotest you should try another; some patients perform quite differently on different tests, often for unknown reasons. For example, some patients may not respond well to red/green rivalry of the TNO test but achieve a normal result on tests using polaroid spectacles to create depth effects or on tests of real depth perception (Frisby).

6.14.8 Most common errors

1. Instructing the patient in a manner that leads the patient to the answers. For example, asking 'Can you see the two butterflies?' (Plate I, TNO) or 'Can you see that the wings of the fly are nearer to you?' (Stereo Fly test).
2. Allowing head tilting by the patient or viewing from oblique angles in an effort to see the

depth. This applies mainly to the Lang and Frisby tests and does not affect the TNO or other random-dot tests.

3. Not allowing sufficient time for the patient to view the stereo figures.
4. Using inappropriate refractive correction. For example, using the patient's own spectacles, which may not be optimal or using a distance correction in presbyopes.
5. Not repeating the test in cases where an abnormal result is obtained.⁹⁴
6. Polaroid-based tests: Allowing the child to view the stimuli before the polaroid goggles are worn.

6.15 MOTILITY TEST AND OTHER TESTS FOR DIAGNOSING/ MEASURING INCOMITANCY

In a comitant heterotropia the angle of deviation is constant in all directions of gaze although it may differ depending upon whether the patient is viewing a near or distant target. In an incomitant heterotropia on the other hand, the angle of deviation varies with direction of gaze. Incomitant deviations may be congenital or acquired. Congenital incomitant deviations are due to a developmental problem in the anatomy or functioning of one of the six extra-ocular muscles or their nerve supply. Acquired incomitant deviations can occur due to conditions such as diabetes, hypertension, multiple sclerosis, thyrotoxicosis, temporal arteritis or tumour. These may be longstanding or of recent onset. Recent-onset incomitancies can be the first sign of the underlying disease and it is therefore essential to determine if a strabismus, comitant or incomitant, is recent onset or longstanding. Missing the signs of these conditions, particularly in children, represents a significant cause of malpractice claims in the US.⁹⁸ Signs and symptoms that can differentiate between new and old ocular muscle palsy are shown in Table 6.5. Longstanding incomitancies tend to become more comitant as time passes due to the process of contracture.

An incomitancy can be due to a paralysis, a paresis or to a mechanical restriction. In paralysis, the action of one or a group of extra-ocular muscles is completely abolished whereas in a paresis, the action of a muscle is impaired but not abolished. An incomitancy caused by mechanical restriction continues to exhibit the same restricted movement when assessed monocularly (i.e. with the fellow eye closed), whereas the movements of a paretic eye are more normal when assessed

Table 6.5 Signs and symptoms that can help to differentiate between an old and new ocular motor palsy

Sign/symptom	Long-Standing	Recent-Onset
Diplopia	Rare	Almost always present
Onset	Generally unknown	Usually sudden
Amblyopia	Common	Rare
Recent trauma?	Not usual	Common
Symptoms	Not usual	Common and extreme
Comitance	Spread of comitance may obscure original palsy	Always incomitant
Abnormal head posture	If present, well established and difficult to alter	Can be marked but easy to alter. Covering paretic eye eliminates problem
Past-pointing	Absent	Present
General health	Not usually a factor	Current health may be a significant issue

monocularly and it is on this basis that a paresis can be distinguished from mechanical restriction.

If there is a problem with an extra-ocular muscle, the angle of deviation is largest when the eyes are turned in the direction of maximum action of the affected muscle. The size of the deviation can also vary with respect to the eye that is used to fixate. The primary angle of deviation is observed when the non-affected eye fixates. The secondary angle of deviation is observed when the affected eye fixates. A difference between the primary and secondary angles of deviation distinguishes a paralytic from a non-paralytic strabismus. The secondary angle is usually larger than the primary angle in recently acquired incomitancy.²⁹

6.15.1 Comparison of tests

The motility test is the simplest method of evaluating a deviation in the nine diagnostic positions of gaze.⁹⁹ It is relatively quick and easy to perform and requires no extra equipment. Assessment of versions (binocular eye movements in the same direction) are used as a screening technique, and the technique can be repeated monocularly (assessing ductions) if an incomitancy is detected to help differentiate between incomitant deviations due to paresis/paralysis and mechanical restrictions. The disadvantages of the motility test relate to the fact that it requires practice in terms of both dexterity (achieving smooth movements of the penlight) and, in particular, the interpretation of the results.

The 9-point cover test/Maddox rod/modified Thorington tests require little additional equipment and provide quantitative information about the size of the deviation in different positions of gaze. Thus they enable the extent of the incomitancy to be quantitatively evaluated. These tests are useful when monitoring an incomitant deviation to determine if it is getting better or worse. The 9-point cover test has an advantage over the Maddox rod test and Thorington methods in that it is an objective test and, therefore, it can be used in patients with suppression. The disadvantage of the 9-point cover test relative to the other methods is that considerable dexterity is required. However, an experienced practitioner will be able to carry out the procedure swiftly and smoothly. The results of the 9-point test can be supported by investigation with the Hess screen method, although this test is seldom available in primary eye care settings.

6.15.2 Procedure: Motility test

See online videos 6.21-6.23.

1. Keep the room lights on and illuminate the eyes without shadows. Explain the test to the patient: 'This test checks whether all your eye muscles are working well together.'
2. Ask the patient to remove any spectacles. Spectacles can make observation of the eyes more difficult and the frame may hide the fixation target. In addition, in peripheral gaze



diplopia can be induced by the prismatic effect produced by anisometric spectacles and the 'jack-in-the-box' effect of myopic spectacles, particularly with small, modern frames. Sit directly in front of the patient so that both eyes can be viewed simultaneously.

3. The target used is not critical as long as the patient can easily see it, although a penlight is particularly useful as it allows you to observe the corneal reflexes and it will indicate when the light has moved from the binocular field into the monocular field as one of the corneal reflexes will disappear. A picture on a fixation stick may be used when examining children.
4. Instruct the patient: 'Please watch my light and follow it with your eyes. Keep your head still. Tell me if the light appears double at any time or if your eyes feel particularly uncomfortable or painful in any of the positions. Don't worry if the light appears blurred.' Patients sometimes call a diplopic or overlapped image 'blurred', so this is useful to include in your instructions.
5. Shine the penlight towards the patient from approximately 40 cm and move it in an arc with the patient's head as the centre. Move the penlight so that the patient's eyes follow to the edge of the binocular field. The loss of the corneal reflex will help to indicate that you have moved into the monocular field. Note that at the limits of movement, even those with normal ocular motility can feel uncomfortable and end-point nystagmus may be visible.
6. Move the penlight into the six diagnostic positions of gaze by moving the target in a cross (Figure 6.22) or broad H formation. Many clinicians have a preference the manner in which the light is moved but either type of movement is acceptable.⁹⁹ During downgaze, you may need to hold up the patient's eyelids to gain a useful view. You should transfer the target/penlight from your left to your right hand when switching between the patient's right and left visual fields.
7. Carefully look for any misalignment of the eyes in all positions of gaze (the corneal reflexes can help you in this). Also determine whether the movements of the eyes are smooth and accurate (see pursuit eye movements, section 6.17).
8. If the eye movements were smooth and accurate with no reported diplopia, the test is complete and the results can be recorded.

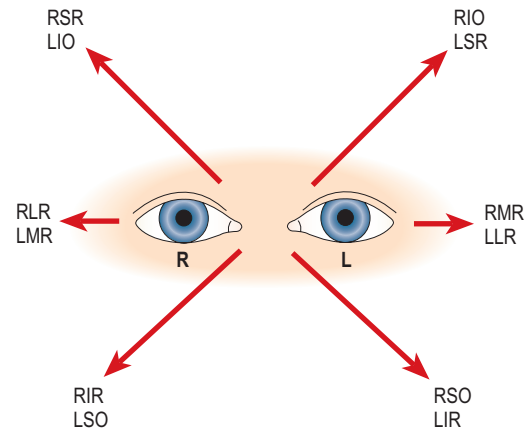


Fig. 6.22 The six cardinal diagnostic positions of gaze, showing the Yoke muscles that principally maintain the eyes in these positions. Assessment of motility in the vertical midline is necessary for the diagnosis of conditions such as A and V patterns. The three diagnostic positions on the midline supplement the six positions of fixation demonstrated in the figure. LR = lateral rectus, MR = medial rectus, IR = inferior rectus, SR = superior rectus, SO = superior oblique and IO = inferior oblique.

9. If both eyes appear not to be looking at the pentorch from your position directly in front of the patient, a useful tip is to switch your viewing position to directly behind the pentorch as the patient looks in this gaze direction. This will enable you to ascertain whether both eyes are in fact looking at the light and if not, which eye is not adopting the appropriate position.
10. Note and record the position of the eyes when any of the following occur:
 - (a) The patient reports any diplopia.
 - (b) The patient reports pain or discomfort in one or more positions of gaze that exceeded that experienced in other gaze directions.
 - (c) Any underaction or overaction in one eye.
 - (d) Jerky or inaccurate pursuit eye movements.
 - (e) The size of the palpebral apertures differs between the right and left eyes and/or varies as a function of the direction of gaze.
11. Locate the gaze direction that yields the greatest diplopia as this indicates the field of action of

the affected muscles. This can be difficult for some patients as similar separations of the doubled images may be reported in different directions of gaze.

12. Establish whether the doubled images are horizontally, vertically or diagonally separated. Diagonal separation is found most commonly in cases where one or more of the oblique or vertical recti muscles are affected.
13. Cover each eye in turn to identify which eye is seeing which image. When the eyes are elevated, the eye that sees the higher image is seen by the eye which is lower; if there is an underaction this is the eye with the underacting muscle. Alternatively, it could be that there is an overaction in which case the fellow eye has risen too high. Similarly, when the eyes are looking down, the eye seeing the lower image is seen by the eye with the underacting muscle; if not, the other eye has an overacting muscle and it has descended too far. Similarly, when the eyes are looking right or left, the eye that sees the image that is further to the right or left, respectively represents the eye which has moved less from the primary position. A cover test (section 6.2) performed in this direction of gaze can be used to confirm the diagnosis.
14. If an incomitancy is observed, repeat the testing monocularly (assessment of ductions) to help discriminate between parietic and mechanical incomitancy.

6.15.3 Procedure: 9-point cover test

Perform a near cover test in each of the nine positions of gaze. A cover/uncover test for tropia (see box 6.1) in a peripheral gaze direction can help to reveal which eye is not looking at the spotlight. An alternating cover test is often carried out because the direction of movements will be more obvious than in a cover/uncover test. Note that in the cover/uncover test, the deviation may differ depending on which eye is fixating. If quantitative measures are required, horizontal and vertical prism bars are needed in order to neutralise the vertical and horizontal deviations.

6.15.4 Procedure: 9-point Maddox rod/Thorington test

Perform a Maddox rod or modified Thorington test (section 6.4) in each of the nine positions of gaze. It may be necessary to hold the Maddox rod in free space

to allow the line to be seen in peripheral gaze directions. At each gaze point, the line is presented horizontally and vertically in order to determine the vertical and horizontal deviation angles, respectively.

6.15.5 Recording

For the motility test, where the ocular movements appear full and no diplopia is reported in any position, a normal result has been obtained. This is usually recorded using the acronym SAFE (or FESA). This indicates that the ocular motility movements were (S) Smooth, (A) Accurate, (F) Full and (E) Extensive. For a patient with strabismus, normal motility can be recorded as 'no incomitancy detected' if the size of the strabismus did not change objectively in different directions of gaze.

In a patient with strabismus in the primary position, it is likely that diplopia will not be reported by the patient in any direction of gaze. For this reason, in patients with strabismus in the primary position, it is objective (i.e. the practitioner's) judgements alone that will decide whether the deviation is comitant or incomitant. In cases where you detect incomitancy or where diplopia is reported by the patient, record a cross/H-pattern to clearly indicate where diplopia was experienced or incomitancy noticed. Also, record any apparent underactions or overactions, clearly stating which eye and in which gaze direction this was observed. Increasingly, incomitancies are recorded using a 9-point scale.¹⁰⁰ Using this system, overactions and underactions are recorded on a basic template in the primary field of action of each muscle. Underactions are recorded as negative numbers on a scale from -1 to -4, where -4 represents the greatest underaction. Similarly, overactions are recorded using positive numbers on a scale from +1 to +4, where +4 represents greatest overaction. For example, underactions that are scored as -4 indicate that the eye is unable to move at all from the primary position into the field of action of that muscle and overaction of a horizontal rectus muscle is graded according to the amount of cornea covered by the canthus; in extreme overaction (+4), half of the cornea is concealed. This diagrammatic representation also provides a useful way of signalling the presence of an A- or V-pattern, restrictions of movements as well as other ocular movement abnormalities (e.g. up- and down-drifts, up- and down-shoots).¹⁰⁰

If a head tilt is present it should be noted and you may find it useful to perform the motility in the head-straight and head-tilted conditions and compare the results. The movements observed during a motility

test may conform to one of the so-called 'alphabet' patterns.²⁹ For example, if the deviation is significantly ($>15^\Delta$) more convergent (i.e. more eso, less exo) in upgaze than in downgaze, this is referred to as an A-pattern. Similarly, the term V-pattern describes a situation where the deviation is significantly more divergent (i.e. more exo, less eso) in upgaze than in downgaze. Note that incomitancies of this nature do not always conform strictly to the A and V patterns. For example, some patterns may be more correctly described as Y or inverted Y- patterns.

Quantitative measures of the deviation angle (horizontal and vertical) are seldom needed in all directions of gaze for the 9-point Maddox rod/modified-Thorington/cover test. Indeed, the aim of these tests is to identify the likely source of the problem. Thus, the test result is normally recorded in a fashion which identifies the muscle(s) that is/are affected; e.g. 'bilateral super rectus underaction'. If quantitative measures are required, both vertical and horizontal prisms are needed to neutralise the movements on cover/uncover or alternating cover test and during the Maddox rod or modified Thorington test in the various gaze positions.

6.15.6 Interpretation

The results of motility testing are relatively straightforward to interpret if there is a problem with the lateral or medial rectus muscles. A movement to the patient's right along the horizontal meridian will examine the right lateral rectus and left medial rectus. Eye movements to the patient's left will assess their left lateral rectus and right medial rectus.

The clinical interpretation of motility test results are more complicated when diplopia is experienced on upwards or downwards gaze, because there are four extra-ocular muscles that help to elevate (the right superior rectus, RSR; left superior rectus, LSR; right inferior oblique, RIO; and left inferior oblique, LIO) and four that depress the eyes (the right inferior rectus, RIR; left inferior rectus, LIR; right superior oblique, RSO; and left superior oblique, LSO). By having the patient look in the various directions of gaze, a clinical determination of affected muscle(s) can be made because the eyes will appear most misaligned (and the diplopia noticed by the patient will be maximal) when the eyes move into the field of action of the affected muscle. Diplopia experienced in peripheral gaze is more usually caused by an underaction of one or more muscles, but a muscle overaction is also possible. An underaction could be caused by a mechanical restriction or muscle palsy/paralysis. An overaction

will occur in the non-paretic eye if the paretic eye is fixating the target.

Versions vs. ductions

Duction (monocular) testing (step 12) helps to differentiate between an incomitant deviation due to paresis/paralysis and one due to mechanical restriction. With an incomitant deviation due to a paresis, an underaction seen during duction testing (binocular) testing is less obvious during duction testing, and any overaction will not be seen monocularly. An underaction that is similar when tested monocularly and binocularly suggests a mechanical restriction and may require further testing using forced ductions. To aid or confirm a diagnosis of an underaction/overaction, to measure the extent of the deviation and to assess the degree of incomitancy, further tests are required such as the 9-point cover test.

6.15.7 Most common errors

1. Allowing the patient to turn their head towards the target. The head should remain in the straight ahead position so as to fully test the ocular motility.

Motility

2. Not using a penlight. This makes the detection of incomitant deviations more difficult. It is also more difficult to determine when the patient's eyes are at the edge of the binocular field.
3. Not asking the patient to report doubling, or not fully investigating reported doubling.
4. Relying too much on the patient to report doubling (i.e. not paying enough attention to symmetry of corneal reflexes) and the appearance of the relative positioning of the eyes.
5. Moving the target too quickly or too slowly.
6. Moving the target in a straight line rather than an arc, so that increasing unequal angular demands are made of the two eyes as the target is moved into a peripheral position of gaze.
7. Not holding the top lid when viewing the eye movements in down-gaze.

9-point cover test

8. Not keeping the viewing distance fixed in the various positions of gaze.
9. Failing to ensure occlusion occurs in peripheral gaze directions (cover test).

10. Switching the cover too quickly and not allowing the eyes time to take up position when prompted to fixate (cover test).

6.15.8 Additional technique: Double Maddox rod

By placing a Maddox rod in front of one eye the extent of an incyclo- or excyclorotation of the eye can be quantitatively evaluated. When the rod is placed vertically the streak should, of course, appear to be horizontally oriented. If the streak does not appear horizontal, this indicates the presence of cyclorotation and the rod orientation in the trial frame can be adjusted until the patient reports that the streak is horizontal. The magnitude and direction of the rotation required to generate a horizontal impression is a measure of the nature and size of cyclorotation. The same procedure can be employed when a Maddox rod is placed before each eye.²⁹ In this case a vertical prism may be needed to dissociate the rods and the patient's task is to assess whether or not they appear parallel. This is known as the double Maddox rod test and it is useful in bilateral conditions in which an underaction or overaction of the elevating or depressing extraocular muscles is present or suspected. If one of the lines appear slanted, the Maddox rod in front of that eye is rotated until the line appears horizontal and therefore parallel to the other line. Note however, that both lines may appear tilted. The patient's head should be in the primary position and held straight.

6.16 IDENTIFYING THE DEFECTIVE MUSCLE: PARKS 3-STEP TEST

The technique of assessing movements of the eyes as the head is tilted successively toward one shoulder and then toward the other was introduced by Hoffmann and Bielschowsky but has since come to be known as the Bielschowsky head tilt test.²⁹ The manner in which this test is normally used in the clinical setting is referred to as the Parks 3-step test.

6.16.1 Comparison of tests

This test can provide useful information to help determine the affected muscle in cases of known or suspected incomitancy. The test is useful in cases of paresis of any of the cyclovertical muscles, but the results are more dramatic when the oblique muscles are affected compared to when the vertical rectus muscles are involved. No additional equipment is

required to perform this test. It offers the additional advantages in that the test is objective, allowing you to observe and measure the magnitude of any deviations without subjective responses from the patient, thus making it suitable for use in young children. However, the test result can be affected by a number of factors including the paresis of more than one muscle and mechanical restrictions by previous surgery to the extra-ocular muscles. Furthermore, interpretation of results may be more difficult than in the case of the Hess screen test.

6.16.2 Procedure

In order to carry out the Parks 3-step test, you should attempt to answer the following three questions:

1. Which is the hyper-deviated eye in the primary position? The answer to this question may be obvious by simply viewing the patient or it may require you to carry out a cover/uncover test in the primary position (section 6.2).
2. Is the hyper-deviation greater in right or left gaze?
3. Is the hyper-deviation greater with head tilted to the right shoulder or to the left shoulder? This portion of the test is the Bielschowsky head tilt test.

6.16.3 Interpretation

Determine the muscle that the Parks 3-step test suggests is paretic by matching the test result to the information provided in Table 6.6. If, for example, the *right* eye is the hyper-deviated eye in the primary position (Answer to Question 1), the deviation is greater on *leftwards* gaze (Answer to Question 2), and greater when the head is tilted to the *right* (Answer to Question 3), the muscle implicated is the *Right Superior Oblique (RSO)* (Table 6.6).

It is easier to recall the result patterns associated with the oblique muscles being affected. In the case of superior oblique muscles, the answers to the three questions will be *right-left-right* when the Right Superior Oblique is affected, and *left-right-left* when the Left Superior Oblique is affected. In the case of the inferior oblique muscles, the result will be *right-right-right* in the case of the Left Inferior Oblique and *left-left-left* for the Right Inferior Oblique.

6.16.4 Most common error

It is not necessary to use prisms in order to complete the test. However, if prisms are used to measure/

Table 6.6 Parks three-step method for identifying the paretic muscle when the deviation is vertical

1. Which is the hyper eye?	RE (OD) hyper				LE (OS) hyper			
2. Is the deviation greater on left or right gaze?	Left gaze		Right gaze		Left gaze		Right gaze	
3. Is the deviation greater on head tilt to the right or left?	Right	Left	Right	Left	Right	Left	Right	Left
Likely paretic muscle	RSO	LSR	LIO	RIR	LIR	RIO	RSR	LSO
<i>LE (OS), left eye; LIO, left inferior oblique; LIR, left inferior rectus; LSO, left superior oblique; LSR, left superior rectus; RE (OD), right eye; RIO, right inferior oblique; RIR, right inferior rectus; RSO, right superior oblique; RSR, right superior rectus.</i>								

neutralise the deviation, the prism must be held with its base parallel to the palpebral fissure when the head is in the tilted position, rather than parallel with the floor. This is to ensure that the prism has the same relation to the eye as in the primary position.²⁹

6.17 ASSESSMENT OF EYE MOVEMENTS

Saccadic eye movements are used to quickly redirect our eyes so that an object of interest falls on the fovea. They are conjugate eye movements in that the eyes move by the same amount and they are the fastest of all eye movements with velocities as high as 700 degrees per second.¹⁰¹ Saccades are used to continually scan the environment and are particularly important during reading. They originate in the left and right frontal eye fields (Brodmann’s area 8) of the frontal lobes. Pursuit eye movements are those used when following a moving target. Ideally pursuit movements will be both smooth and accurate. When a foveated target moves, the pursuit response begins after a latency of around 100–150 milliseconds and the pursuit movements are at the same velocity as the target.¹⁰² Because of the latency, a small, catch-up saccade is seen initially to allow the moving target to be foveated. Assuming the target moves in a predictable fashion (constant speed and direction), it can then be followed using pursuit movements. Since saccadic eye movements are the eye movements primarily used in reading, assessing saccades is potentially informative in patients experiencing symptoms during close work and in children who are not doing well with their school work.

6.17.1 Comparison of tests

In most clinical settings, the equipment required to quantitatively assess eye movements is not available. Hence, clinical assessment of pursuit and saccadic eye movements is usually qualitative in the sense that there is a need for a rating scale. A simple assessment of saccadic eye movements can be made by direct observation of the patient’s eyes as they switch fixation from one target to another. Very little additional equipment is required and these eye movements can be assessed in a simple, quick and reasonably reliable fashion.¹⁰³ It should be pointed out that a simple and repeatable assessment of pursuit eye movements can be made by direct observation of the patient’s eyes as they follow a moving target and, as this task is performed during motility/Broad H testing for incomitancy (section 6.15), the pursuit reflexes can be assessed at the same time.¹⁰³ Alternatively, pursuit eye movements can be assessed separately and this is preferred. The tests of pursuits and saccades described here are the NSUCO (Northeastern State University College of Optometry) tests which are claimed to be both reliable and repeatable.^{19,103,104}

6.17.2 Procedure: NSUCO pursuits test

1. The patient is asked to stand directly in front of you.
2. The patient is informed that the test is to ‘look at how well your eyes can follow a target’ and is instructed to ‘follow the target as closely as possible as it moves around’. No instructions are given about head/body movements since

you will want to observe whether these spontaneously take place as the target is followed.

3. One target is used (e.g. brightly coloured bead on a stick) and it is held at 40 cm. The target is first positioned directly in front of the patient along the midline. Then it is moved in, tracing a circle of around 20 cm.
4. Look for jerky pursuit movements, fixation losses or other eye movements that are not at the same speed or in the same direction as the movement of the target. Also, look for body or head movements that are made.
5. Four rotations are made, two clockwise and two counter-clockwise. A sweep horizontally along the midline may be made when you are switching from clockwise to counter-clockwise movements.

6.17.3 Procedure: NSUCO Saccades test

1. The patient should stand directly in front of you.
2. Keep the room lights on. Position additional lighting to illuminate the patient's eyes or the target (whichever is necessary) without shadows.
3. The patient is informed that the test is to 'look at how quickly your eyes can switch to a new position' and is instructed to move their eyes as quickly as possible when you give the signal. No instructions are given about head/body movements since you will want to observe whether these spontaneously take place.
4. Hold two fixation sticks, one with red sticker, one with green sticker) approximately 10 cm either side of the patient's midline and at a distance of ~40 cm from a point midway between the patient's eyes.
5. Instruct the patient: 'Do not move your eyes until I instruct you. When I say green, please turn to look at the green target as quickly as you can. Keep looking at the green target until I say to look at the red target'. Repeat for five cycles.
6. Grade the saccadic movements out of five, giving separate scores for 'ability', 'accuracy', 'head movement' and 'body movement' using Table 6.7.

6.17.4 Recording: Pursuits

The NSUCO method uses a 5-point scale for recording ability, accuracy of movement and the extent to which

head and/or body movements have taken place during the test (Table 6.7). An example of a record would be: 'pursuits: ability 4, accuracy 3, head movement 4, body movement 5'. Descriptive terms may be also used. For example, if normal pursuit eye movements are seen, record 'smooth and accurate pursuits' or similar. If pursuits are abnormal, record the type of abnormality (e.g., 'jerky eye movements' or 'unable to maintain fixation') and indicate if one eye is more at fault than the other.

6.17.5 Interpretation

All saccadic eye movements should be fast (completed in much less than 1 second), conjugate and accurate, with no overshoots requiring secondary compensatory eye movements. A small undershoot with a compensatory eye movement is normal. Dysmetria denotes inaccurate saccadic eye movements and includes hypometria (undershooting) or hypermetria (overshooting). Abnormal saccadic and/or pursuit eye movements could indicate conditions including ocular motor nerve palsy, cerebellar disease, Parkinson's disease, or could be due to systemic medications, or particular anti-depressants. In cases of abnormal saccadic and/or pursuit eye movements, additional testing is warranted and referral may be necessary. It is worth remembering that disorders of saccadic, pursuit and fixational eye movements generally occur together.

6.17.6 Most common errors

1. **Pursuits:** Moving the target at an inappropriate speed, or in a non-smooth fashion.
2. **Saccades:** Misinterpreting the results due to lack of experience. For example, not realising that small undershoots are frequently seen.

6.18 CONSIDERING TEST RESULTS IN COMBINATION

Although this chapter describes many procedures that test diverse aspects of the accommodation and binocular visual systems, the results from any one test need to be considered alongside the results from other tests in order for you to put them in context and thus reach a diagnosis. Firstly clinicians should be aware that a single abnormal test result is unlikely to be significant on its own. Single abnormal test results should be always be rechecked as there is a strong likelihood that the result will be (more) normal

Table 6.7 NSUCO Oculomotor Test: Scales for Grading Pursuits and Saccades¹⁰⁴

Eye movement	Ability	Accuracy	Head movement	Body movement
Pursuits	1. Cannot complete $\frac{1}{2}$ rotation in either the clockwise or counter-clockwise direction. 2. Completes $\frac{1}{2}$ rotation in either direction. 3. Completes 1 rotation in either direction but not 2 rotations. 4. Completes 2 rotations in one direction but less than 2 rotations in the other direction. 5. Completes 2 rotations in either direction.	1. No attempt to follow the target or requires >10 re-fixations. 2. Re-fixations 5–10 times. 3. Re-fixations 3–4 times. 4. Re-fixations 2 times or less. 5. No re-fixations noted.	1. Large movement of the head at any time. 2. Moderate movement of the head at any time. 3. Slight movement of the head (>50% of the time). 4. Slight movement of the head (<50% of the time). 5. No movement of the head.	1. Large movement of the body at any time. 2. Moderate movement of the body at any time. 3. Slight movement of the body (>50% of the time). 4. Slight movement of the body (<50% of the time). 5. No movement of the body.
Saccades	1. Completes less than 2 round trips. 2. Completes 2 round trips. 3. Completes 3 round trips. 4. Completes 4 round trips. 5. Completes 5 round trips.	1. Large over- or undershooting is noted one or more times. 2. Moderate over- or undershooting is noted one or more times. 3. Constant slight over- or undershooting noted (>50% of the time). 4. Intermittent slight over- or undershooting noted (<50% of the time). 5. No over- or undershooting noted	1. Large movement of the head at any time. 2. Moderate movement of the head at any time. 3. Slight movement of the head (>50% of the time). 4. Slight movement of the head (<50% of the time). 5. No movement of the head.	1. Large movement of the body at any time. 2. Moderate movement of the body at any time. 3. Slight movement of the body (>50% of the time). 4. Slight movement of the body (<50% of the time). 5. No movement of the body.

on repeat testing.⁶¹ This is particularly true in the case of children who may perform poorly on initial testing, perhaps due to unfamiliarity with test expectations or instructions.

In fact, if there is a problem with the accommodative or binocular vision system it is highly likely that abnormal performance will be evident on a number of tests. This is because most of the tests presented in this chapter simultaneously test both accommodation and vergence, though to a greater or lesser degree. For example, when the amplitude of accommodation is measured binocularly, the eyes need to accommodate appropriately to achieve a clear view of the target but the vergence system also needs to respond appropriately if diplopia is to be avoided. Thus a vergence problem could 'contaminate' a measure of binocular amplitude of accommodation, although listening closely to what the patient reports (diplopia before blur) could alert you to this fact. Similarly, if there is a primary problem of accommodation, this could produce an abnormal result on a test that is primarily designed to test vergence function (e.g. fusional reserves). Most of the tests presented in this chapter test both accommodation and vergence simultaneously. From your perspective this makes identification of the presence of an accommodative/vergence problem quite straight-forward but definite diagnosis of the primary problem difficult. For example, an abnormal (i.e. elevated) near point of convergence, exophoria at near greater than at distance, a low AC/A ratio and a reduced positive (i.e. base-out) fusional reserve at near strongly suggests a diagnosis of convergence insufficiency; but patients with this condition might, for the same reason, exhibit a reduced amplitude of accommodation when tested binocularly, a reduced binocular accommodative facility and an increased lag of accommodation. In order to establish whether the primary problem is caused by the accommodation or vergence system, it is necessary to resort to less frequently used tests, or versions of tests, in which accommodation is tested independently of vergence, or in which vergence is tested without changing the stimulus to accommodation. An example of the former is the monocular amplitude of accommodation test (section 6.9) and an example of the latter is vergence facility (section 6.8).

REFERENCES

1. O'Connor AR, Wilson CM, Fielder AR. Ophthalmological problems associated with preterm birth. *Eye* 2007;21:1254–60.
2. Mohnsey BG, Erie JC, Hodge DO, Jacobsen SJ. Congenital esotropia in Olmsted County, Minnesota. *Ophthalmology* 1998;105:846–50.
3. Pardhan S, Elliott DB. Clinical measurements of binocular summation and inhibition in patients with cataract. *Clin Vision Sci* 1991;6:355–9.
4. Fogt N, Baughman BJ, Good G. The effect of experience on the detection of small eye movements. *Optom Vision Sci* 2000;77:670–4.
5. Rainey BB, Schroeder TL, Goss DA, Grosvenor TP. Reliability of and comparisons among three variations of the alternating cover test. *Ophthalmic Physiol Opt* 1998;18:430–7.
6. Walline JJ, Mutti DO, Zadnik K, Jones LA. Development of phoria in children. *Optom Vision Sci* 1998;75:605–10.
7. Evans BJW. *Pickwell's Binocular Vision Anomalies*. 5th ed. Oxford: Butterworth-Heinemann; 2007.
8. Freier BE, Pickwell LD. Physiological exophoria. *Ophthalmic Physiol Opt* 1983;3:267–72.
9. Choi RY, Kushner BJ. The accuracy of experienced strabismologists using the Hirschberg and Krimsky tests. *Ophthalmology* 1998;105:1301–6.
10. Miller JM, Hall HL, Greivenkamp JE, Guyton DL. Quantification of the Bruckner test for strabismus. *Invest Ophthalmol Vis Sci* 1995;36:897–905.
11. Gräf M, Alhammouri Q, Vieregge C, Lorenz B. The Brückner transillumination test: limited detection of small-angle esotropia. *Ophthalmology* 2011;118:2504–9.
12. Casillas EC, Rosenfield M. Comparison of subjective heterophoria testing with a phoropter and trial frame. *Optom Vision Sci* 2006;83:237–41.
13. Rainey BB, Schroeder TL, Goss DA, Grosvenor TP. Inter-examiner repeatability of heterophoria tests. *Optom Vision Sci* 1998;75:719–26.
14. Antona B, Gonzalez E, Barrio A, et al. Strabometry precision: intra-examiner repeatability and agreement in measuring the magnitude of the angle of latent binocular ocular deviations (heterophorias or latent strabismus). *Binocul Vis Strabolog Q Simms Romano* 2011;26:91–104.
15. Lyon DW, Goss DA, Horner D, et al. Normative data for modified Thorington phorias and prism bar vergences from the Benton-IU study. *Optometry* 2005;76:593–9.
16. Pointer JS. An enhancement to the Maddox Wing test for the reliable measurement of horizontal heterophoria. *Ophthalmic Physiol Opt* 2005;25:446–51.

17. Wong EP, Fricke TR, Dinardo C. Interexaminer repeatability of a new, modified prentice card compared with established phoria tests. *Optom Vision Sci* 2002;79:370–5.
18. Calvin H, Rupnow P, Grosvenor T. How good is the estimated cover test at predicting the von Graefe phoria measurement? *Optom Vision Sci* 1996;73:701–6.
19. Scheiman M, Wick B. *Clinical management of binocular vision: Heterophoric, accommodative and eye movement disorders*. Philadelphia: Wolters Kluwer; 2008.
20. Saladin JJ, Sheedy JE. Population study of fixation disparity, heterophoria, and vergence. *Am J Optom Physiol Opt* 1978;55:744–50.
21. Sheedy JE. Fixation disparity analysis of oculomotor imbalance. *Am J Optom Physiol Opt* 1980;57:632–9.
22. Jenkins TCA, Pickwell LD, Yekta AA. Criteria for decompensation in binocular vision. *Ophthalmic Physiol Opt* 1989;9:121–5.
23. Yekta AA, Pickwell LD, Jenkins TCA. Binocular vision, age and symptoms. *Ophthalmic Physiol Opt* 1989;9:115–20.
24. Mallett R. Techniques of investigation of binocular vision anomalies. In: Edwards K, Llewellyn R, editors. *Optometry*. London: Butterworths; 1988. pp. 238–69.
25. Ngan J, Goss DA, Despirito J. Comparison of fixation disparity curve parameters obtained with the Wesson and Saladin fixation disparity cards. *Optom Vision Sci* 2005;82:69–74.
26. Frantz KA, Elston P, Michalik E, et al. Comparison of fixation disparity measured by Saladin card and disparometer. *Optom Vision Sci* 2011;88:733–41.
27. Corbett A, Maples WC. Test-retest reliability of the Saladin card. *Optometry* 2004;75:629–39.
28. Evans BJW. Optometric prescribing for decompensated heterophoria. *Optom in Pract* 2008;9: 63–78.
29. von Noorden GK. *Binocular vision and ocular motility: Theory and management of strabismus*. London: CV Mosby; 2002.
30. Flom B, Fried A, Jampolsky A. Fixation disparity in relation to heterophoria. *Am J Ophthalmol* 1957;43:97–106.
31. London R. Fixation disparity and heterophoria in ocular assessment. In: *Ocular assessment: The manual of diagnosis for office practice* (B Barresi, ed.). Boston: Butterworth-Heinemann; 1984. pp. 141–50.
32. Saladin JJ. Stereopsis from a performance perspective. *Optom Vision Sci* 2005;82:186–205.
33. Conway ML, Thomas J, Subramanian A. Is the aligning prism measured with the Mallett unit correlated with fusional vergence reserves? *PLoS One* 2012;7:e42832.
34. Brautaset RL, Jennings JA. The influence of heterophoria measurements on subsequent associated phoria measurement in a refractive routine. *Ophthalmic Physiol Opt* 1999;19:347–50.
35. North RV, Henson DB. Adaptation to prism induced heterophoria in subjects with abnormal binocular vision or asthenopia. *Am J Optom* 1981;58:746–52.
36. Pickwell LD, Hampshire R. The significance of inadequate convergence. *Ophthalmic Physiol Opt* 1981;1:13–8.
37. Rouse MW, Borsting E, Hyman L, et al. Frequency of convergence insufficiency among fifth and sixth graders. The Convergence Insufficiency and Reading Study (CIRS) group. *Optom Vision Sci* 1999;76:643–9.
38. Scheiman M, Gwiazda J, Li T. Non-surgical interventions for convergence insufficiency. *Cochrane Database Syst Rev* 2011;3:CD006768.
39. Convergence Insufficiency Treatment Trial Group (CITT). Long-term effectiveness of treatments for symptomatic convergence insufficiency in children. *Optom Vision Sci* 2009;86: 1096–103.
40. Scheiman M, Kulp MT, Cotter S, et al. Vision therapy/orthoptics for symptomatic convergence insufficiency in children: treatment kinetics. *Optom Vision Sci* 2010;87:593–603.
41. Rouse MW, Borsting E, Deland PN. Reliability of binocular vision measurements used in the classification of convergence insufficiency. *Optom Vision Sci* 2002;79:254–64.
42. Scheiman M, Gallaway M, Frantz KA, et al. Near-point of convergence: test procedure, target selection, and normative data. *Optom Vision Sci* 2003;80:214–25.
43. Siderov J, Chiu SC, Waugh SJ. Differences in the near point of convergence with target type. *Ophthalmic Physiol Opt* 2001;21:356–60.
44. Adler PM, Cregg M, Viollier AJ, Woodhouse MJ. Influence of target type and RAF rule on the measurement of near point of convergence. *Ophthalmic Physiol Opt* 2007;27:22–30.
45. Sheedy JE, Saladin JJ. Phoria, vergence, and fixation disparity in oculomotor problems. *Am J Optom Physiol Opt* 1977;52:474–81.
46. Penisten DK, Hofstetter HW, Goss DA. Reliability of rotary prism fusional vergence ranges. *Optometry* 2001;72:117–22.

47. Schor CM, Narayan V. Graphical analysis of prism adaptation, convergence accommodation, and accommodative convergence. *Am J Optom Physiol Opt* 1982;59:774–84.
48. Rosenfield M, Ciuffreda KJ, Ong E, Super S. Vergence adaptation and the order of clinical vergence range testing. *Optom Vision Sci* 1995;72:219–23.
49. Jiménez R, Pérez MA, García JA, González MD. Statistical normal values of visual parameters that characterize binocular function in children. *Ophthalmic Physiol Opt* 2004;24:528–42.
50. Sheedy JE, Saladin JJ. Association of symptoms with measures of oculomotor deficiencies. *Am J Optom Physiol Opt* 1978;55:670–6.
51. Kaban T, Smith K, Beldavs R, et al. The 20-prism-dioptre base-out test: an indicator of peripheral binocularity. *Can J Ophthalmol* 1995;30:247–50.
52. Gall R, Wick B. The symptomatic patient with normal phorias at distance and near: what tests detect a binocular vision problem? *Optometry* 2003;74:309–22.
53. Gall R, Wick B, Bedell H. Vergence facility: establishing clinical utility. *Optom Vision Sci* 1998;75:731–42.
54. Gall R, Wick B, Bedell H. Vergence facility and target type. *Optom Vision Sci* 1998;75:727–30.
55. Charman WN. The path to presbyopia: straight or crooked? *Ophthalmic Physiol Opt* 1989;9:126–32.
56. Rosenfield M, Cohen AS. Repeatability of clinical measurements of the amplitude of accommodation. *Ophthalmic Physiol Opt* 1996;16:247–9.
57. León AÁ, Medrano SM, Rosenfield M. A comparison of the reliability of dynamic retinoscopy and subjective measurements of amplitude of accommodation. *Ophthalmic Physiol Opt* 2012;32:133–41.
58. Rosenfield M. Accommodation. In: *The Ocular Examination: Measurements and Findings* (K Zadnik, ed.). Philadelphia: WB Saunders; 1997.
59. Atchison DA, Capper EJ, McCabe KL. Critical subjective measurement of amplitude of accommodation. *Optom Vision Sci* 1994;71:699–706.
60. Kragha IKOK. Amplitude of accommodation: population and methodological differences. *Ophthalmic Physiol Opt* 1986;6:75–80.
61. Adler P, Scally AJ, Barrett BT. Test-retest reproducibility of accommodation measures gathered in an unselected sample of UK primary school children. *Br J Ophthalmol* 2013;97:592–7.
62. Woodhouse JM, Meades JS, Leat SJ, Saunders KJ. Reduced accommodation in children with Down's syndrome. *Invest Ophthalmol Vis Sci* 1993;42:2382–7.
63. Leat SJ. Reduced accommodation in children with cerebral palsy. *Ophthalmic Physiol Opt* 1996;16:385–90.
64. Wick B, Hall P. Relation among accommodative facility, lag and amplitude in elementary school-children. *Am J Optom Physiol Opt* 1987;64:593–8.
65. Rouse MW. Management of binocular anomalies: efficacy of vision therapy in the treatment of accommodative deficiencies. *Am J Optom Physiol Opt* 1987;64:415–20.
66. Sterner B, Abrahamsson M, Sjostrom A. The effects of accommodative facility training on a group of children with impaired relative accommodation – a comparison between dioptric treatment and sham treatment. *Ophthalmic Physiol Opt* 2001;21:470–6.
67. Maxwell J, Tong J, Schor CM. Short-term adaptation of accommodation, accommodative vergence and disparity vergence facility. *Vision Res* 2012;62:93–101.
68. Wick B, Yothers TL, Jiang BC, Morse SE. Clinical testing of accommodative facility: part 1. A critical appraisal of the literature. *Optometry* 2002;73:11–23.
69. Yothers T, Wick B, Morse SE. Clinical testing of accommodative facility: part II. Development of an amplitude-scaled test. *Optometry* 2002;73:91–102.
70. Siderov J, Johnston AW. The importance of the test parameters in the clinical assessment of accommodative facility. *Optom Vis Sci* 1990;67:551–7.
71. Zellers JA, Alpert TL, Rouse MW. A review of the literature and a normative study of accommodative facility. *J Am Optom Assoc* 1984;55:31–7.
72. Scheiman M, Herzberg H, Frantz K, Margolies M. Normative study of accommodative facility in elementary schoolchildren. *Am J Optom Physiol Opt* 1988;65:127–34.
73. McClelland JF, Saunders KJ. The repeatability and validity of dynamic retinoscopy in assessing the accommodative response. *Ophthalmic Physiol Opt* 2003;23:243–50.
74. Rosenfield M, Portello JK, Blustein GH, Jang C. Comparison of clinical techniques to assess the near accommodative response. *Optom Vision Sci* 1996;73:382–8.

75. McClelland JF, Saunders. Accommodative lag using Nott dynamic retinoscopy: Age norms for school age children. *Optom Vision Sci* 2004;81: 929–33.
76. Cacho PM, Garcia-Munoz A, Garcia-Bernabeu JR, Lopez A. Comparison between MEM and Nott dynamic retinoscopy. *Optom Vision Sci* 1999;76: 650–5.
77. Horwood AM, Riddell PM. Hypo-accommodation responses in hypermetropic infants and children. *Br J Ophthalmol* 2011;95:231–7.
78. Schor CM, Horner D. Adaptive disorders of accommodation and vergence in binocular dysfunction. *Ophthalmic Physiol Opt* 1989;9:264–8.
79. Ciuffreda KJ, Rosenfield M, Chen HW. The AC/A ratio, age and presbyopia. *Ophthalmic Physiol Opt* 1997;17:307–15.
80. Hung GK, Ciuffreda KJ, Rosenfield M. Proximal contribution to a linear static model of accommodation and vergence. *Ophthalmic Physiol Opt* 1996;16:31–41.
81. Rosenfield M, Rappon JM, Carrel MF. Vergence adaptation and the clinical AC/A ratio. *Ophthalmic Physiol Opt* 2000;20:207–11.
82. Le T, Koklanis K, Georgievski Z. The fixation target influences the near deviation and AC/A ratio in intermittent exotropia. *J AAPOS* 2010;14: 25–30.
83. Simons K, Elhatton K. Artifacts in fusion and stereoscopic testing based on red/green dichoptic image separation. *J Paediatr Ophthalmol Strabismus* 1994;31:290–7.
84. Frantz KA, Cotter SA, Wick B. Re-evaluation of the four prism dioptre base-out test. *Optom Vision Sci* 1992;69:777–86.
85. Lueder GT, Arnoldi K. Does “touching four” on the Worth 4-dot test indicate fusion in young children? A computer simulation. *Ophthalmology* 1996;103:1237–40.
86. Schmidt P, Maguire M, Kulp MT, et al. Random dot E stereotest: testability and reliability in 3- to 5-year old children. *J AAPOS* 2006;10:507–14.
87. O'Connor AR, Birch EE, Anderson S, Draper H; FSOS Research Group. The functional significance of stereopsis. *Invest Ophthalmol Vis Sci* 2010;51:2019–23.
88. Heron G, Dholakia S, Collins DE, McLaughlan H. Stereoscopic threshold in children and adults. *Am J Optom and Physiol Opt* 1985;62:505–15.
89. Hall C. The relationship between clinical stereo-tests. *Ophthalmic Physiol Opt* 1982;2:133–43.
90. Birch E, Williams C, Drover J, et al. Randot Preschool Stereoacuity Test: normative data and validity. *J AAPOS* 2008;12:23–6.
91. Broadbent H, Westall C. An evaluation of techniques for measuring stereopsis in infants and young children. *Ophthalmic Physiol Opt* 1990;10: 3–7.
92. Saunders KJ, Woodhouse JM, Westall CA. The modified Frisby stereotest. *J Pediatr Ophthalmol Strabismus* 1996;33:323–7.
93. Manny RE, Martinez AT, Fern KD. Testing stereopsis in the pre-school child: is it clinically useful? *J Pediatr Ophthalmol Strabismus* 1991;28: 223–31.
94. Adler P, Scally AJ, Barrett BT. Test-retest variability of Randot stereoacuity measures gathered in an unselected sample of UK primary school children. *Br J Ophthalmol* 2012;96:656–61.
95. Friedman JR, Kosmorsky GS, Burde RM. Stereoacuity in patients with optic nerve diseases. *Arch Ophthalmol* 1985;103:37–8.
96. Menon V, Bansal P, Prakash P. Randot stereoacuity at various binocular combinations of Snellen acuity. *Indian J Ophthalmol* 1997;45:169–71.
97. Odell NV, Hatt SR, Leske DA, et al. The effect of induced monocular blur on measures of stereoacuity. *J AAPOS* 2009;13:136–41.
98. Classe JG, Rutstein RP. Binocular vision anomalies: an emerging cause of malpractice claims. *J Am Optom Assoc* 1995;66:305–9.
99. Clement RA, Boylan C. Current concepts of the actions of the extraocular muscles and the interpretation of oculomotility tests. *Ophthalmic Physiol Opt* 1987;7:341–4.
100. Vivian AJ, Morris RJ. Diagrammatic representation of strabismus. *Eye* 1993;7:565–71.
101. Kowler E. Eye movements: The past 25 years. *Vision Res* 2011;51:1457–83.
102. Büttner U, Kremmyda O. Smooth pursuit eye movements and optokinetic nystagmus. *Dev Ophthalmol* 2007;40:76–89.
103. Maples WC, Ficklin TW. Interrater and test-retest reliability of pursuits and saccades. *J Am Optom Assoc* 1988;59:549–52.
104. Maples WC. *NSUCO Oculomotor Test*. Santa Ana: Optometric Extension Program Foundation; 1995.

OCULAR HEALTH ASSESSMENT

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7.1 DIFFERENTIAL DIAGNOSIS INFORMATION FROM OTHER ASSESSMENTS

During a problem-oriented examination, a list(s) of tentative diagnoses is made during the case history and this is used to determine which tests may be useful to help differential diagnosis. The list is then updated after consideration of the results from each test of the eye examination. A brief introduction to some of the relevant information regarding ocular health provided in the case history and assessments of other systems is provided here.

7.1.1 Symptoms

Blurred vision, asthenopia, headache and diplopia are most commonly caused by ametropia and decompensated heterophoria, but can be caused by diseases of the oculo-visual system. In particular, symptoms of *sudden* vision loss are suggestive of an ocular disease rather than ametropia, although such symptoms can also be due to gradual monocular vision loss that was

suddenly noticed. Gradual vision loss in elderly patients can often indicate age-related cataract and/or maculopathy. A myriad of other symptoms can accompany ocular diseases and some are characteristic, such as the association of flashes and floaters with retinal and posterior vitreous detachment. Note that some diseases, such as primary open-angle glaucoma, are generally asymptomatic until the late stages.

7.1.2 Ocular history

A history of previous ocular disease and treatment can indicate what findings should be detected during your subsequent investigations (e.g., keratic precipitates after iritis, posterior capsular remnants after cataract surgery) and a detailed ocular history can save significant unnecessary investigation. In addition, a history of certain recurring diseases, such as trichiasis, corneal erosion and blepharitis, can make subsequent diagnoses easier. A positive family history often indicates that there is a greater chance that the patient will also have the particular hereditary condition. Common familial eye diseases include age-related cataract, age-related macular degeneration and both primary open-angle and primary closed angle glaucoma.

7.1.3 General health and medications

Some systemic diseases, such as diabetes mellitus and hypertension, are well known to cause complications in the eye. In addition, certain systemic medications have a higher risk of adverse ocular effects and these should be investigated, particularly if the patient has been taking the medication for a long period and/or at high dose. For example, it is well known that beta-blockers prescribed for systemic hypertension can cause dry eyes and oral corticosteroids can cause posterior subcapsular cataracts.

7.1.4 Visual function

Optimal visual acuity measurements (section 3.2) that are different in the two eyes or are reduced compared to age-matched normal values or compared to a previous visit indicate some ocular abnormality. A pinhole visual acuity test can be used to make sure that the

reduced visual acuity is not due to an incorrect determination of the refractive correction. Reductions in visual fields and contrast sensitivity and increases in disability glare (Chapter 3) can indicate ocular disease, even when visual acuity is normal.

7.1.5 Incomitant heterotropias

Recent-onset incomitant heterotropias can be the first sign of the underlying ocular or systemic disease including diabetes, hypertension, multiple sclerosis, thyrotoxicosis, and temporal arteritis and it is therefore essential to determine if the condition is of recent-onset or longstanding (section 6.15; Table 6.5). Missing the signs of these conditions, particularly in children, is a significant cause of malpractice claims in the US.¹

7.2 EXAMINATION OF THE ANTERIOR SEGMENT AND OCULAR ADNEXA

An examination of the anterior segment of the eye and adnexa including the eyelids, eyelashes, conjunctiva, tear layer, cornea, anterior chamber, iris, crystalline lens and anterior vitreous is typically performed during most oculo-visual and contact lens assessments. It should also be performed before and after any procedure that touches the eye such as tonometry and gonioscopy to determine the presence and severity of any iatrogenic damage.

7.2.1 Comparison of tests

Slit-lamp biomicroscopy examination is greatly preferred over direct ophthalmoscopy, penlight and loupe or Burton lamp assessment as it provides much greater resolution, depth of field and control of illumination, as well as higher illumination and more variable and greater magnification (from about 10× to 40×). Involuntary eye movements reduce the clarity of highly magnified images and limit the value of increasing the magnification beyond 40×. The quality of the image is better in slit-lamp models that have higher optical quality lenses that use multi-aspheric lens designs and anti-reflection coatings. Disadvantages include that slit-lamp examination can produce discomfort in some patients who are photophobic due to the high illumination and obese patients or those that have neck or back problems may find positioning themselves in the slit lamp uncomfortable.

7.2.2 Procedure

See online video 7.1 for general slit-lamp examination. Familiarity with the adjustment controls of the slit lamp is required. The positions of the controls differ for different models but all slit lamps have similar features. It should be possible to change the width and height of the beam, rotate the beam, change the angle between the light source and viewing system, add filters over the light source (Table 7.1), change the magnification (this may involve changing the eyepieces to a stronger power), change illumination intensity, adjust the microscope height and focus the microscope with the joystick. With most instruments it is possible to break the linkage between the illumination and viewing systems (decoupling), which allows focus on a point other than that being illuminated.

Brands of slit lamps differ in their illumination and their observation systems. The Haag-Streit type slit lamps have a tower illumination system with the bulb above a mirror. This system has the advantage of being able to be decoupled in the vertical meridian, which is helpful when the slit lamp is used for gonioscopy or fundus examination. Magnification is provided in one of three ways, a flip magnification system (the most basic with magnification typically provided at 10× and 16×), a rotating barrel or zoom continuous magnification (typically from 10× to 40×). Slit lamps also differ in the degree of convergence of the microscope and clinician preference seems to vary depending on their own convergence stability.

1. Wash your hands thoroughly and clean the slit-lamp contact surfaces with a sterile wipe in front of the patient.
2. If one is available, place the focusing rod in the appropriate holder, with the flat surface towards the viewing system. Normally, you will perform the biomicroscope examination without glasses, as the field of view is greater the closer your eyes are to the slit-lamp eyepieces. If you have a high cylinder in your glasses, you may need to wear your correction to obtain adequate resolution. To focus the eyepieces, first switch on the illumination system to produce a slit-image on the focusing rod. Look through one eyepiece and turn it fully counter clockwise (plus direction) then, while viewing the focusing rod, turn the eyepiece clockwise until the slit-image on the rod is first in sharp focus. Repeat the procedure for the other eyepiece. The eyepiece should be set at approximately zero if you are an emmetrope or wearing your correction and set to your mean sphere



Table 7.1 Filters available on most slit-lamp biomicroscopes

Filter	Typical symbol	Use
Cobalt blue	Blue filled circle	Enhances the view of fluorescein dye in the tear film of the eye. Typically used for fluorescein staining and Goldmann tonometry.
Red free	Green filled circle	Used to enhance the view of blood vessels and haemorrhages
Neutral density	Circle with hashed lines	Decreases maximum brightness for photosensitive patients
Heat absorbing	Built into most slit lamps	Decreases patient discomfort
Grey	Circle with thick line	Decreases maximum brightness for photosensitive patients
Yellow filter	Yellow filled circle Located in the observation system	For good contrast enhancement when using fluorescein and the cobalt blue filter
Diffuser	May be a flip-up filter placed on the illumination source	Used for general overall observations of the eye and adnexa

correction (sphere + half of cylinder) if you are not wearing your glasses. More minus might be required in younger practitioners due to proximal accommodation. Once you have each eyepiece focused, adjust the distance between the eyepieces so that the image is centred in the field of view of each eye. You should see a single clear image.

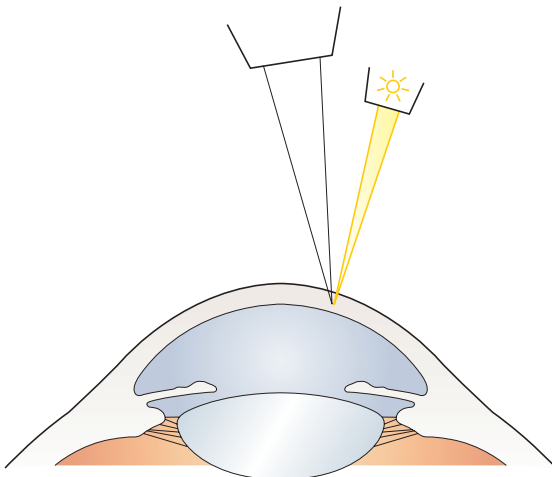
3. Seat the patient comfortably on a stable chair without rollers, and ask the patient to remove any glasses. Explain the procedure in lay terms to your patient: 'I am going to use this special microscope to carefully examine the front of your eyes.'
4. Adjust the height of the biomicroscope table so that the patient may lean forward comfortably and place their chin in the chin rest and forehead against the forehead rest. Adjust the chin rest so that the patient's eyes are at an appropriate height to provide a large enough vertical range to allow adequate examination of the adnexa. Many biomicroscopes have an eye alignment marker on a supporting beam of the headrest that should be level with the patient's outer canthus. If your patient is obese, an exaggerated bend at their waist will often allow satisfactory positioning. Having the patient hold onto the handles if available can also be helpful.
5. Dim the room lights and ask the patient to look at your ear (your right ear for the patient's right eye and your left ear for the patient's left eye) or the instrument's fixation device so that the patient's gaze is in the primary position.
6. Use one hand to control the joystick (focusing and lateral/vertical movement) and the other to control the magnification and illumination and to manipulate the patient's eyelids. A useful tip is to have a low rheostat setting for a wide, diffuse beam (for patient comfort) and a high rheostat setting for a narrower beam, or when filters are used, to give sufficient image contrast.
7. There are several types of illumination that with experience you will use alternately or in combination to thoroughly examine the anterior segment and adnexa. A general procedure is to use diffuse illumination followed by a parallelepiped and is described below. This is followed by descriptions of additional techniques with examples of when they might be used.
8. **Diffuse illumination:** Provides an overall assessment under low magnification (~10×). Adjust the illumination to a wide beam and place a diffusing filter in front of it to systematically examine the components of the anterior segment and adnexa as described below.

9. **Direct illumination using a parallelepiped:**

Use low to moderate magnification ($\sim 10\times$) as magnification that is too high will result in missing obvious, moderately sized abnormalities. Set the illumination system at approximately 45° from the microscope position on the temporal side and use a beam width of approximately 2 mm. An illuminated block of corneal tissue in the shape of a parallelogram should be visible (Figure 7.1). A beam that is too narrow will make it difficult to detect abnormalities. Assess each of the structures described below in a systematic manner using the following procedure: Focus on the temporal tissue first with the illumination coming from the temporal side. Move the slit lamp laterally across the tissue until the centre is reached, maintaining good focus at all times. Then sweep the illumination system across to the nasal side, taking care not to bump into the patient's nose, and examine the nasal tissue. This scanning procedure may be repeated several times to examine all areas of the tissue concerned and may require more than one level of magnification. Being able to keep a parallelepiped sharply in focus as you scan from temporal limbus to central cornea and then nasal limbus to central cornea, is the foundation for good slit-lamp technique.

- (a) Eyelids and lashes: Examine the superior eyelid and lashes first using the scanning procedure described above. This can be easier with the patient's eyes closed. Examine the inferior lid and lashes in the same manner, while also examining lid apposition to the eye and meibomian gland appearance (section 7.3.3). Assess the lid for anomalies including an abnormal lid position (e.g., ptosis, entropion, ectropion), redness, inflammation, ulcers and growths. Inspect the lashes for colour (e.g., white), areas where the lashes are missing or misdirected and the presence of scales.
- (b) Conjunctiva: Ask the patient to look upwards while you pull the lower eyelid gently downward to expose the lower fornix for examination. Examine both the bulbar and palpebral conjunctiva using a scanning process. Next ask the patient to look downwards and gently pull up the upper eyelid, thereby exposing the superior bulbar conjunctiva for examination. Finally ask the patient to look in right and then left gaze to allow examination of the entire conjunctiva, plica and the caruncle.
- (c) Cornea and tear film: Use the scanning process to examine the cornea in three sweeps: inferior, central and superior.

(a)



(b)

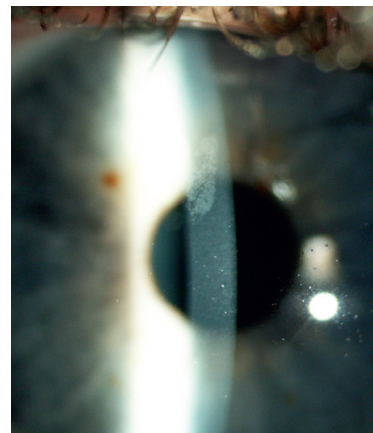
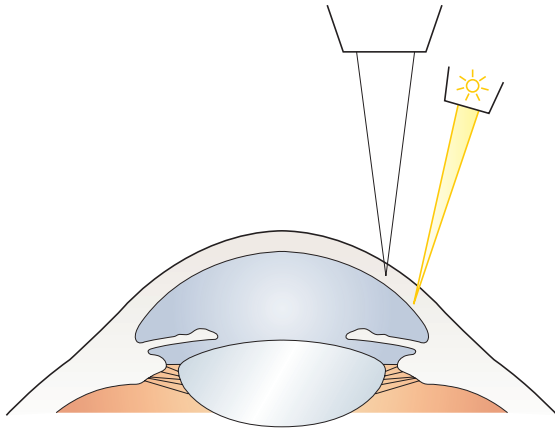


Fig. 7.1 (a) Diagram illustrating the position of the illuminating and viewing systems when using direct illumination. (b) A parallelepiped section of the cornea showing an irregularity above the corneal apex.

(a)



(b)

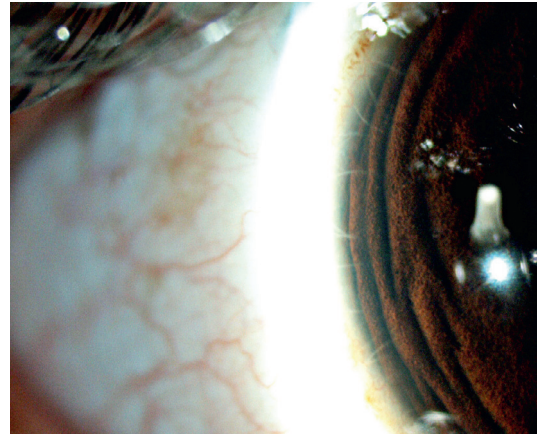


Fig. 7.2 (a) Diagram illustrating the position of the illuminating and viewing systems when using indirect illumination. (b) Corneal nerve fibres seen in indirect illumination.

Examine the inferior cornea by having the patient look up and the superior cornea by having the patient look down while holding up the upper eyelid. With increasing experience you will be able to look at both the area illuminated (direct illumination, [Figure 7.1](#)) and the area just outside the area of illumination (indirect illumination, [Figure 7.2](#), examples in [Figures 8.12, 8.16](#)). It can be useful to assess the tear film after a blink and note the quantity and type of debris if any. You can increase the width of the section of stroma seen by increasing the angle between the microscope and illumination system. You can obtain greater detail by increasing the magnification.

- (d) Assessment of the tear meniscus: The height of the tear meniscus can be estimated by decreasing the height of the slit-lamp beam to one millimetre and then judging the relative height of the meniscus at the lower lid margin as a proportion of the beam height.
- (e) Iris: Examine the iris with direct illumination by moving the joystick towards the patient. Take note of the depth of the anterior chamber and the shape of the pupil.
- (f) Lens: For a non-dilated pupil the illumination angle must be reduced until an optic section of the lens is just seen. This may be as small as 15° for an elderly

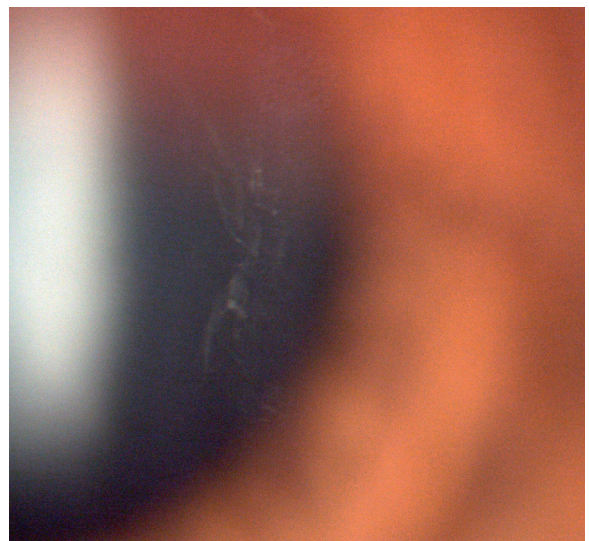


Fig. 7.3 Vitreous floaters seen in the anterior vitreous by direct illumination.

patient with a small pupil. Further discussion of slit-lamp assessment of cataract under mydriasis is provided in [section 8.4](#).

- (g) Anterior vitreous: Moving the joystick further towards the patient allows viewing of the anterior vitreous with a parallelepiped when the pupil is dilated. To look for anterior vitreous floaters ([Figure 7.3](#)), it can be useful to ask the patient to look up, look down and then

straight ahead, so that the opacities become visible as they float through the field of view (see online video 8.1).



7.2.3 'Specialised' slit-lamp techniques



See online video 7.2. If an abnormality/anomaly is suspected from the case history or detected during a routine slit-lamp examination, one or more of the following illumination techniques may be used. With experience many or all techniques are used in fast succession. The slit-lamp magnification can be varied to examine the anomaly more carefully noting its size, shape, appearance, depth and location.

1. Optic section

This is a type of direct illumination in which the illumination beam is narrowed to allow a judgement of depth of any abnormalities within the cornea or lens (Figure 7.4). For example, it can be used to judge the depth of a foreign body in the cornea, whether an opacity is anterior or posterior cortical or subcapsular and is the technique used to grade nuclear lens opacity (section 8.4).

1. Set the illumination system at approximately 45° from the microscope using low to moderate magnification (~10×).
2. If the area of the cornea/lens you wish to view is temporal, place the illumination on the

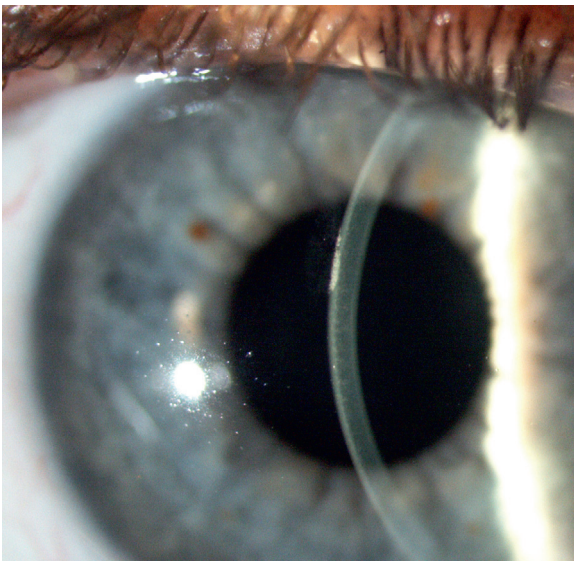


Fig. 7.4 A corneal section indicating that the corneal abrasion shown in Figure 7.1 is in the corneal epithelium.

temporal side and if it is nasal, place it on the nasal side.

3. Narrow the beam to the narrowest possible width and sharply focus on the cornea/lens using the joystick. As you have greatly narrowed the beam, you need to increase the slit-lamp illumination using the rheostat.
4. A slice of the cornea/lens should now be visible (cornea, Figure 7.4; lens, Figure 7.5; nuclear cataract, Figure 8.22). If the illumination system is temporal to the viewing system, the corneal epithelium or anterior lens will be on the temporal side of the image with the corneal endothelium or blurred posterior lens on the nasal side.
5. To view the posterior lens, the joystick needs to be moved further forward and the angle of the illumination system may need to be reduced further, depending on the pupil size.
6. The section of corneal stroma can be broadened by increasing the angle between the microscope and illumination system. The focusing should be precise enough to allow the graininess of the stroma to be visualised.
7. Once the object of interest is identified, increase the magnification to obtain greater detail.

2. Indirect illumination

This technique (Figure 7.6) is used to view areas that become bleached with excessive light using direct illumination, such as fine blood vessels at the limbus and



Fig. 7.5 An optical section of the lens anterior cortex (on the left side within the pupil) and lens nucleus (central). The posterior cortex is blurred and on the right side of the pupil. The blurred arc to the left is the out-of-focus cornea.

microcysts. It is also used to look for iris features such as the outer rim of the iris sphincter.

1. Use a 1–2 mm parallelepiped, low to moderate magnification ($\sim 10\times$) and set the illumination system at $\sim 45^\circ$ from the microscope.
2. Rather than focus on the illuminated area (direct illumination), simply direct your gaze just outside the area that is illuminated (indirect illumination). Subtle abnormalities can be seen using light scattered by the cornea away from the main area of illumination.
3. Increase the magnification as required.

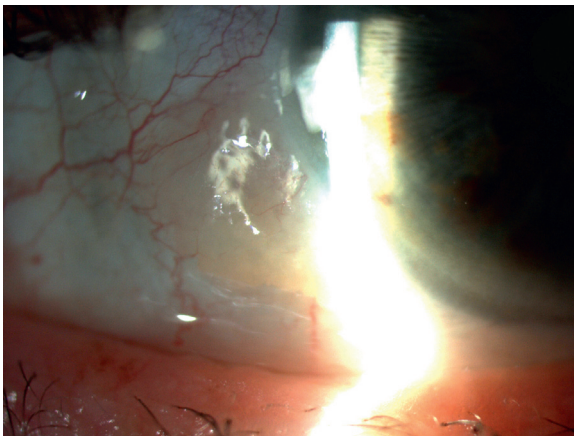


Fig. 7.6 A pinguecula seen in indirect illumination by viewing outside the illuminated area.

4. The technique can also be used after decoupling the illumination and viewing systems.

3. Specular reflection

This technique is used to examine the endothelium (for polymegethism and pleomorphism), the precorneal tear film and variations in contour of the epithelium.

When learning this technique, it is best to start by attempting to obtain an image of the anterior lens surface by specular reflection ([Figure 7.7](#)).

1. Set the illumination system at approximately 30° to 45° from the microscope, using a moderately wide 2–3 mm parallelepiped. Look through the eyepieces and focus the parallelepiped on the anterior lens.
2. Change the angle of illumination until the reflection of the instrument lamp is seen from the lens surface. This occurs when the angle of incidence equals the angle of reflection from the lens ([Figure 7.7a](#)).
3. View the orange peel textural appearance of the anterior lens ([Figure 7.7b](#)) to the side of the bright reflex.
4. To examine the tear film and epithelium, set the illumination system at approximately 45° to 60° from the microscope, using a moderately wide 2–3 mm parallelepiped. Look through the eyepieces and focus the parallelepiped on the cornea. Ask the patient to blink and use the particles floating in the tear film to help you focus.

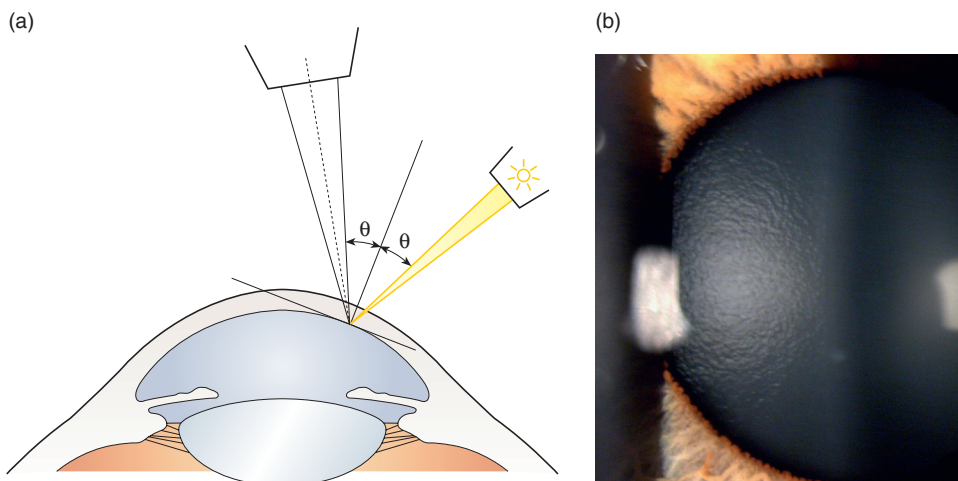


Fig. 7.7 (a) Diagram illustrating the position of the illuminating and viewing systems when using specular reflection to view the corneal endothelium. (b) Specular reflection from the anterior surface of the lens showing its orange peel appearance.

5. Change the angle of illumination until a bright reflection is seen from the precorneal tear film. This occurs when the angle of incidence equals the angle of reflection from the cornea. This can also be obtained by moving the illumination/microscope system laterally until the two angles are equal.
6. To examine the endothelium, set the magnification to about 16× with a fairly wide 2–3 mm parallelepiped and initially focus on the tear film.
7. Alter the illumination angle and/or lateral position of the slit lamp until the bright corneal reflexes (Purkinje images) fall on top of the corneal section. There should be two reflexes: On the epithelial side of the corneal section there should be a bright white reflex from the tear film (conjugate with the epithelium) and on the endothelial side a less bright, slightly yellowed reflex from the endothelium. You may need to alter the angle of illumination very slightly to separate the two reflections.
8. Increase the magnification to about 40× and move the joystick slightly forward to focus on the endothelium. If you then look to the side of the dull endothelial slightly yellowed reflex (nasal or temporal to the reflex depending on the position of the illumination system) the duller picture of the endothelial hexagonal cells will be in view.

4. Eyelid eversion

This technique is used to examine the superior and inferior palpebral conjunctivae, particularly in contact lens wearers and when looking for allergic conjunctival changes, papillae, and foreign bodies.

1. Ask the patient to look down and grasp the superior eyelashes and pull them slightly away from the eye. It can be useful to press a cotton bud onto the superior lid to lift it away from the inferior lid, making it easier to grab just the superior lashes.
2. Gently press down on the superior margin of the tarsal plate at the crease using a cotton swab (or the index finger or thumb of the other hand), and at the same time pull the eyelashes up and over the cotton bud. This technique will evert the eyelid to permit viewing of the superior palpebral conjunctiva (Figure 7.8) using a parallelepiped.
3. To re-evert the eyelid, hold the eyelashes and ask the patient to look up and gently pull the eyelashes away from the eye.



Fig. 7.8 The superior palpebral conjunctiva viewed after lid eversion.

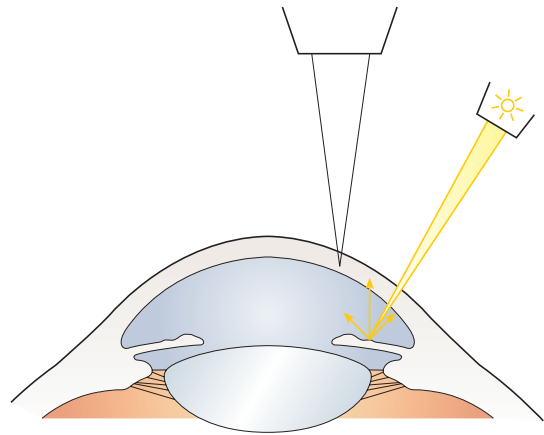


Fig. 7.9 Diagram illustrating the position of the illuminating and viewing systems when using retro-illumination from the iris.

4. To evert the lower eyelid, pull the eyelid down and press under the eyelid margin while moving your finger upwards. The eyelid will evert over your finger.

5. Retro-illumination from the iris

This technique (Figure 7.9) is used in the examination of corneal vessels, epithelial oedema, pigment deposits or keratic precipitate on the endothelium and small scars on the cornea using light reflected from the iris. Opaque features appear dark against a light background.

1. Use a 1–2 mm parallelepiped with low magnification and set the illumination system to an angle of about 45°.

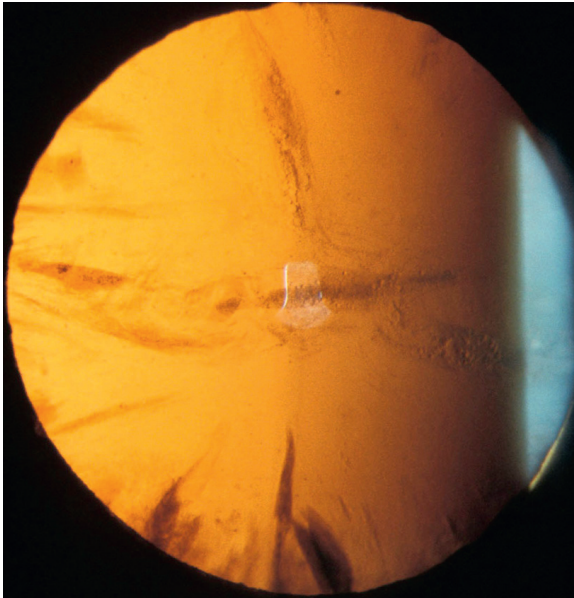


Fig. 7.10 A cortical cataract seen in retro-illumination from the fundus.

2. If it is possible to view the abnormality in direct illumination, bring it into focus and then lock the joystick position.
3. Decouple the illumination and viewing systems, direct the light onto the iris and view the structure against the light reflected from the iris. The magnification can be varied as necessary.

6. Retro-illumination from the fundus

This is a commonly used technique to examine iris disorders and cataracts using light reflected from the fundus. Cataracts are seen as dark opacities against the red background glow from the fundus (Figures 7.10, 8.20–8.24) and it is a particularly useful for examination of cortical and posterior subcapsular cataracts (section 8.4). Retro-illumination can also be used to detect iris abnormalities such as peripheral iridotomies and loss of pigment (iris transillumination, Figure 7.11). In this case, the red glow of the fundus is seen through the iris. The shape and location of the defects can help in identifying the cause of the transillumination.

1. Use a 1–2 mm parallelepiped with low magnification and set the illumination system to an angle of 0°. Adjust the beam height to the height of the pupil.
2. Focus on the iris or lens as appropriate.
3. You will only be able to focus the anterior or posterior part of the lens at any one time. You

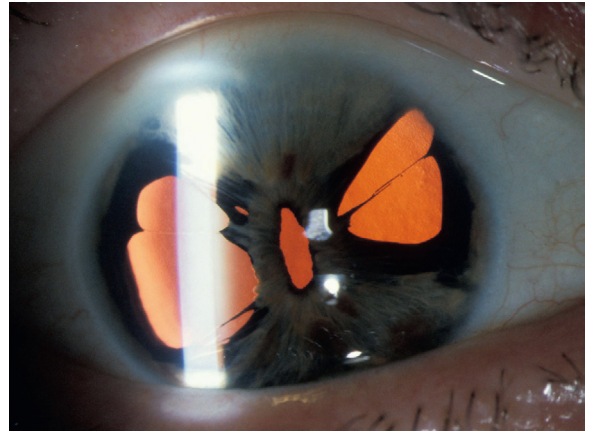


Fig. 7.11 Iris transillumination. Loss of localised iris pigment is shown by the red fundal glow appearing through parts of the iris when light is shone through the pupil. (Courtesy of Dr David Williams, University of Waterloo.)

- can gain an approximate focus on the anterior lens by focusing the iris. To focus the posterior lens you will need to push the joystick forwards (towards the patient). To gain a retro-illumination image of the lens with an undilated small pupil, you may need to decouple the instrument slightly and alter the angle of illumination by a small amount.
4. Observe any illumination coming through the iris. While lens opacities are best observed with the pupil dilated, iris transillumination is best observed before dilation.

7. Sclerotic scatter

Sclerotic scatter involves observing the cornea while the illumination is directed at the limbus. The light is totally internally reflected in a healthy cornea and creates a glowing halo of light where it escapes from the opposite limbus (Figure 7.12).

1. Turn off the room lights to keep the surrounding light levels as low as possible so you can observe subtle amounts of light scatter.
2. Set the magnification at about 10× and use a 1–2 mm slit at about 45°. Focus the central cornea by ensuring the particles in the tear film are focused. Asking the patient to blink will move the tear film debris making them easier to find. Lock the slit-lamp position to ensure the viewing system remains focused on the central cornea.

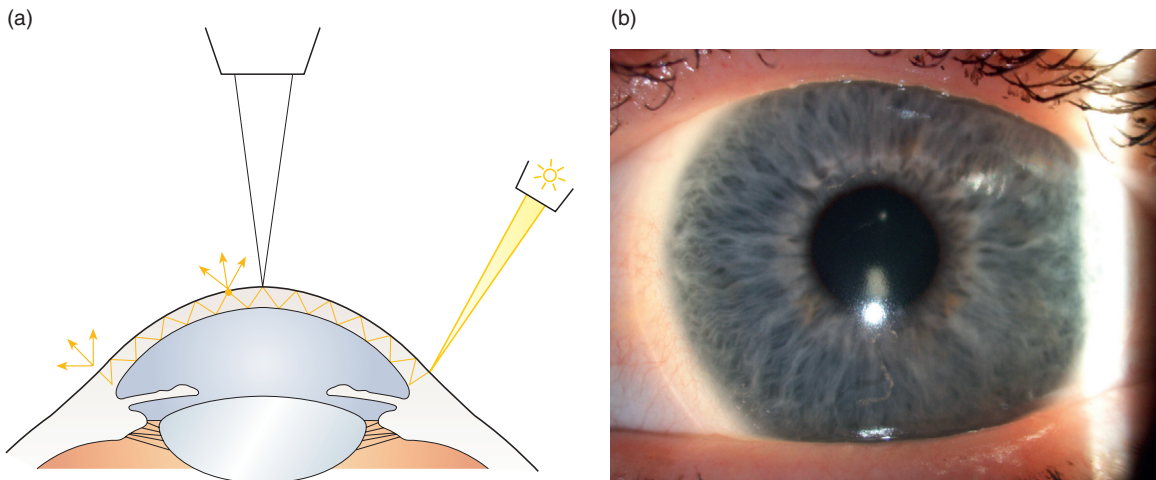


Fig. 7.12 (a) Diagram illustrating the position of the illuminating and viewing systems when using the sclerotic scatter technique. (b) Sclerotic scatter showing an S-shape of contact lens deposits.

- Decouple the illumination and viewing systems and from 45–60° on the temporal side, move the 1–2 mm slit onto the temporal limbus. Ideally, shorten the length of the slit so that it enters at the limbus. Any extra slit length can produce light scatter from the sclera that may reduce the visibility of subtle defects.
- Although you can scan the cornea for areas of light scatter with the naked eye, it is preferable to view it using the decoupled slit-lamp viewing system. Iatrogenic damage due to novice contact tonometry or gonioscopy use, foreign bodies, scars and central corneal clouding due to rigid contact lens wear can all be observed with this technique.

8. Anterior chamber assessment

This technique is used to look for flare (i.e., protein) or floating cells in the anterior chamber (by using more magnification and a longer beam). The following procedure has been recommended by the Standardization of Uveitis Nomenclature Working Group.²

- Turn off all the room lights and close your own eyes for a few minutes to start to dark-adapt.
- Set the illumination system at approximately 45° from the microscope using moderate magnification (~16×).
- Narrow the height and width of the beam to obtain a beam 1 mm by 1 mm in size. Move the beam to the centre of the pupil and focus in the anterior chamber midway between the anterior surface of the crystalline lens and the posterior

surface of the cornea. Focusing forward and back within the anterior chamber will facilitate the viewing of cells.

- Cells are a sign of active inflammation and should be counted in the grading process. Aqueous flare is the result of leakage of protein through damaged iris blood vessels and is graded by the degree of obscuration of the iris details.

9. Double eyelid eversion

This technique is used to find small foreign bodies in the superior fornix. Care should be taken to minimally irritate the palpebral conjunctiva. The eyelid is not actually everted twice.

- Sterilise Desmarres Lid Retractor using an alcohol wipe.
- Instil anaesthetic and fluorescein into the eye.
- With the patient at the slit lamp, single-evert the upper eyelid. Use the Desmarres lid retractor to hook under the everted tarsus with the blade placed between tarsus and bulbar conjunctiva.
- Gently pull up and out to expose the fornix.
- Observe for any small foreign bodies using fluorescein and the cobalt blue filter on the slit lamp or irrigate the fornix in free space to try to dislodge any foreign bodies.

7.2.4 Recording

Normal appearance: If no abnormalities are detected, record 'clear' if the tissue is transparent, such as

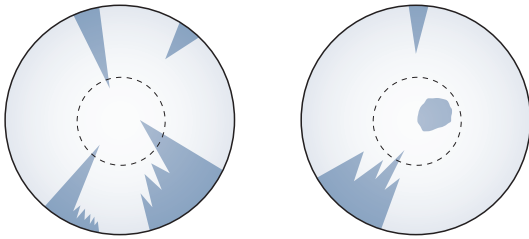


Fig. 7.13 Recording of cataract.

the cornea and lens. Otherwise record 'No abnormalities detected' (NAD) or 'Within normal limits' (WNL) or equivalent.

Anomalies/abnormalities: Record the size, shape, appearance and location of any abnormalities/anomalies using a diagram and a written description as well as digital imaging if available. In addition, observations such as fluorescein staining, corneal oedema, conjunctival anomalies (papillae, follicles), injection and vascularisation may be graded on a scale of 0 to 4+ with 0 being absence of a response, 1+ being trace response, 2+ being mild response, 3+ being moderate response and 4+ being severe response.

Cataracts: Unless digital imaging is available, record cortical and subcapsular cataracts by drawing them (Figure 7.13). The undilated pupil can be recorded as a dashed line on this diagram. If there are cortical opacities in both the anterior and posterior cortex, both should be recorded. Nuclear yellowing and opacification can be graded on a scale of 0 to 4+ with 0 being absence of opacity and 4+ being the most severe form of opacity. For more precise grading, a cataract grading system such as the LOCS III system may be used.³ In this type of system the cataract is graded on a decimal scale against standardised colour photographs.

Cells and flare: Cells in the anterior chamber are graded according to the number observed with grade 0 being <1 cell, 0.5+ being 1–5 cells, 1+ being 6–15 cells, 2+ being 16–25 cells, 3+ being 26–50 cells, and 4+ being >50 cells.² Aqueous flare is graded from 0–4+ depending upon the visibility of the iris detail; with grade 0 being no flare, grade 1+ being faint flare, 2+ being moderate (iris and lens details remain clear), 3+ being marked (iris and lens details are hazy), and 4+ being intense (fibrous or plastic aqueous).

Contact lens complications: Contact lens complications can be graded by using the Centre for Contact Lens Research Unit (CCLRU) or the Efron grading scales (Section 5.6).⁴

7.2.5 Interpretation

A good understanding of the normal anatomy and physiology of the anterior segment and adnexa as well as the normal changes with age is required. Variations in normal appearance of the anterior segment and changes with age are discussed in Chapter 8.

7.2.6 Most common errors

1. Not positioning the slit lamp so that the patient is leaning forward into the chin rest. This often results in the patient not being able to maintain their forehead against the headrest, resulting in the image going in and out of focus.
2. Not focusing the eyepieces to compensate for your refractive error.
3. Not increasing the brightness when narrowing the beam or using a filter.
4. Not maintaining a sharp focus as the beam is swept across the eye.
5. Not developing a smooth, logical routine that can be repeated.

7.3 TEAR FILM AND OCULAR SURFACE ASSESSMENT

The tear film is usually assessed during the slit-lamp examination of the anterior segment, and is specifically indicated in those wearing or wishing to wear contact lenses (Chapter 5), patients who have undergone or wish to undergo refractive surgery and patients with any symptoms of dry eye or a history that might suggest susceptibility (e.g. patients taking medications that include beta-blockers, antihistamines, oral contraceptives and acne medications, and smokers).⁵ The incidence of dry eye is increased following laser refractive surgery and nearly half of contact lens wearers report symptoms of dryness.^{6,7} Dry eye is a multifactorial disease that results in symptoms of discomfort, visual disturbance and tear film instability with potential damage to the ocular surface and is accompanied by increased osmolarity of the tear film and inflammation of the ocular surface.⁸ It is classified based upon aetiology as either aqueous tear-deficient or evaporative. Aqueous deficient dry eye includes Sjögren syndrome (autoimmune) and non-Sjögren syndrome dry eye and evaporative types are classified according to intrinsic causes (e.g., meibomian gland dysfunction) and extrinsic causes (topical drug preservatives, contact lens wear and ocular surface disease such as allergy).⁸ Symptoms commonly include irritation, dryness,

foreign body sensation, burning, gritty sensation, transient blurring of vision, stinging pain, epiphora and contact lens intolerance. Less commonly mentioned symptoms include haloes around lights (especially at night), excessive tearing, stringy mucus discharge, redness, photophobia, itching and asthenopia. Patients often report closing their eyes to obtain some relief.

In primary eye care, practitioners are most commonly trying to diagnose and manage marginal rather than severe cases of dry eye. A patient with marginal dry eye is likely to exhibit signs and symptoms when the relationship between the tear film and the ocular surface is under stress, such as when fitted with a contact lens, or when undertaking concentrated tasks that reduce the blink rate, such as reading, using display screen equipment or driving. Environmental factors such as wind, air conditioning, airline travel and low humidity indoors in winter months can produce similar effects. Those with more serious dry eye disease will have an exacerbation of their symptoms under such conditions.

The international standard criteria for dry eye diagnosis is symptom assessment, interpalpebral surface damage, tear instability and tear hyperosmolarity. Although tear hyperosmolarity is mentioned as part of the criteria for diagnosis, it is currently impractical to measure in the clinical setting.⁹ Assessments appropriate for primary care would include symptom recording, including by standardised questionnaire, lower tear meniscus height, tear break-up time, tear volume by Schirmer or phenol red thread test, grading of conjunctival and corneal fluorescein staining and meibomian gland expression.⁷

Lacrimal occlusion can also be useful for the patient with marginal dry eye who wishes to continue wearing contact lenses, as well as for short-term occlusion during the healing process after ocular surgeries such as LASIK.^{6,10} Patients must be evaluated for the suitability for use of punctal or intracanalicular plugs as they are relatively expensive and reversal of the occlusion may be difficult in some cases if patient selection was inappropriate and excess tearing or complications occur. Temporary occlusion with dissolvable collagen plugs is a relatively inexpensive diagnostic test which allows the determination of suitability for therapeutic occlusion options.

7.3.1 Comparison of tests

Ocular surface damage caused by dry eye can be assessed using various vital dyes such as fluorescein, lissamine green and rose bengal. Fluorescein, which

can pool in an indentation and is taken up by damaged cells and adheres to the surface of cells is the standard assessment for ocular surface damage.^{11,12} Lissamine green exhibits staining properties that are similar to rose bengal, but with significantly less toxicity and discomfort.¹³ Indeed, now that lissamine green is in widespread use, rose bengal tends to be rarely used in primary eyecare and is reserved for assessing more severe dry eye cases. Lissamine green stains dead and devitalised cells along with mucin but is not toxic to healthy cells. It is particularly useful for viewing more subtle conjunctival damage, in suspected marginal dry eye, patients with ocular allergies and current or potential contact lens wearers.

Tear break-up time (TBUT) is fast, easy to perform and comfortable for the patient. It requires equipment that is standard to optometric practice such as a biomicroscope with a cobalt blue filter and sodium fluorescein. The main disadvantage of the technique is that it is intrinsically invasive. In addition, a localised corneal surface abnormality will typically produce a break-up of the tear-film in that location and can suggest a falsely low TBUT. However, although a wide variability of the TBUT is present in normal individuals, a TBUT shorter than 10 sec has sufficient specificity to screen patients for evidence of tear film instability.¹⁴

Evaporative dry eye can be assessed with meibomian gland evaluation, the evaluation of lid and blink dynamics and lid anomalies causing poor lid closure. Aqueous deficient dry eye can be detected using tear flow/volume tests, such as the assessment of the tear meniscus and the Schirmer and phenol red thread tests.⁷ Note that these conditions are not mutually exclusive as meibomian gland dysfunction is present in 70% of patients with aqueous-deficient dry eye.¹⁴ The phenol red thread test is very easy to perform and patients generally tolerate it well as only a soft thread is touched to the lid and the results are obtained in 15 seconds per eye. Due to the relatively quick assessment, it is useful for examining the tear volume before and after insertion of lacrimal occlusive devices. The Schirmer tear test uses a 5 by 35 mm strip of filter paper to measure basic and reflex tear secretion when used without anaesthetic. The Schirmer test is used in severe dry eye patients and as part of the definition of Sjögren syndrome, although research has suggested that it has limited reliability and validity.¹⁴⁻¹⁶

Short-term dissolvable collagen plugs are the only diagnostic test that determines whether more permanent punctal and intracanalicular plugs are suitable for the patient. They imbibe water and expand in the canaliculus to approximately two times their

diameter, then proceed to dissolve in 4–7 days. After approximately one week, the patient is asked to return and subjective and objective assessments of dry eye are compared pre- and post-insertion of the plugs. The only decisions to be made are the number of implants required and which canaliculi to occlude. More than one trial of collagen implants may be required to prove to you and/or the patient that (semi-)permanent plugs will be a useful therapeutic option for their particular case. For example, patients with poor corneal sensitivity from nerve damage or chronic ocular surface disease may be unable to detect an improvement in comfort during the course of the collagen trial, and therefore may feel that long-term occlusion options will not be helpful for them. In those cases, the objective signs are more helpful in determining suitability and therefore repeated trials may be considered to monitor the corneal and conjunctival health to determine if occlusion is advisable. It is also generally true that a single collagen plug (even the largest size that can fit into the punctal opening) is often insufficient to appropriately occlude a canaliculus and therefore may generate a false negative trial. This is because the diameter of the canaliculus may be unrelated to the size of the punctum and a single plug may migrate out of the system before it has had the opportunity to imbibe water and occlude the drainage. Similarly, some clinicians occlude only the inferior canaliculi for the diagnostic test. While this may be appropriate in some circumstances, it is also more likely to generate a false negative diagnostic test. Full occlusion, even if it generates some degree of epiphora, is generally preferred and is short-lived. Measurement of tear thinning time suggests that superior plug insertion may not be necessary and that occlusion of the lower punctum is sufficient, although occlusion of both prolonged the preservation of tear volume.¹⁷

7.3.2 Procedure for corneal and conjunctival staining

The procedure for fluorescein instillation is provided here. The procedure for lissamine green is performed in exactly the same way, except that approximately twice the volume of the dye is required. You should wait 2–3 min before examining the eye and white light is used with the contrast enhanced using a red filter (Wratten 25).

1. Wet the tip of a fluorescein strip with sterile saline solution. Be careful not to contaminate the saline by touching the strip to the tip of the bottle. Shake excess fluid from the strip over a

sink (too much fluid will delay the time to maximum fluorescence and may drip onto and stain the patient's lids and cheeks).

2. Ask the patient to look up and touch the strip to the inferior bulbar or tarsal conjunctiva, being careful not to touch the cornea. Do not use a sweeping movement to 'paint' the conjunctiva as it can provide too much fluorescein and create unnecessary discomfort for the patient. The strip can also be touched to the upper bulbar conjunctiva, but this has the disadvantage that if the patient blinks or attempts to blink, the eye will rotate upwards (Bell's phenomenon) and the strip may scratch the superior cornea. Ask the patient to blink several times to allow the fluorescein to spread across the cornea. Remove any excess fluorescein using a tissue and be careful not to spill the dye on the patient's clothes as a stain will result.
3. With the patient at the biomicroscope, observe the cornea with cobalt blue light and medium magnification. When you are using the cobalt blue light, you will need to increase the illumination. A Kodak Wratten number 12 yellow gelatin filter held in front of the biomicroscope viewing system will facilitate the view by filtering out the reflected blue light. Newer slit lamps have this filter as a built-in option over the observation system. Observations should be made within 10 min of instillation of the dye otherwise intercellular diffusion surrounding a lesion may mask its exact nature.
4. It can be useful to examine the eye using both diffuse illumination and then a wide parallelepiped beam, altering the angle of the illumination throughout.
5. In addition to the standard examination, evert the upper eyelid to inspect its inner margin for staining due to lid wiper epitheliopathy caused by friction, secondary to dry eye.⁹ Also inspect the lower lid margin for parallel bulbar conjunctival folds.¹⁸
6. Soft contact lens wearers can replace their lenses after a biomicroscopic investigation using fluorescein or lissamine green as long as the dye is irrigated out of the eye using saline prior to lens reinsertion. Otherwise irrigation is not necessary. An alternative is to use Fluorexon which is a high molecular weight fluorescein that will not penetrate into a soft contact lens.

7.3.3 Procedure for meibomian gland evaluation

1. Assessment should be done after other tests used in the diagnosis of ocular surface disease.⁷
2. With the patient at the biomicroscope, use white light and medium magnification to inspect the lower eyelid margins.
3. Look for stenosis and closure of the meibomian gland orifices, inspissated (thickened and blocking the glands) secretions and frothing of the tears on the eyelid margins. The lids should be examined closely for telangiectasis of vessels on the lid margin, notching of the gland openings and migration of these openings towards the posterior surface of the lids, all indicative of chronic disease.
4. Pull the lower eyelid down and look for concretions (section 8.2.8) in the palpebral conjunctiva.
5. Inform the patient that you are going to press on his or her eyelid and that they will feel some pressure. With the patient looking up, apply moderate pressure on the lower eyelid margins near the eyelashes, while observing the meibomian gland orifices and assess the expressibility and secretion quality. Clear fluid should be expressed. If this is not the case apply pressure over the central third of the upper and low lids to determine the extent and severity of the dysfunction.⁷
6. Capping of the orifices, a cheesy secretion on expression and frothing of the eyelid margins indicates meibomian gland dysfunction. Another method of assessing the meibomian gland function is to determine the position of the *Marx line* which is a clear line running along the lower lid margin after fluorescein or lissamine green is instilled into the eye. In normal eyes this line is located on the conjunctival side of the meibomian gland orifices and in meibomian gland dysfunction it is located on the cutaneous side of the orifices.¹⁹

7.3.4 Procedure for tear break-up time (TBUT)



See online video 7.3. TBUT is used to assess the stability of the tear film between blinks. Dry spots appear in the tear film that are thought to form by evaporation and retraction of the tear film after each blink and by diffusion of the superficial lipid through the aqueous layer to the mucin surface. Topical anaesthetics should

not be used prior to TBUT measurement, as this may cause a further reduction in TBUT.

1. With the patient at the biomicroscope, instil fluorescein into the tear film and ask the patient to blink several times.
2. Examine the tear film with a wide 2–3 mm parallelepiped and low magnification. Switch to the cobalt blue filter on the slit lamp. The tear film should appear as a fine green film due to the fluorescein.
3. Ask the patient to hold their eyes open without blinking.
4. From the time of the blink, time how long it takes in seconds before dark spots or streaks appear in the even green tear film after a blink. The use of the Kodak Wratten yellow filter number 12 held over the observation system is helpful for this evaluation.
5. If the patient blinks before 10 seconds have passed then the measurement cannot be made and the procedure must be re-started.
6. Repeat the measurement at least once and take an average.
7. If the tear film breaks up immediately and consistently in the same location there may be an epithelial basement membrane defect in that location on the cornea. The TBUT should be repeated, not considering this defect, to get an indication of tear film stability.

7.3.5 Procedure for non-invasive break-up time (NIBUT)

NIBUT or tear thinning time measurements involve projecting a pattern on to the tear film and observing the specular image. Keratometer mires are commonly used in clinical practice but grids are also available and the tearscope is a commercially available test for measuring NIBUT.^{14,20}

1. The illumination of the room should be low to provide the best image contrast.
2. With the patient's head in position on the chin rest of the slit-lamp biomicroscope or the keratometer, focus the instrument so that a clear view of the pattern is seen. If using a keratometer, the mires should be central positioned and sharply in focus.
3. Instruct the patient to blink fully and normally, and then to hold their eye wide open and not blink until instructed.
4. The time between the last complete blink and the first indication of pattern break-up is recorded with a stop-watch.

7.3.6 Procedure for phenol red thread test

1. The test may stimulate some degree of reflex tearing and should be undertaken prior to manipulation of the eyelids or to instillation of any fluid or dye into the tear film.
2. Instruct the patient to look up slightly and blink normally during the test.
3. Remove the threads by gently peeling the plastic film covering from the unsealed end of the aluminium sheet. Make sure that the folded 3 mm end of the thread is bent open at an angle that allows for easy placement onto the palpebral conjunctiva.
4. Pull the lower eyelid away from the globe slightly and place the folded 3 mm portion of the thread on the palpebral conjunctival junction, approximately $\frac{1}{3}$ of the distance from the lateral canthus of the lower eyelid with the eye in the primary position.
5. Begin timing as soon as the thread touches the tear layer.
6. After 15 seconds, gently remove the thread.
7. Measure the length of the red portion of the thread in mm from the very tip (ignoring the fold).
8. Since tear volume can vary, reliability can be improved by repeating the test on different days. It may also be helpful to ask the patient if they could feel the thread during testing, as it could be indicative of a reflex tearing component to the measurement. Excessively high measures (approaching 30mm+) should be repeated.

7.3.7 Procedure for Schirmer tear test

1. The test may stimulate some degree of reflex tearing and should be undertaken prior to manipulation of the eyelids or to instillation of any fluid or dye into the tear film.
2. Bend the round wick end of the test strips at the notch approximately 120° before opening the sterile pouch. Peel back the pouch and remove the strips. Only handle the strips by the non-wick ends to avoid contamination.
3. Have the patient look up and gently pull the lower eyelid down and temporally. Place the bent hooked end of the strip at the junction of the temporal and central third of the lower eyelid margin. The strip should not touch the cornea when the eyelid is released. Release the eyelid and have the patient continue to look up,

blinking normally. The patient can close his or her eyes if this is more comfortable but should not squeeze the eyes shut. Both eyes should be measured at the same time.

4. Note the time of insertion. Remove the strip after 5 minutes or when it is completely wet, whichever comes first. Measure the wetted portion of the strip from the notch towards the flat end in mm. Record this value.

7.3.8 Procedure for diagnostic collagen plugs

See online video 7.4.

1. Ask the patient whether they have any allergy (or opposition) to (bovine) collagen, silicone or other materials or anaesthetics. Discuss the procedure, any sensations the patient might experience during the procedure, and any potential adverse effects. Obtain informed consent.
2. Disinfect jeweller forceps.
3. Inspect the puncta and choose the largest implant size that seems likely to fit into the punctal opening without punctal dilation. The 0.40 mm plug size is the most commonly used. Choosing a plug size that is too small (e.g. the 0.3 mm size) will often result in a false negative trial due to the plugs migrating straight through the system.
4. Seat the patient comfortably at the slit-lamp biomicroscope or in an examination chair capable of reclining. In the latter case, a loupe may be used for magnification.
5. Do not anaesthetise the puncta and ocular surface as it reduces the ability of the patient to detect an immediate improvement in ocular surface symptoms and the procedure is generally well tolerated by patients.
6. Open the sterile packet and grasp a single implant from the foam packet ([Figure 7.14a](#)),

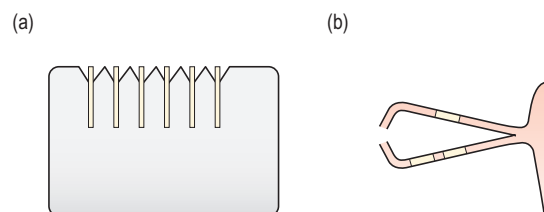


Fig. 7.14 Diagrammatic representation of (a) a set of six collagen plugs in their foam packaging; (b) hydrated collagen plugs in the canaliculi.

preferably very close to the end of the plug and with it oriented approximately perpendicular to the forceps. This can be undertaken either using the biomicroscope magnification or outside the slit lamp.

7. Inferior plug insertion: Inferior plug insertion is generally easier than superior. Instruct the patient to look upwards and temporally and with a finger of the opposite hand to the forceps pull the lower eyelid away from the globe just enough to expose the punctum. Pulling the lid down and away too much will bend or kink the canaliculus.
8. Place the implant partially into the opening vertically, then pull *laterally* on the eyelid to straighten out the vertical and horizontal portions of the canaliculus. With the canaliculus straightened, advance the plug as far as possible, preferably almost all the way in, and release the forceps. Keep the eyelid in the same position, close the tips of the forceps and gently push the rest of the implant into the opening until it disappears below the punctal ring. No part of the plug should be visible at the punctal opening.
9. Generally, use two implants in the inferior and one in the superior canaliculus to effectively occlude the system for diagnostic purposes (Figure 7.14b). Single collagen implants may flush or reflux out of the system before they expand. Three implants in a canaliculus minimises the likelihood of the plugs refluxing out or flushing through.
10. Superior plug insertion: Instruct the patient to look downwards and temporally for the upper plug insertion. Using the thumb of the opposite hand to the forceps, press in towards the globe on the upper nasal lid. The upper punctum should evert from the eye. Again, try not to kink the canaliculus. Insertion proceeds as per the inferior plug insertion described above.
11. Repeat the phenol red thread test (section 7.3.6) after the patient has settled for a few minutes after plug insertion.
12. Ask the patient to keep a diary of symptoms over the next 5–10 days, and arrange a follow-up appointment in 7–10 days. If symptoms and tear film and ocular surface evaluations suggest that (semi-) permanent occlusion is appropriate, discuss the various options for therapeutic occlusion.

7.3.9 Recording

Dye staining. The staining areas on the cornea and the conjunctiva should be both described and drawn on a diagram of the anterior segment or photographed. The staining should be classified and differentiated from other causes (Figure 7.15). The CCLRU scale can be used to grade staining.

Tear break-up time. The TBUT or NIBUT value should be recorded in seconds for each eye individually. Indicate the method that was used to determine this value. For example, NIBUT with grid pattern, 10 s RE (OD), 12 s LE (OS).

Phenol red thread and Schirmer tests. Record the distance in mm that the thread is red (phenol red test) or that the strip is wet (Schirmer test) for each eye. For example:

Schirmer: RE 8 mm; LE 5 mm.

Phenol red thread: OD 12 mm; OS 15 mm.

Diagnostic collagen plugs. Record the type and number of plugs inserted into each canaliculus and the symptoms, ocular lubricant use and the results

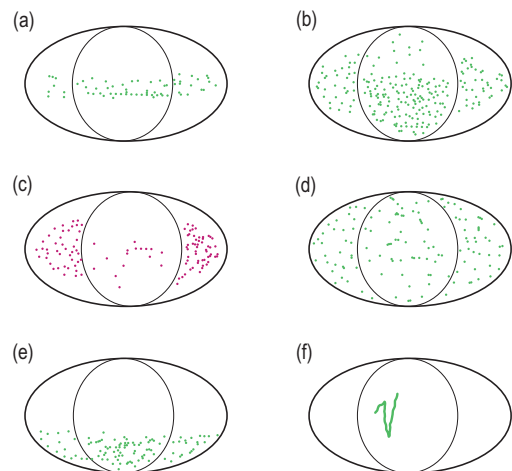


Fig. 7.15 Characteristic fluorescein staining patterns. (a) Band superficial punctate staining (SPS) due to conditions such as mild dry eye or exposure of the region. (b) More severe band SPS possible in severe dry eye. (c) Rose bengal staining in dry eye. (d) Diffuse SPS due to conditions such as adenoviral and staphylococcal keratoconjunctivitis and reactions to diagnostic or therapeutic eyedrops. (e) Inferior SPS due to conditions such as staphylococcal blepharoconjunctivitis and exposure of the region. (f) Foreign body or trichiasis (particularly when in the inferior cornea) tracks.

of all dry eye assessment tests before and after their use. The results of the phenol red thread tear volume test (section 7.3.6) before and just after insertion of the plugs are of particular importance to determine if occlusion has been achieved. Consider adding additional plugs per canaliculus (up to three) if the phenol red thread results are not increased from the pre-plug values.

7.3.10 Interpretation

Dye staining. Surface damage on both the cornea and conjunctiva is revealed with fluorescein staining and staining due to dry eye has a characteristic distribution confined to the interpalpebral area of the ocular surface. Lissamine green staining is dose-dependent, therefore if a very small amount is used the staining will be very minimal.²¹ Temporal and nasal interpalpebral bulbar conjunctival lissamine green staining is predictive of dry eye. With rose bengal it can be difficult differentiating its red stain from the underlying hue in patients with inflamed red eyes.

Tear break-up time. The normal TBUT is between 15 and 45 seconds and a break-up time of less than 10 seconds is indicative of an unstable tear film. Normal NIBUT measured with a keratometer is between 28 and 60 seconds and a break-up time of less than 10 seconds is indicative of an unstable tear film.^{22,23} TBUT measurements are significantly lower than NIBUT values, and the disparity is smaller for short break-up times associated with poor tear quality.²⁴ Normal TBUT and NIBUT measurements are sometimes limited by the patient's ability to keep their eyes open and not blink.

Phenol red thread and Schirmer tests. For the phenol red thread test, a measurement of <10 mm wetting represents true dryness, while 10 to 20 mm wetting is considered borderline, and >20 mm is generally considered normal. Measurements in the high 20s or 30s is most likely due to reflex tearing. For the Schirmer test, a measurement of 10–15 mm or more without anaesthesia is regarded as normal tear production. A value of less than 5 mm represents a significant aqueous dry eye. Several measurements should be made on repeated visits and averaged to obtain as accurate a result as possible.

Diagnostic collagen plugs. If a positive response is obtained with collagen plugs, a more long-lasting type of occlusion is indicated. If occlusion is not sufficient to relieve symptoms to an acceptable

level and ocular signs remain, occlusion of the superior canaliculi may be considered. Before placing (semi-)permanent implants in the superior system, perform a second diagnostic test in the superior canaliculus with collagen plugs. If this procedure also shows benefit in either symptoms or ocular surface signs, consider a more long-lasting occlusion method for the superior puncta or canaliculi. If bothersome epiphora is reported during the second diagnostic test, superior occlusion is not advised.

7.3.11 Most common errors

1. Performing TBUT with a fluorescein/ anaesthetic combination.
2. Spilling fluorescein on the patient's lids or clothes.
3. Touching the cornea with a fluorescein strip or wiping the fluoret against the conjunctiva, causing discomfort and reflex tearing.
4. Not obtaining a sharply focused image of the grid or mires before measuring NIBUT.
5. Performing the red thread or Schirmer test after manipulation of the lids, instillation of diagnostic drugs or dyes, or applanation tonometry.

7.4 ASSESSMENT OF THE LACRIMAL DRAINAGE SYSTEM

Many patients complain of excess tearing. True nasolacrimal system obstruction (epiphora) must be differentiated from reflex tearing associated with conditions such as dry eye. Obstruction may occur anywhere in the pathway from the ocular surface to the nose (Figure 7.16). The most common locations include the punctum, the vertical or horizontal canaliculus, the common canaliculus and the nasolacrimal duct. The latter two listed are more likely to cause significant tearing as they affect overall drainage, whereas a single punctum or canaliculus will reduce outflow through one of the two channels but will not impede it completely. If nasolacrimal system obstruction is suspected, an assessment of the lacrimal drainage system is required.

7.4.1 Comparison of tests

The dye disappearance test and/or the Jones 1 test help to determine whether there is a stenosis or blockage of the nasolacrimal system. If they suggest a stenosis or blockage, then dilation and irrigation of the

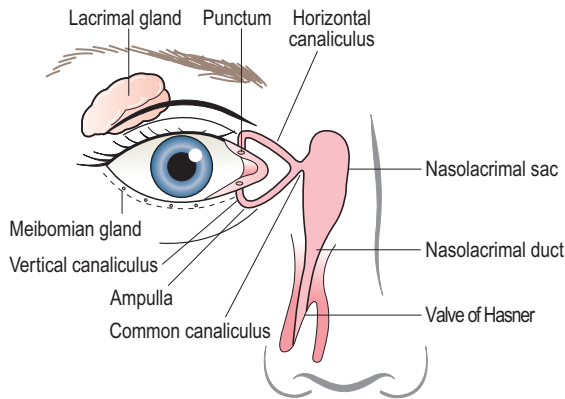


Fig. 7.16 The anatomy of the nasolacrimal system.

system is indicated. Contraindications for dilation and irrigation include symptoms and signs of canaliculitis and dacryocystitis (including regurgitation of discharge from the punctum). Lacrimal sac palpation may help to determine if dilation and irrigation of the system is contraindicated. Dilation and irrigation itself may dislodge a concretion or mucous plug that has blocked the canaliculus. In this respect it is a therapeutic procedure. However, it is also a diagnostic procedure in that it helps to determine if the system is patent. Jones 2 testing, which attempts to determine the site of any blockage, is rarely used in primary eye care as if dilation and irrigation was unsuccessful the patient would likely be referred.

7.4.2 Initial procedures

1. Try to assess if the tearing is due to a nasolacrimal obstruction or eyelid abnormality such as ectropion or entropion or due to paradoxical reflex tearing from a dry eye or other ocular surface problem (intermittent tearing). Ask about any history of facial trauma and/or nasal surgery.
2. Explain the procedure and obtain informed consent. Encourage the patient to blink normally and not to squeeze the eyes during the procedure(s).
3. Ask the patient to blow their nose and clean it thoroughly with tissues.

7.4.3 Procedure for fluorescein dye disappearance test

1. Instil equal amounts of fluorescein in each eye and observe the patient for five minutes.

2. Compare the relative heights of the tear meniscus at the inferior margin of each eye and the degree of fluorescein spilling over the patient's eyelids.
3. Do not allow the patient to blot the fluorescein as this might draw an excessive amount of fluorescein and tears out of the conjunctival sac. Wipe away any excess fluorescein dye which has spilled onto the patient's cheek to avoid unnecessarily staining the skin.

7.4.4 Procedure for Jones 1 or primary dye test

1. Moisten two to four fluorescein strips with sterile saline and touch to the inferior nasal palpebral conjunctiva, introducing a large amount of dye and fluid into the conjunctival sac. False test results are more likely if insufficient dye is applied.²⁵
2. Allow the patient to blink normally for five minutes. Again, ensure that fluorescein dye does not remain in contact with the facial skin long enough to dry.
3. Note that the dye disappearance test may be undertaken simultaneously with the Jones 1 test by observing the dye distribution and disappearance characteristics.
4. Instruct the patient to occlude the nostril on the unaffected side (if tearing problem is unilateral) or one nostril at a time (if tearing problem is bilateral) and blow into a white tissue.
5. Inspect the tissue for fluorescein using a Burton lamp or the cobalt blue light on the slit-lamp biomicroscope.
6. If no fluorescein is detected and especially if the dye was noted to have cleared from the eye other than over the lids onto the face, a false result may have been noted. Consider repeating the test or ask the patient to roll a sterile swab about 1 cm into the nose against the inferior turbinate. Check the swab for fluorescein with the cobalt blue light.
7. If *fluorescein is recovered* (Figure 7.17a) no further tests are required as the nasolacrimal system is patent. Reflex tearing from dry eye and other causes should be reconsidered. Dilation and irrigation may still be considered if it is thought that there may be a partial blockage that might be relieved with irrigation.
8. If *no fluorescein is recovered* (Figure 7.17b,c), there is either some degree of blockage of the drainage, there is a failure of the lacrimal pump

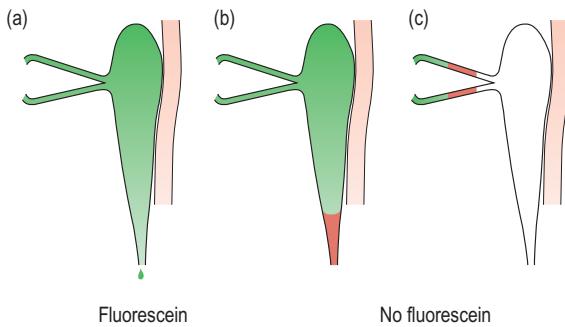


Fig. 7.17 Jones I test. (a) Fluorescein is recovered, indicating that the system is patent. (b) and (c) The absence of fluorescein indicates a blockage or stenosis in the system and the need for dilation and irrigation; (b) shows a lower system blockage and (c) an upper system blockage.

mechanism, or a false test result was obtained, likely due to insufficient fluorescein being used.

9. Consider dilating the punctum on the affected side and repeating steps 1 to 5. If fluorescein is now recovered, the source of the poor drainage was likely stenosis of the punctum.

7.4.5 Procedure for dilation and irrigation

Dilation and irrigation is generally undertaken if no fluorescein is recovered with the Jones 1 test.

1. Prepare the instruments with appropriate disinfection of internal and external surfaces. Attach a reinforced 23-gauge cannula to a 3, 5, or 10 cc syringe.
2. Fill the syringe with 3 to 5 cc sterile saline. Push most of the saline through the cannula to thoroughly rinse the disinfectant, reserving approximately 1 cc for irrigation.

Dilation

3. Anaesthetising the surface and puncta are not required but are determined based on patient and practitioner preference. Anaesthetise the superior and inferior puncta with a cotton-tipped applicator soaked with anaesthetic (e.g. proparacaine). Have the patient open his or her eyes. Pull the lower eyelid out of apposition with the globe and place the soaked pledget firmly on the inferior punctum. Have the patient close their eyes for several minutes over the soaked bud such that both puncta come into contact with the applicator.

4. Recline the patient slightly in the chair, and direct their gaze out and away from the canaliculus being dilated/irrigated. For example, have the patient look superior temporally to irrigate the inferior system. Use a magnifying lens (loupe) if necessary.
5. Pull the inferior eyelid away from the globe and place a long-tapered dilator vertically into the inferior punctal opening (<2 mm).
6. If the punctum is tight around the dilator, gently roll the dilator back and forth between your fingers to begin to dilate the punctum.
7. Once the dilator is inserted 1–2 mm, advance the dilator a little further while pulling laterally on the eyelid to straighten out the canaliculus. Continue to roll the dilator back and forth while directing the tip of the dilator nasally towards the location of the opening into the common canaliculus (i.e. orientation of the dilator is now horizontal). Whitening of the punctal ring indicates expansion of the opening. Do not force the dilator too deeply into the canaliculus and retract if resistance is encountered or the patient experiences significant discomfort or a sharp pain.
8. If the punctum is not sufficiently enlarged or closes down before the cannula can be inserted, dilate again with the long tapered dilator and gently advance it further, again respecting the anatomy and the patient's comfort.
9. The primary dye test (Jones 1) may be repeated after only punctal dilation; however, generally you will proceed to irrigation.

Irrigation

10. Insert the cannula immediately after dilating the punctum. If the punctum cannot be opened sufficiently to insert the cannula, consider a smaller gauge cannula or a wider dilation of the punctum.
11. Pull the eyelid away from the globe slightly and insert the cannula 1–2 mm vertically then pull the eyelid taut laterally to continue 1 to 4 mm into the horizontal canaliculus, as with the dilator. If the cannula meets with gentle resistance, this is termed 'soft stop', and the cannula should not be advanced further as an obstruction exists in the canaliculus. The 'hard stop' position indicates that the cannula has come into contact with the nasal bone. This can only be achieved with a sufficiently long cannula to transverse the vertical, horizontal

and common canaliculi and the lacrimal sac (>10 mm advancement).

12. Reach up with the thumb of the hand *not* holding the cannula/syringe. While watching carefully that the position of the cannula is maintained (i.e. that it is not inadvertently advanced further into the canaliculus), apply pressure to the plunger to introduce a small amount of saline (less than 0.5 cc) into the system. Never force the fluid if resistance is encountered. If resistance is encountered, first withdraw the cannula and test that the cannula/syringe combination itself is not obstructed by pushing fluid through the syringe and cannula. Reintroduce the cannula.
13. Once a small amount of saline is introduced, the patient is asked to report when it is detected in the throat, at which time pressure on the plunger of the syringe is stopped and the cannula carefully withdrawn (go to step 15). Keep talking to the patient throughout the procedure to ensure that they remain still until the cannula is withdrawn safely.
14. If saline regurgitates from the canaliculus being irrigated, it is likely that this canaliculus is obstructed or stenosed.
15. If saline regurgitates from the contravertical punctum, a common canaliculus blockage should be suspected. Hold a sterile cotton-tipped applicator firmly on that punctum and try to irrigate again. Carefully withdraw the cannula.
16. Offer the patient a mint or lozenge as the saline can have an unpleasant taste for some patients.

7.4.6 Recording

Fluorescein dye disappearance: Record if the meniscus height is equal in each eye and if dye runs down over the patient's cheek or disappears into the nasolacrimal drainage system. Relative speed of disappearance between the eyes is also relevant. Take note of the completeness of the blink, including apposition of the puncta, and the lid position.

Jones 1: Record whether or not dye was recovered on each side. Note that some sources label the presence or recovery of dye as 'positive' and absence of dye as 'negative', so that a 'positive Jones 1 test' means that the system is patent. This is opposite to the usual convention of a positive test result being one that indicates a problem, so it

is best to record whether or not dye is recovered in each test in order to avoid confusion, e.g. dye recovered in left nostril (left nasolacrimal system patent).

Dilation and irrigation: Record whether or not the patient tasted salt or felt the solution in the throat. Also note if saline was regurgitated from the same canaliculus or from the contravertical canaliculus.

7.4.7 Interpretation

Fluorescein dye disappearance: If the heights of the tear meniscus are unequal, it implies that the eye with the larger meniscus may have impaired tear drainage. It is less likely that there is a unilateral poor meniscus due to dry eye or unilateral pseudoepiphora from reflex tearing from the dry eye.

Jones 1: If fluorescein is recovered, no further tests are required as the nasolacrimal system is patent. However, some clinicians may consider dilation/irrigating if they feel there is a chance to dislodge a partial obstruction. If no dye is recovered, this indicates either a partial or full blockage in the system, a failure of the lacrimal pump mechanism, or it could be a false positive. Insufficient fluorescein is the most likely cause of a false positive result.²⁵ If mucopurulent effluent is recovered, irrigation should not be attempted as there is an active infection/inflammation.

Dilation and irrigation: Normally fluid should exit from the system and be noted by the patient in the throat. A blocked system will offer resistance to fluid injection or cause regurgitation from the contravertical punctum. No fluid flow in the throat indicates a complete obstruction. Fluid subsequently noted in the throat indicates that the obstruction was relieved or there had been a partial obstruction or a stenosis.

7.4.8 Most common errors

1. Instilling insufficient fluorescein or making inadequate attempts to recover fluorescein for the Jones 1 test can lead to false results.²⁵
2. Not introducing the cannula quickly enough such that the punctum closes down after dilation, making it difficult to insert the cannula.
3. Failing to respect the anatomy of the canaliculi with the dilator/cannula during dilation/irrigation, leading to patient discomfort.

7.5 ANTERIOR CHAMBER ANGLE DEPTH ESTIMATION

The most common reason for estimating the anterior angle is as a safety precaution prior to dilating a patient's pupils. The risk of inducing angle closure glaucoma with a mydriatic is minimal, providing appropriate precautions are made. An estimation of the anterior chamber angle depth may also be used in patients who are taking systemic medication known to cause pupil dilation and possible angle closure.

7.5.1 Comparison of tests

The van Herick anterior angle assessment is a relatively quick and simple procedure and can be part of a routine assessment of the anterior eye using the slit-lamp biomicroscope. The superior angle is the narrowest and most likely to close. Although the van Herick angle assessment is unable to assess the superior angle, in most cases the technique is sufficient to indicate whether there is a danger of angle closure.²⁶ Only if the angle appears narrow using this assessment is gonioscopy required to determine whether dilation is safe. The van Herick assessment is a conservative one in that many patients with a narrow angle as determined by the test can be safely dilated.²⁷

The simple shadow test is very quick and simple and is useful when a biomicroscope is not available or when a van Herick assessment is not possible, such as with a patient in a wheelchair or a young child. Most young children are very unlikely to have a narrow angle unless they are a high hyperope and the shadow test is ideal to use as a safety check prior to the use of a cycloplegic drug. It is not as accurate as van Herick's grading system with the biomicroscope.

7.5.2 Procedure: van Herick assessment



See online video 7.5.

1. Seat the patient at the slit-lamp biomicroscope and set up the biomicroscope with magnification at the medium setting (~16×).
2. Explain the procedure to the patient and then ask them to look straight ahead.
3. Narrow the beam to an optic section (section 7.2.3) with the illumination system at 60° temporal to the microscope. Because you have narrowed the beam, you may need to increase its brightness.
4. Move the illumination system temporally to the very edge of the temporal limbus, keeping

the cornea in focus (Figure 7.18). It is important to move only until the first shadow is seen.

5. Judge the depth of the anterior chamber by the width of the optically clear space between the cornea and the iris. Compare this width to the width of the cornea (Figure 7.19). Record the result using a ratio or van Herick's grading system.
6. Repeat the measurement on the nasal anterior chamber angle. You may have to rotate both the

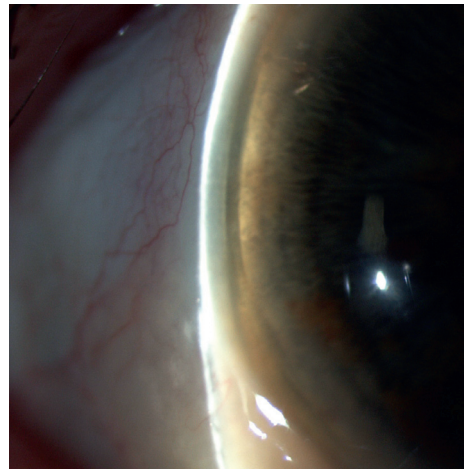


Fig. 7.18 A van Herick grade III anterior angle.

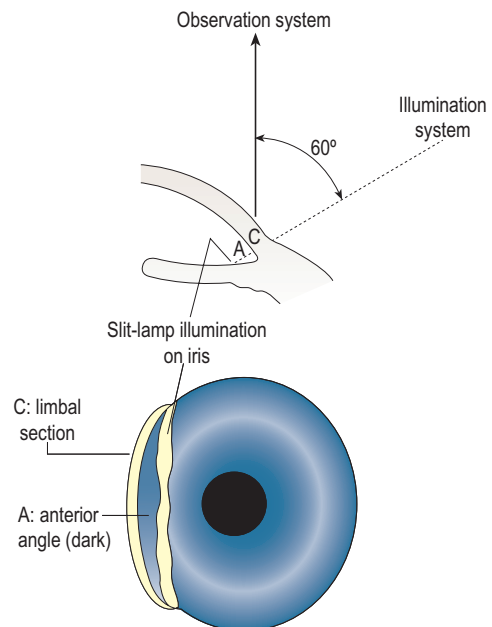


Fig. 7.19 Diagrammatic representation of van Herick's technique for anterior angle estimation.

illumination and viewing systems (keeping them 60° apart) to ensure the illumination system avoids the patient’s nose.

- 7. Repeat for the other eye.

7.5.3 Procedure: Shadow test angle estimation

- 1. Dim the room lights and ask the patient to look straight ahead.
- 2. Hold a penlight a few cms from the outer canthus and at an angle of 100° temporally in the horizontal plane of the patient’s right eye and rotate it around to 90°. The temporal side of the iris will illuminate.
- 3. Observe the nasal iris carefully and note how much of it is in shadow (Figure 7.20).
- 4. Repeat with the left eye.

7.5.4 Recording

van Herick: Record the result as a ratio with the cornea being unity and the anterior chamber width being a fraction of the corneal width. Alternatively, van Herick’s grading system can be used (Table 7.2). If only one measurement is recorded, it can be assumed to be temporal. Examples:

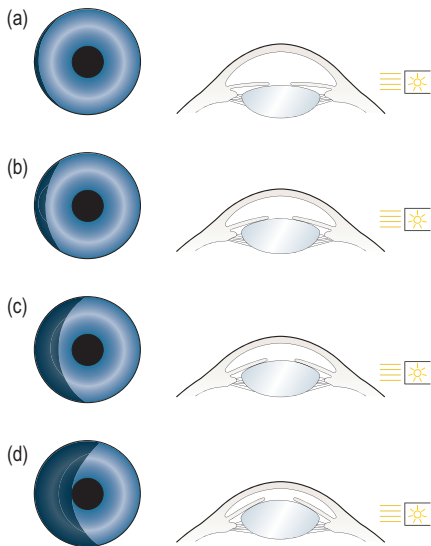


Fig. 7.20 The penlight test for anterior angle estimation. The penlight illuminates various amounts of the nasal iris depending on the size of the anterior angle. (a) grade IV; (b) grade III; (c) grade II; (d) grade I.

van Herick. C/AC RE. 1:1, LE. 1:1.5.
van Herick. C/AC OD. 1: 0.5, OS. 1:0.4.
van Herick. OD: IV, OS: III.
van Herick. RE: II T, III N. LE: III T and N.

Shadow test: Grade the angle according to the percentage of the nasal iris that is in shade or use the equivalent grade (Table 7.3). For example:

Shadow test: 25% in shade RE and LE.
OD: grade IV. OS: grade III (shadow test).

7.5.5 Interpretation

The angle should normally be grade III or grade IV (Figure 7.18). The prevalence of narrow angles of grade I and II is about 2%. If the angle is grade II or narrower, there is a risk of angle closure and the pupil should be dilated only if a gonioscopy examination indicates that it is safe to do so. Hyperopic eyes, being relatively small, tend to have smaller anterior angles while the larger, myopic eye tends to have larger anterior angles. The growth of the crystalline lens

Table 7.2 Van Herick’s anterior chamber angle grading system		
Van Herick grade	Cornea: anterior angle depth	Probability of angle closure
Grade 0	Closed	100%
Grade I	<1 : 1/4	Very likely
Grade II	1 : 1/4	Possible
Grade III	1 : 1/2	Unlikely
Grade IV	1:1 or greater	Impossible

Table 7.3 Anterior angle estimation by penlight grading system		
Penlight grade	% Nasal iris in shadow	Probability of angle closure
Grade 0	100	100%
Grade I	75	Very likely
Grade II	50	Possible
Grade III	25	Unlikely
Grade IV	0	Impossible

throughout life (before cataract surgery) means that elderly patients are much more likely to have a small anterior angle and children typically have large anterior angles. Note that early age-related cataract, particularly anterior and posterior subcapsular cataracts, typically lead to a thinner lens and a wider anterior angle.²⁸

7.5.6 Most common errors

1. van Herick: Failure to position the optical system as close to the limbus as possible. The measured angle will increase in size as you move away from the limbus.
2. van Herick: Having the angle between the illumination system and the microscope less than 60°.
3. Shadow test: Improper penlight position.

7.6 GONIOSCOPY

Gonioscopy is the standard procedure for examination of the anterior chamber angle. Light from the anterior chamber angle is totally internally reflected by the cornea, so that the angle cannot be viewed directly. Gonioscope lenses are high minus contact lenses that neutralise the power of the cornea and include appropriately angled mirrors to allow examination of the anterior chamber angle. There is significant physiological variation between normal eyes with regard to the prominence of the various angle structures, including pigmentation. Therefore, gonioscopy should be performed frequently to be able to distinguish between normal and abnormal angle structures.

Specific indications for gonioscopy include:

- Narrow anterior chamber angles suggested by van Herick to assess the relative risks for pupillary dilation. Gonioscopy is the gold standard technique against which screening tests for narrow angles are compared.²⁹
- Narrow (or closed) angle glaucoma including evaluation and documentation of peripheral anterior synechiae if present.²⁹
- Primary open angle glaucoma (POAG) and risk factors for POAG (e.g. elevated intraocular pressure) to confirm 'primary' diagnosis.
- Secondary open angle glaucoma and risk factors (e.g. pseudoexfoliation, pigment dispersion, chronic uveitis) to contribute to determination of disease severity.
- Risk of angle neovascularisation (e.g. confirmed rubeosis iridis, and ischaemic posterior segment

conditions including vein or artery occlusions and diabetic retinopathy).³⁰

- Risk of angle recession post blunt trauma.
- Risk of intraocular foreign body.
- Congenital or acquired structural irregularities of the iris and anomalies of the anterior chamber (e.g. iris cysts or tumours, ectopic pupil).
- Post laser peripheral iridotomy to assess effect on angle depth.

Gonioscopy is contraindicated in patients who have experienced:

- Recent ocular trauma especially in the presence of hyphaema or microhyphaema.
- Recent intraocular surgery, including cataract surgery.

7.6.1 Comparison of different gonioscope lenses

Scleral-type lenses such as the Goldmann 3-mirror lens (Figure 7.21) provide excellent optics and mirror placement allowing for the detection of subtle angle findings (e.g. early angle neovascularisation), which can be more difficult with the poorer image quality of corneal-type lenses. Scleral-type lenses also provide excellent lens stability on the eye once inserted and good eyelid control even with a patient with blepharospasm. This allows a better view in patients with significant loss of corneal transparency. The image may be more transient with corneal-type lenses as the tear film seal is disrupted easily if the lens is not maintained on the central cornea. The Universal lens also contains two additional mirrors angled for evaluation

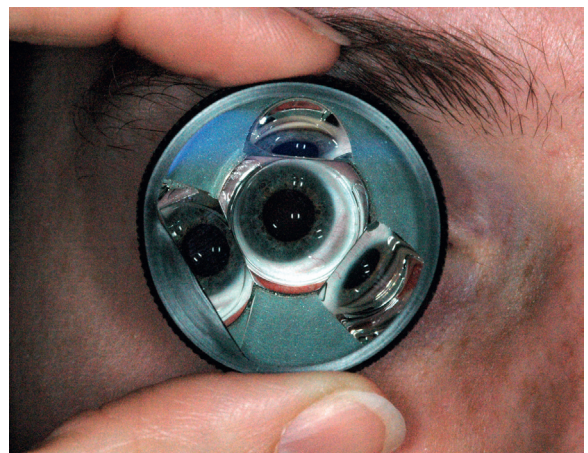


Fig. 7.21 A Goldmann 3-mirror Universal lens on the eye.

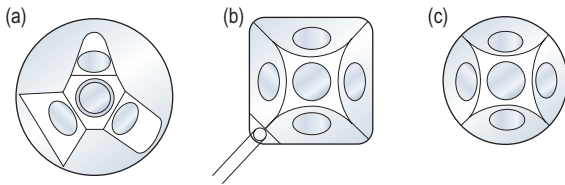


Fig. 7.22 Types of gonioscope lens (not to scale). (a) Goldmann 'Universal' 3-mirror. (b) Posner or Zeiss corneal lens with a handle. (c) Sussman corneal lens.

of the peripheral and midperipheral fundus as well as a central lens for evaluation of the vitreous and posterior pole (section 7.12).

All *corneal-type* lenses (e.g. Posner, Zeiss, Sussman; Figure 7.22) have a smaller (9 mm) and flatter area of contact on the cornea as compared to the scleral-type lenses and have four mirrors, all of which are angled to allow examination of the anterior chamber angle. The smaller, less concave surface enables gonioscopy without the need for a viscous coupling solution and essentially no lens rotation is required as all four mirrors are angled for gonioscopic assessment. The lens is easily inserted onto the cornea of a cooperative patient thus facilitating a relatively quick assessment, unlike the more challenging lens insertion and required coupling solution with scleral-type lenses. Corneal compressions can only be undertaken with corneal-type lenses and allows differentiation between appositional and synechial angle closure. Disadvantages of corneal-type lenses include the identification of an artificially wider angle if too much pressure on the cornea causes the angle to appear to widen. Corneal epithelial disruption may also occur if significant lens movement occurs on the corneal surface.

7.6.2 Goldmann 3-mirror (Universal) gonioscopy procedure (see summary in Box 7.1)

▶ See online video 7.6.

1. Describe the specific indications for gonioscopic assessment to the patient and outline the procedure: 'I would like to use a contact lens on the front of your eye to examine the hidden part of the front of your eye. I will be putting a drop in your eyes to numb the cornea, so do not rub your eyes for at least half an hour or you could scratch your eye without feeling it.' Obtain informed consent.
2. Lens preparation: Clean and disinfect the gonioscopy lens. Fill approximately two-thirds of the concave lens surface with a viscous

Box 7.1 Summary of gonioscopy procedure

1. Disinfect the lens and fill the lens surface with viscous coupling solution.
2. Anaesthetise both eyes
3. Align the biomicroscope illumination and observation systems. Set the magnification and the rheostat to low settings.
4. Insert the lens and (for Goldmann 3-mirror) wipe away excess solution.
5. Rotate the Goldmann 3-mirror lens through 360° to establish a good seal.
6. Place the thumbnail mirror at 12 o'clock on the cornea to view the inferior angle first.
7. Identify the *most posterior structure* observable.
8. Position the slit beam horizontally to view the nasal and temporal sides.
9. Examine all quadrants (through 360°) in a systematic manner.
10. Remove the lens by introducing air under the lens and releasing from contact with the cornea.

coupling solution, ensuring no bubbles remain to interfere with the view.

3. Anaesthetise both eyes. Gonioscopy can be performed immediately following applanation tonometry so that additional anaesthetic is not necessarily required. Fluorescein does not interfere with the examination.
4. Position the patient comfortably at the biomicroscope and ensure the eye is aligned with the lateral canthal marker on the slit lamp so that the chin rest need not be adjusted while the lens is on the eye. Consider using the lens case under your elbow or hook your little finger over the headrest bar of the biomicroscope to promote stability of the lens.
5. Align the illumination system to be co-axial with the viewing system, set the magnification to a low power (e.g. 10×), and the rheostat to low or medium intensity.
6. **Lens insertion:** Move the microscope off to the side or reach around the microscope to insert the lens. Advise the patient that pressure and a turning feeling may be detected with the lens in place, but that there will be no discomfort. Instruct the patient to look up. Eyelid control is usually required to ensure the lens is properly



Fig. 7.23 Inserting the Goldmann 3-mirror contact lens.

inserted in one attempt. One method is to hold the eyelashes of the upper eyelids tightly against the orbital rim with the thumb, then pull the lower eyelid down and away from the globe and introduce the rim of the lens over the lower eyelid margin. Use the lens edge to pull down the lower eyelid further, while simultaneously and quickly rotating the lens upwards onto the eye (Figure 7.23). Once the lens is on the eye, ask the patient to *slowly* look straight ahead. Keep the flat front surface perpendicular to the line of sight. If air bubbles are present, apply a little pressure and gently rock the lens to see if they can be removed. The angle can often be viewed around air bubbles, but if they remain a significant problem with the view, remove and re-insert the lens.

Consider manipulating the lens through a couple of rotations with both hands to establish the lens seal and enable smooth rotation of the lens while observing the various angle quadrants. Wipe excess solution that may have dripped onto the patient's cheek.

7. **Examination/observation procedure:** For examination, it is preferable to hold the lens with the left hand when examining the right eye and vice versa for the left eye. Either two hands can be used to rotate the lens to view all four quadrants, or one hand can be used with stabilisation of the lens between rotations with the middle finger.
8. Start with a vertical parallelepiped beam 1–3 mm wide. Keep the illumination moderate to reduce pupillary constriction that may decrease the perceived width of the angle and prevent patient discomfort.

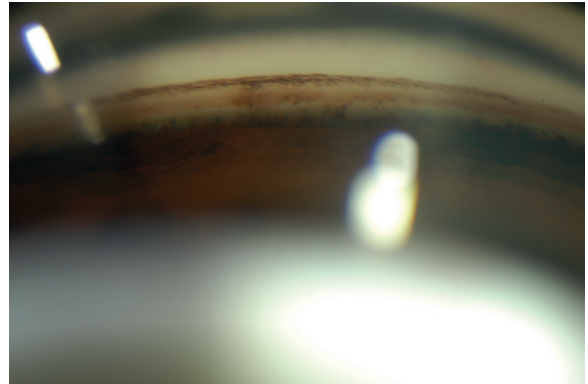


Fig. 7.24 A wide-open angle of a brown iris (Asian). There is pigment on Schwalbe's line (Sampaolesi's line); iris processes overlying the ciliary body, mild pigment in the posterior trabecular meshwork and the reddish tinge is blood reflux through Schlemm's canal.

9. Start with the thumbnail mirror placed in the 12 o'clock position to enable a view of the inferior angle first. The inferior quadrant is usually the widest and most pigmented, making it easier to identify the various structures.
10. In normal angles, look for the prominently discernible pigmented posterior structure, the ciliary body (CB) band, and identify the adjacent angle structures from posterior through to anterior (Figure 7.24). Identify the most posterior structure observable and note any abnormal findings.
11. When the ciliary body band is less visible or is not visible at all, such as with a narrow angle, with unusual pigment patterns or when peripheral anterior synechiae or neovascularisation obscure or distort the angle, use the *focal line technique* to identify Schwalbe's line, which is the last (most anterior) structure visible in a progressively narrow angle. Use a very bright optic section at a 20° angle with the mirror in the 12 o'clock position. Two separate beams representing the anterior and posterior surfaces of the cornea will be observed in the domed cornea above the angle. These two beams will collapse into one beam in the angle at Schwalbe's line. All other structures can be identified posteriorly from Schwalbe's line. This technique can also be used with the thumbnail mirror in the 6 o'clock position (superior angle examination), but it is usually not necessary if

you follow the structural variations through the examination of all 360° of the angle.

12. The *convex iris technique* can be used to help identify the most posterior angle structure observable before the iris inserts into the angle.
13. Use both hands and rotate the lens by 90° to observe the nasal or temporal angle. Use one hand to hold the lens to maintain contact with the eye and use the other hand to rotate the lens. The lateral angles may be more easily viewed when the slit beam is rotated horizontally.
14. Examine all quadrants (through 360°) in a systematic manner.
15. Lens removal: Instruct the patient to look toward the nose and blink forcefully (the strongest eyelid force is nasally), while simultaneously applying digital pressure through the inferior eyelid on the temporal side of the globe to introduce air beneath the lens. A popping sound may be heard as the lens releases from the eye. Repeat with more pressure temporally if the first attempt fails to release the lens. Do not use a pulling force to remove the lens. Consider lavage of the superior and inferior cul-de-sacs with irrigating solution (or saline) if viscous, preserved coupling solution was used.
16. Always examine both eyes as relative comparison of angle structures between eyes and quadrants is important.

7.6.3 Additional examination technique: The convex iris technique

The convex iris technique involves changing the angle of the gonioscopy lens relative to the angle being viewed in order to visualise the otherwise obscured angle details in an eye with a shallow anterior chamber and narrow angle. This involves tilting the lens into the quadrant to be examined and/or having the patient look toward the position of the thumbnail mirror. The light from the angle can then vault over the anteriorly bowed iris to the mirror and allow the more posterior structures of the angle to be visualised. With a scleral-type lens, it is generally best to have the patient look towards the mirror (i.e., for examining the inferior angle with the mirror placed at 12 o'clock, ask the patient to look up while maintaining the seal of the lens on the eye). However, the view may still not be optimal and the lens may also need to be tilted away from the mirror being used. For *corneal-type* lenses,

less movement is needed to facilitate the view into the angle as the mirrors are placed closer to the apex of the cornea. Less eye movement by the patient and more lens manipulation is generally better. However, when observing very narrow angles, it may be necessary to both tilt the lens away from the mirror and have the patient look towards the mirror.

7.6.4 Corneal-type gonioscopy procedure

1. Describe the specific indications for gonioscopic assessment to the patient and outline the procedure; for example, 'I would like to use a contact lens on the front of your eye to examine the structures which drain the fluid of the eye. I will be putting a drop in your eyes to numb the cornea, so do not rub your eyes for at least half an hour or you could scratch your eye without feeling it.'
2. **Lens preparation:** Clean and disinfect the gonioscopy lens. No solution is absolutely required; however, a drop of solution may improve the contact and facilitate maintenance of the contact and therefore the view. A drop of saline, artificial tear or viscous solution may be used.
3. Anaesthetise both eyes. Gonioscopy can be performed immediately following applanation tonometry so that additional anaesthetic is not necessarily required. Fluorescein does not interfere with the examination.
4. Position the patient comfortably at the biomicroscope and ensure the patient is aligned properly with the lateral canthal marker so that the chin rest need not be adjusted while the lens is on the eye.
5. Align the illumination system to be co-axial with the viewing system, set the magnification to a low power (e.g. 10×), and the rheostat to low or medium intensity. Pull the biomicroscope back toward you.
6. Lens insertion. Before applying the lens, consider the orientation of the mirrors, especially with lenses with handles (Zeiss – Unger holder, Posner – one piece). Generally, the lens is applied with the handle superior- or inferior-temporally in a 'square' pattern (Figure 7.22b), although a 'diamond' pattern is preferred by some clinicians. Advise the patient that the lens will be felt if the lids touch it but otherwise will not be uncomfortable.
7. It is preferable to hold the lens with the left hand when examining the right eye and vice

versa for the left eye. Lens stability is critical so it is important to have good arm support.

8. Instruct the patient to hold their eyes widely and to look straight ahead (a specific target to fixate on is helpful). Pull the microscope back, and bring the lens in from the patient's temporal side. Rotate the lens quickly and directly onto the central cornea so that the flat front surface is perpendicular to the line of sight. At all times, hold the lens just barely in contact with the corneal surface such that the tear prism is maintained. Do not apply excessive pressure with the lens. A wrinkled appearance through the lens indicates that folds in Descemet's membrane are occurring due to too much pressure on the lens. Maintain the flat lens perpendicular to the cornea to maintain the tear film seal, and reposition the lens on the centre of the cornea if sliding is noted or if the patient changes fixation.
9. Position the vertical slit beam in the mirror placed in the 12 o'clock position to enable a view of the inferior angle first. The inferior quadrant is usually the widest and most pigmented, making it easier to identify the various structures.
10. In normal angles, look for the prominently discernible pigmented posterior structure, the ciliary body (CB) band, and identify the adjacent angle structures from posterior through to anterior. Identify the most posterior structure observable and note any abnormal findings.
11. When the ciliary body band is less visible or is not visible at all, such as with a narrow angle, with unusual pigment patterns or when peripheral anterior synechiae or neovascularisation obscure or distort the angle, use the focal line technique to identify Schwalbe's line, which is the last (most anterior) structure visible in a progressively narrow angle. Use a very bright optic section at a 20° angle with the mirror in the 12 o'clock position. Two separate beams representing the anterior and posterior surfaces of the cornea will be observed in the domed cornea above the angle. These two beams will collapse into one beam in the angle at Schwalbe's line.
12. The convex iris technique can be used to identify the most posterior angle structure observable before the iris inserts into the angle and pressure gonioscopy can be used in narrow angles to ensure there are no peripheral anterior synechiae, and to differentiate appositional and synechial angle closure.
13. Rotate the slit beam horizontally and position the beam in the appropriate mirror to observe the nasal or temporal angle.
14. Examine all quadrants (through 360°) in a systematic manner.
15. Lens removal: Remove the lens by simply releasing from contact with the cornea. No ocular lavage is required as no preserved coupling solution is used. Examine the cornea after the procedure to ensure the epithelium is intact.
16. Always examine both eyes as relative comparison of angle structures between eyes and quadrants is important.

7.6.5 Additional examination technique: The corneal compression technique

The corneal compression technique is also termed compression, pressure or indentation gonioscopy. This technique can be used to differentiate if an observed angle closure is appositional (i.e. iris is in contact with the angle structures but is not adherent) or synechial (i.e. the iris is physically and irreversibly adherent to the angle). Pressure is applied with the four-mirror gonioscopic lens directly on the centre of the cornea forcing aqueous into the peripheral chamber and forcing the iris posteriorly. Pressure on an eye with an appositionally closed angle will cause the iris to pull away from the angle to reveal some angle structures, while a synechial angle closure will remain closed.

7.6.6 Recording

The most common reason for a gonioscopic assessment is to determine the relative openness of the anterior chamber angle. There are several published grading systems but the suggested method is to use an anatomically descriptive recording system, thus eliminating the discrepancies and controversies that exist between grading systems. The anterior chamber angle is widest inferiorly and is most narrow superiorly, with the nasal and temporal quadrants in between. All quadrants should be inspected and graded independently. Recording of observations should include the following:

- Most posterior angle structure observed (e.g. posterior trabecular meshwork).
- Angular approach at the recess (approximation, in degrees).

- Iris contour (e.g. 'flat', 'steep' or 'convex' in mid-peripheral iris as in narrow angles; 'convex at iris root' as in plateau iris; 'convex over entire iris' as in pupillary block; or 'concave' or 'posteriorly bowed' as in pigment dispersion).

Other characteristics and pertinent negatives include:

- Amount of pigment.
- Presence of iris processes, angle recession, peripheral anterior synechiae (PAS), and normal and abnormal vasculature.
- Other findings: lens cortex material, naevi and surgical alterations such as sclerectomy and peripheral iridotomy (PI).
- Whether or not lens tilt (convex iris technique) was required to observe the angle properly.
- To what degree the angle opens with indentation (if relevant).

Common alternate grading systems include that of Shaffer which grades the angle by the estimate of the geometrical angle between the iris and angle wall at the recess. This system most closely correlates with the van Herick angle estimation method. Grades III to IV are widely open angles of 30–40°. In both the van Herick and Shaffer systems, angles designated grade II (20°) or less are considered capable of closure. Grade 0 angles are considered closed. The Spaeth grading system uses three criteria to describe the angle. The angle is initially described in a similar way to the Shaffer system but in degrees. The peripheral iris contour is then described as being either regular (r), steep (s), or concave (q for queer). Finally the site of iris insertion is described anatomically (see further reading for details).

In addition to grading and describing the angle, the trabecular meshwork can be graded with respect to the degree of pigmentation. The scale is somewhat arbitrary but convention describes 0 as no pigment, 1 as trace, 2 as mild, 3 as moderate, and 4 as dense pigment deposition. The absence of pigment (grade 0) makes the angle assessment difficult as the various structures are highlighted with pigment. The focal line technique helps to delineate the faint Schwalbe's line and therefore to help determine the most posterior structure.

7.6.7 Interpretation

With the mirror in the 12 o'clock position and when examining the angle in the right aspect of the mirror (i.e. 1 o'clock), the view is of the 5 o'clock position of the angle (not the 7 o'clock position). Examination of the wider inferior angle first facilitates the identification of the various structures. It is useful to approach

the angle evaluation from an anterior to posterior direction as all structures are not always present:

Schwalbe's line (SL)

This is the most anterior structure of the angle and is a demarcation line marking the termination of the transparent cornea at Descemet's membrane. It is a very narrow, usually white or translucent line and is not always prominent. Sampaolesi's line is the term applied to a pigmented Schwalbe's line. It appears as pigment deposited in a wavy discontinuous fashion anterior to Schwalbe's line and is a feature of pseudoexfoliation and pigment dispersion syndromes.

Trabecular meshwork (TM)

The trabecular meshwork or trabeculum has a translucent appearance and is frequently dull grey or brown in appearance. The anterior portion of the trabecular meshwork (ATM) is usually less pigmented and is considered the non-filtering portion of the meshwork. The more posterior portion of the trabecular meshwork (PTM) overlies the Schlemm's canal and is more active in the drainage process. The PTM is pigmented and may accumulate pigment with age and in specific eye disease such as pigment dispersion and pseudoexfoliation syndromes. Trauma, uveitis and surgery are also causes of pigment deposition in the angle. It is advisable to grade the level of pigmentation in the angle, and it is usually noted that pigment deposits most heavily in the inferior quadrant. Schlemm's canal can be seen through the translucent meshwork only if blood is refluxed back into it from the venous system (Figure 7.24). This occurs if excess pressure is applied with the gonioscope (usually a scleral-type lens), such that the pressure in the draining veins exceeds the intraocular pressure.

Scleral spur (SS)

The scleral spur is a slight protrusion of the white sclera into the anterior chamber. The trabecular meshwork attaches anteriorly and the longitudinal muscle of the ciliary body posteriorly. The scleral spur becomes more visible when the ciliary body and trabeculum are pigmented. If the scleral spur appears unusually wide, angle recession may be present.

Ciliary body (CB)

The visible band of ciliary body represents the longitudinal muscle and may appear black, brown, grey, or have a mottled appearance. If visible, the angle is widely open. In lightly pigmented eyes, blood vessels can occasionally be observed running circumferentially in the ciliary body. The presence of a very wide

ciliary body band along with a history of trauma may indicate angle recession. Iris processes are strands of the iris that are seen to project anteriorly onto the ciliary body or scleral spur and occasionally even more anteriorly on to the trabecular meshwork. These are found in approximately one third of normal eyes.

Iris root

The iris root runs from the most posterior section of the iris and inserts onto the ciliary body. It can occasionally obscure the view of the ciliary body.

7.6.8 Other gonioscopic findings

Peripheral anterior synechiae (PAS) are adhesions formed between the iris tissue and the trabecular meshwork or even Schwalbe's line. Their appearance is dependent on the aetiology of the adhesion. Angle closure PAS are usually found where the angle is narrowest, whereas inflammatory PAS are often located inferiorly due to the settling of inflammatory debris. PAS may be seen adjacent to surgical incisions, such as for cataract or glaucoma surgery or in association with posteriorly located laser burns following laser trabeculoplasty.

Neovascular growth may be preceded by rubeosis iridis at the pupillary ruff; however, neovascularisation of the angle may occur without neovascularisation of the iris. Early neovascular bridging vessels across the angle can be very difficult to detect. The risk of missing neovascularisation by not performing gonioscopy in patients with central retinal vein occlusion is about 10%.³⁰

7.6.9 Most common errors

1. Misinterpreting angle structures. A narrow angle is the most difficult to interpret.
2. Using the wrong amount of solution with scleral-type lenses: too little solution can cause bubbles behind the lens limiting the view of the angle, while too much can cause the excess solution to run onto the patient's cheek.
3. Using too much pressure with a *corneal* type lens, which indents the cornea, causing folds in Descemet's membrane as well as falsely widening the angle.

7.7 TONOMETRY

Although tonometry is now known to be a poor screening test for glaucoma compared to optic nerve head and visual field assessment, it identifies ocular

hypertensive patients who should subsequently be monitored more closely and provides essential additional information when used in conjunction with the other assessments.³¹ In addition, intra-ocular pressure (IOP) measurement is critical in monitoring glaucoma treatment as reducing IOP is currently the only effective approach to slow down glaucoma progression.³² Tonometry must be performed in any patient with glaucoma or 'at risk' of glaucoma, e.g. suspicious discs, family history of glaucoma, central visual field defect, narrow anterior angles, etc.

7.7.1 Comparison of tonometers

Goldmann applanation tonometry (GAT) has long been the gold standard for IOP measurements and its accuracy is such that it is used to determine the validity of other tonometers. The Perkins tonometer uses the same principal as the GAT, but is a hand-held tonometer and does not require a slit-lamp biomicroscope (Figure 7.25). Its advantages are that it is portable, can be used on domiciliary (home) visits and



Fig. 7.25 A Perkins tonometer.

being hand-held may be used with the patient either sitting up or lying down (note that the IOP will likely be higher when the patient is lying down). In addition, some patients are less apprehensive with this technique. Its disadvantages include that it is less stable than the biomicroscope-mounted instrument, has a fixed low magnification for viewing the mires and does not allow for efficiently examining the cornea before and after the test as the patient is not already at the biomicroscope.

Both GAT and Perkins have the disadvantage that they only provide valid measurements for corneas with near average thickness. For a very thick corneas, GAT tends to overestimate IOP, and for very thin corneas it underestimates IOP. For example, Johnson et al. reported details of a 17-year old patient with GAT readings between 30 and 40 mmHg due to extremely thick corneas of 0.90 mm (compared to a normal average of 0.54 mm) whose 'real' IOP was 11 mmHg.^{33,34} This inaccuracy of GAT has been known for some time, but has come to the fore since the findings of significant IOP reductions due to the corneal thinning induced for refractive surgery.^{34,35} The influence of central corneal thickness on applanation IOP may lead to the classification of some normal subjects with thick corneas as ocular hypertensives and several reports have suggested that central corneal thickness should be measured in ocular hypertensives,^{33,34,36} making the measurement of central corneal thickness the standard of care in the assessment of those at risk of glaucoma. Some reports have suggested that non-contact tonometry provides even higher IOP values than Goldmann tonometry in patients with thick corneas.^{37,38} In addition, this effect could also mean that some patients diagnosed as having normal tension glaucoma using GAT may actually be patients with high IOP but a thin cornea.³⁹ In this regard, a clinical note reports two cases of post-LASIK patients with steroid response progressing to end-stage glaucoma, and that the late detection may have been partly caused by unreliably low IOP after surgery.⁴⁰ Attempts have been made to determine the relationship between corneal thickness and GAT to provide a validated correction factor, but there is wide disagreement among investigators.⁴¹

Of the non-Goldmann tonometers, a systematic review of the literature suggested that the NCT seems the most accurate, with two-thirds of readings within 2 mmHg of GAT.⁴² Most non-contact tonometers (NCTs) are now highly automated and simply involve lining up the instrument in the correct position when it will automatically take measurements. They are easier to perform than Goldmann or Perkins tonometry, do not require corneal anaesthesia, and can be

performed by trained clinical assistants. However, results are typically less reliable than GAT with slight differences that are model dependent.⁴² You should check the literature for information regarding the model type you have. At least three readings are required to average the effects of the arterial pulse, which varies IOP by over 4 mmHg. However, averaging four measurements appears to provide the best sensitivity and specificity of results and is recommended.⁴³ If an NCT is used, a useful protocol can be to screen patients who do not have risk factors for glaucoma using NCT measurements taken by a clinical assistant and to repeat any measurements which are high, unequal or increased from previous visits using GAT or Perkins. Any patient with glaucoma or any risk factors for glaucoma should have pressures measured by contact tonometry.

7.7.2 Procedure for GAT

See online video 7.7.



1. Make certain that the tonometer probe tip has been appropriately disinfected. Check the integrity of the cornea for any contraindications to performing the technique.
2. Explain the test to the patient and obtain informed consent. Ask about any sensitivity to the anaesthetic. For example: 'I am now going to measure the pressure in your eye, which is one of the tests for glaucoma. This involves putting a drop in your eye. Have you ever reacted badly to drops or an anaesthetic before at an optometrist's or dentist's office?'
3. Inform the patient that the drops will sting at first but that the stinging will disappear very quickly. Instil one drop of anaesthetic or anaesthetic/fluorescein solution in both of the patient's eyes (section 7.8). You may suggest that the patient closes their eyes as this can be more comfortable. Keep a tissue handy to dab the patient's tears subsequently. Allow approximately 30 seconds for the anaesthetic to take effect.
4. Position the patient comfortably at the slit lamp, with their lateral canthus aligned with the marker on the head rest and with the patient's chin in the chinrest and forehead against the headrest.
5. If required, add a small amount of fluorescein to both conjunctivae. Fluorets can be wet with preserved saline or another drop of the anaesthetic, although the pH of the anaesthetic will reduce the fluorescence of fluorescein.

Insufficient fluorescein will result in poorly visible mires.

6. With the fluorescein in place, check for corneal staining prior to performing tonometry. Ensure there are no conditions that would contraindicate applanation tonometry, such as a serious corneal injury (this is likely to have been identified in the case history).
7. Insert the tonometer probe into the Goldmann tonometer and align the white line on the carrier with the $0^\circ/180^\circ$ degree line on the probe. Astigmatic corneas produce an error of 1 mmHg for every 4 D of corneal cylinder. To reduce this error, adjust the tonometer head to 43° from the flattest corneal meridian if the corneal cylinder is greater than 3 D. If astigmatism is with-the-rule or against-the-rule, the probe can be aligned with the red line on the probe carrier (at 43°).
8. Goldmann tonometry is a monocular technique. Position the Goldmann probe in front of the slit-lamp eyepiece that corresponds to your dominant eye. For example, if you are right eye dominant, insert the tonometer body into the right hand hole on the slit-lamp tonometer plate, so that you will view the probe image through the right eyepiece.
9. Set the tonometer scale to an average setting of about 16 mmHg (1.6 g on the GAT scale), so that minimal movement of the tonometer scale is subsequently required. Use low ($\sim 10\times$) to moderate ($\sim 16\times$) magnification, turn the illumination system to 45° to 60° to the temporal side of patient, and adjust the system to the widest beam and the cobalt blue filter. You may need to increase the slit-lamp illumination.
10. Adjust the biomicroscope to align the probe with the centre of the patient's cornea.
11. Encourage the patient to blink a few times, then to stare straight ahead.
12. Bring the probe towards the cornea. Corneal contact is signalled by either a green glow on the peripheral cornea when you are looking outside the instrument or by the appearance of two green arcs when you are looking into the eyepiece.
13. At first contact, two green hemispherical pools of fluorescein may be seen. These are caused by the tears filling in the gap between the cornea and the tonometer probe. If these are seen, move the probe very slightly further forward to applanate the cornea. The probe and its arm will then be seen to move backwards.
14. Determine whether you have the correct amount of fluorescein by assessing the diameter of the green arcs. Their thickness should be about one-tenth the size of the diameter of the arcs (Figure 7.26). If the arcs are too thin, there is insufficient fluorescein and more should be instilled. If the arcs are too thick, a tear meniscus has formed around the outside of the probe and you should attempt to remove excess tears from the eye and probe using a tissue. This is a common problem in patients with a large tear volume.
15. If the arcs can both be seen, but are not correctly positioned (Figure 7.26), move the probe while still in contact with the cornea until the two green arcs are of equal size above and below the horizontal line of the probe beam splitter and are centred in your view (Figure 7.26). Always move the probe towards the larger ring. If only one (or neither) arc can be seen, remove the tonometer tip from corneal contact to make small adjustments to the

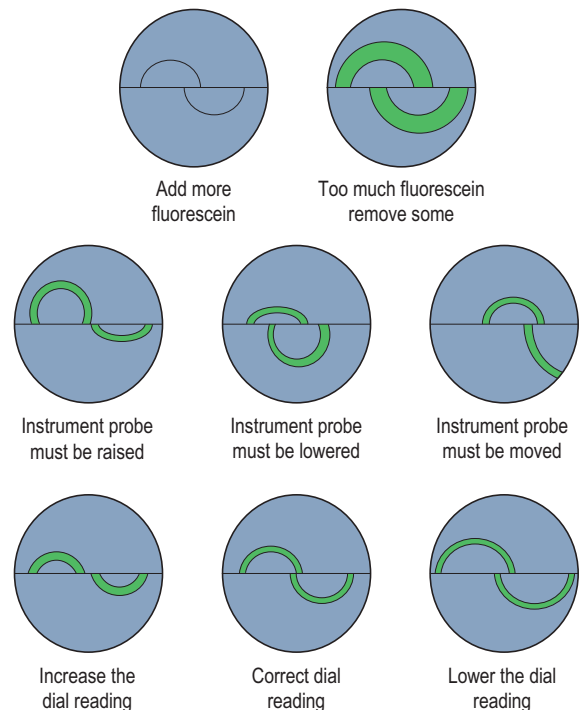


Fig. 7.26 Possible appearances seen with Goldmann applanation tonometry.

position of the tonometer probe until both arcs can be seen.

16. Some clinicians gently hold the superior eyelid with the forefinger and lower lid with the thumb to ensure the eyelids do not touch the probe. Do not put pressure on the patient's globe as this will artificially increase the IOP.
17. Adjust the tonometer scale until the inner edges of the green arcs are just touching, then remove the probe from the patient's eye. If a pulsation is perceived, adjust the scale such that the pulse centres on the correct alignment pattern.
18. Take the tonometry reading. The dial is calibrated in grams, with each gram being equivalent to 10 mmHg, so that a reading of 1.6 grams indicates an IOP of 16 mmHg.
19. Examine the cornea for unintentional damage. Examine the depth of any abrasion using an optical section technique. Deep and/or extensive abrasions made by novices may need analgesic or other treatment and should be monitored.
20. Inform the patient not to rub their eyes and to avoid dusty or windy environments for at least half an hour because of the anaesthetised cornea. Contact lens wearers must be warned to not wear their contact lenses for at least the same time period.
21. Disinfect the probe.

7.7.3 Alternative procedure: Perkins tonometry

1. The procedure is the same as that with GAT, except for the setting up of the instrument:
2. Adjust the chair so that the patient is slightly below your eye level.
3. Instruct the patient to look at the duochrome or other target that fixes the eyes in a slightly elevated position looking towards the instrument.
4. Rest the instrument on the patient's forehead and pivot the instrument so that the probe can make contact with the centre of the cornea.
5. Hold the patient's eyelids apart if needed, taking care not to press on the globe.
6. The remainder of the procedure is the same as for Goldmann tonometry. Contact time must be kept to a minimum as there is a greater possibility of abrasion with Perkins compared to GAT.

7.7.4 Recording

Record the tonometer readings for the right and left eyes on the right and left side respectively of a capital letter 'T'. Also indicate that you used a Goldmann or Perkins tonometer and the time of day (IOP varies diurnally). For example:

¹⁵T₁₆ – Goldmann – 11.30 am; ¹⁸T₁₆ – Perkins – 2.30 pm.

With NCTs, it is best to record all 3–4 tonometer readings. For example:

^{15,16,17,18}T_{16,14,17,18} – NCT – 11.30 am.

7.7.5 Interpretation

The range of normal Goldmann IOPs is from 7 to 20 mmHg (mean of about 13 mmHg). However, note that Goldmann readings are influenced by central corneal thickness and provide a significant underestimation with corneal epithelial oedema.^{34,44} Various systemic drugs can alter IOP, including systemic and topical steroid use that can significantly raise IOP in steroid 'responders' and beta-adrenergic blockers that can lower IOP. IOPs below 7 mmHg may suggest conditions such as retinal detachment, uveitis or wound leak. IOPs above 20 mmHg indicate ocular hypertension and may suggest glaucoma. However, note that patients can have primary open-angle glaucoma and have a normal IOP below 21 mmHg. The difference in IOP between the two eyes should not exceed 4 mmHg. IOPs vary diurnally, with the highest IOP generally measured in the mornings. If a suspected glaucoma patient has a normal IOP in the afternoon, ask the patient to return on another day in the early morning, so that IOPs can be remeasured at that time.

7.7.6 Most common errors

1. Obtaining high IOPs because of patient apprehension. Describing the procedure to the patient in non-threatening terms can help.
2. Taking a reading when a tear meniscus has formed around the GAT probe leading to two thick tonometer arcs and an invalid, low pressure measurement.
3. Not explaining the NCT procedure and demonstrating it to the patient, so that he or she is unnecessarily startled.
4. Not repeating NCT measurements four times on each eye.

7.8 INSTILLATION OF DIAGNOSTIC DRUGS

7.8.1 What are the risks with diagnostic drugs?

Diagnostic drugs are available to the majority of optometrists and other primary eye care practitioners throughout the world. The three major types of diagnostic drugs available are anaesthetics, cycloplegics and mydriatics. Staining agents are discussed in [section 7.3](#). The advantages to be gained by using these drugs far outweigh the possible adverse ocular and systemic effects that rarely occur. For example, in a systematic review of published research between 1933–1999, Pandit and Taylor concluded that the risk of inducing acute glaucoma following mydriasis with tropicamide alone is close to zero, and the risk with long-acting or combined agents is between 1 in 3380 and 1 in 20,000.²⁷ Mydriasis with tropicamide alone is safe even in patients with primary open angle glaucoma. Note that the most common cause of malpractice claims in the US is misdiagnosis of intraocular disease, principally retinal detachment, open-angle glaucoma, and tumours. The great majority of claims alleging misdiagnosis involve optometrists who have failed to use diagnostic drugs for dilation of the pupil with very few claims being due to adverse responses to ophthalmic drugs.⁴⁵ Of course, precautions must always be taken when using any of these drugs to ensure that the patient is at minimal risk.

7.8.2 Obtaining informed consent

1. Using lay terms, inform the patient about the technique you wish to use and the rationale for doing so.
2. Inform the patient whether the drops will sting, how long any side effects (e.g., near blur and photosensitivity with mydriatics) will last and the chances of an adverse reaction.
3. If you wish to use a mydriatic or cycloplegic, ask the patient whether they are going to operate heavy machinery or drive or perform a similar activity requiring good vision following the eye examination. Ideally patients should be informed not to drive after the examination if possible and if pupillary dilation is likely, it is good practice to advise patients to bring a driver with them or use alternative transport to the practice. Indeed, if pupillary dilation is routine, this advice can be provided to patients

when they make the appointment and printed on their appointment card. If driving is their only option for transport home, allow sufficient time for them to adapt to a dilated pupillary state and recommend that they drive only on familiar roads. Commercially available paper sunglasses or attachments could be provided if it is sunny. If the patient has to operate heavy machinery or perform a similar possibly dangerous task, make another appointment for them when they can have their pupils dilated.

7.8.3 Safety checks

1. Case history/case history notes. If the following information is not included in your initial case history notes, make sure you ask about them prior to instillation of the drops.
 - (a) Does the patient report symptoms suggestive of angle closure?
 - (b) Does the patient have any systemic or ocular disease that could be aggravated by the use of a diagnostic drug? For example, patients with angle closure glaucoma, with or without surgical or laser treatment, should be dilated with caution.
 - (c) Does the patient have a systemic condition that could be aggravated by the instillation of a diagnostic drug? For example, one case highlighted the need to avoid hyper extending the neck of a child with Down's syndrome when instilling drops to prevent spinal cord injury.⁴⁶
 - (d) Has the patient been given similar drops before and did they have a reaction to them?
2. Visual acuity. Make sure that you record distance visual acuity before any procedure is carried out on the patient. If you have not already measured visual acuity, make sure that it is measured prior to instillation of the drops.
3. Anterior angle assessment. You should estimate the size of the anterior chamber angle before using any drug that has mydriatic effects ([section 7.5](#)). Do not use miotics after mydriasis as it is generally unnecessary and pilocarpine can even cause angle closure by producing a mid-dilated pupil.^{27,47} As indicated previously, the risk of inducing acute angle glaucoma using a mydriatic is very low. Indeed, some clinicians take the view that it is better for patients to have a mydriatic-induced angle closure in their

office/practice, where appropriate treatment can be provided, than in the patient's home. In situations where you dilate a pupil of a patient 'at risk' of angle closure, make sure that you obtain informed consent, and be prepared to manage any subsequent angle closure.⁴⁸ Angle closure is even less likely to occur with mydriasis due to a cycloplegic, as cycloplegia is generally used on a much younger population than mydriatics.

4. Slit-lamp examination. Prior to mydriatic instillation, check for contraindications such as synechiae, subluxated crystalline lens, dislocated intraocular lens implant, exfoliation or pigmentary glaucoma. If any of these conditions are found, avoid mydriasis if possible or proceed with great caution. Determine the integrity of the cornea before any drops are instilled and after any procedure involving the cornea, such as contact tonometry or gonioscopy.
5. Tonometry. Assess IOP prior to the instillation of mydriatics/cycloplegics. Some exceptions include when cyclopleging infants and very young children for refractive error assessment.

7.8.4 Choosing the appropriate drug and dosage

1. Case history/case history notes. If the following information is not included in your initial case history notes, make sure you ask about them to help you choose the appropriate drug and dosage.
 - (a) Does the patient have any systemic or ocular disease that could be aggravated by the use of a diagnostic drug? For example, phenylephrine 10% should not be used in those patients with severe cardiac disease, systemic hypertension and hypotension, insulin-dependent diabetes, aneurysms or advanced arteriosclerosis. Phenylephrine 2.5% should only be used with great caution in these patients. There have also been reports of similar problems after the use of hydroxyamphetamine hydrochloride 0.25% used in combination with tropicamide 0.25%.⁴⁹
 - (b) Does the patient have any systemic or ocular disease that could have an influence on the choice of a diagnostic drug? For example, it is often difficult to obtain satisfactory mydriasis in patients with diabetes and they may require additional mydriatic drops and/or a combination of mydriatic drops (tropicamide 0.5% or 1% plus phenylephrine 2.5%). Patients with kidney disease can have unusually slow detoxification and elimination of ocular diagnostic drugs systemically absorbed and care should be given to use the lowest necessary dosage of the drug. Conversely, note that patients with a compromised corneal epithelium can have enhanced penetration of a diagnostic drug.
 - (c) Is the patient taking systemic medication that could interact with a diagnostic drug? For example, phenylephrine should not be used if the patient is taking monoamine oxidase inhibitors or tricyclic antidepressants.
 - (d) There is a general lack of information on the use of specific drugs in women who are pregnant or breastfeeding. However, diagnostic drugs, including topical ophthalmic dyes, anaesthetics and mydriatics, are generally considered safe as long as standard cautions, warnings and contraindications are considered.
 - (e) Has the patient had an allergic reaction to eye drops previously?
2. Iris colour. In general, patients with lighter irides will respond quicker and to a greater degree than those patients with dark irides. Therefore, give a higher drug dosage to a patient with dark irides and/or use a combination drug approach.
3. The drug(s) and dosage (concentration and number of drops) will depend on the procedure you are going to perform. Some clinicians choose to use a combination drug routinely and other clinicians use this approach when greater dilation is required, such as when using head-band binocular indirect ophthalmoscopy. This is achieved either with a drop of two drugs, such as one drop of phenylephrine 2.5% and one drop of tropicamide 0.5% (or 1%) or the use of a combination drop which contains both of these agents (e.g., tropicamide 0.8% and phenylephrine 5%).
4. Instilling a topical ocular anaesthetic prior to the use of a mydriatic or cycloplegic agent (one may have been used for contact tonometry) results in an enhanced mydriatic/cycloplegic

effect. The anaesthetic, as well as reducing possible discomfort, can reduce lacrimation and thus reduce drug washout for subsequently instilled drugs. It has also been suggested that the mildly toxic effects of a topical anaesthetic on the cornea opens up the intracellular spaces and aids penetration of other drugs.

5. In all cases, choose the drug with the least possible adverse effects and the lowest concentration that will allow you to efficiently attain the cycloplegia or mydriasis that you require. For example, research has suggested that cyclopentolate 1% is sufficient to produce good cycloplegia, with an effect similar to atropine 1%, in patients with accommodative esotropia and that tropicamide 1% is as effective as cyclopentolate 1% for the measurement of refractive error in most healthy, non-strabismic infants.^{50,51}

7.8.5 Checks prior to instillation

1. Ensure that you have performed all the procedures prior to instillation of the diagnostic drug that would not be possible after it has been instilled. For example, make sure that you assess pupil reflexes, near muscle balance and accommodation prior to using a cycloplegic and tonometry prior to a mydriatic.
2. Carefully identify any drops before instillation by checking the brand name, ingredients, and expiration date and checking for discoloration and precipitates. If the expiration date has passed, or if there are precipitates, discoloration or other signs of contamination, the suspect container should be discarded and a new one obtained.
3. Before the instillation, record the drug type (preferably by its brand name) and dosage (concentration and number of drops used in each eye). The use of the brand name is useful since it uniquely identifies the particular preparation that has been used. Different brands may well have different preservatives or other non-active ingredients.
4. Recheck the container of the diagnostic drug for its identity and remove the cap in preparation for drug instillation. If a dropper bottle is being used, do not place the dropper cap on any surface in such a way as to risk contaminating the inside of the bottle cap. It is best if you hold it in your hand.

7.8.6 Drug instillation procedure

See online video 7.8.



1. The patient should be seated in a fixed chair with a proper back support and arm rests. There is a chance that upon instillation, the patient (especially a child) will abruptly move. Therefore do not use a stool or a chair on casters.
2. Ask the patient to tilt their head backwards with the chin raised slightly.
3. Gently pull down the lower eyelid or pull it forward slightly to form a pouch.
4. Instil a drop or drops into the temporal side of the pouch. Avoid touching the eyelashes, eyelids or conjunctiva with the dropper tip. Gently release the lower eyelid.
5. In the case of ointment, gently squeeze a 1.5 cm ribbon of ointment inside the lower fornix.
6. Ask the patient to look downward and gently release the upper eyelid over the eye.
7. Press firmly over the lacrimal sac (just medial to the inner canthus) for at least ten seconds. Nasolacrimal occlusion prevents any excess drug entering the nasolacrimal duct, keeping systemic absorption to a minimum. Nasolacrimal occlusion is not required when an ointment is used. Make sure that you wipe any excess drops/ointment away from the eye with a tissue.
8. If two drops are to be used, wait at least three minutes between drops. Instilling two drops consecutively without this wait overfills the lacrimal lake and negates the theoretical effect of applying more drug.

7.8.7 Post drug instillation procedure

1. Return the cap to the bottle (and screw on securely) or dispose of single dose products such as Minims.
2. Anaesthetics: Inform the patient not to rub their eyes and avoid dusty or windy environments for at least half an hour after use of an anaesthetic. Contact lens wearers must be warned to not wear their contact lenses for at least the same time period.
3. Mydriasis: Measure intra-ocular pressure post-mydriasis for patients at risk of angle closure. A rise of more than 5 mmHg should be monitored until it returns to normal levels.

4. Provide commercially available paper sunglasses or attachments after mydriasis when necessary to avoid photophobia.
5. Use appropriate follow-up procedures and/or emergency care should any untoward reactions or sequelae occur. All these drugs (with the exception of tropicamide, for which no serious adverse effects have been recorded) can give rise to systemic effects such as altered mental states and increased heart rates. Patients may also faint. Note that an unwanted reaction such as a rise in IOP due to pupil block post-mydriasis can develop some hours later, and 'at risk' patients should be told who to contact in case of an emergency.

7.8.8 Recording

Record the time, the number of drops instilled into each eye and the drug and its concentration.

For example:

9.30 am: 2 drops 0.5% tropicamide.

7.8.9 Most common errors

1. Instilling two drops consecutively without waiting for 3 minutes after the first drop.
2. Not checking drops carefully enough before instillation by forgetting to check the brand name, ingredients, and/or expiration date and/or not checking for discoloration and precipitates.

7.9 PUPIL LIGHT REFLEXES

Observing the pupil reflexes as a light is shone into an eye (the direct reflex) and the fellow eye (consensual reflex) can indicate abnormalities affecting the afferent or efferent neurological pathways responsible for pupillary function. The swinging flashlight test accentuates small defects in a unilateral direct pupil reflex that could otherwise easily be missed.

7.9.1 Pupillary function

Evaluation of pupillary function provides valuable information about the integrity and function of the iris, optic nerve, posterior visual pathways and the third and sympathetic nerves to the eye, and some of the conditions that cause pupil reflex abnormalities are life threatening. Afferent pupillary defects are caused by lesions in the 'front end' of the pupillary

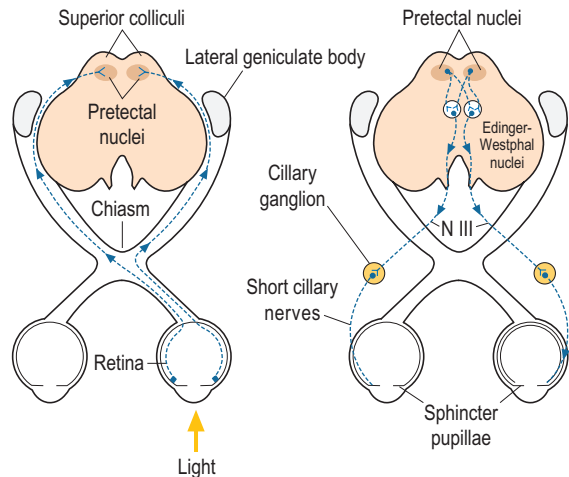


Fig. 7.27 The pupillary reflex pathway.

light reflex pathway and most commonly by lesions in the retina and optic nerve. The afferent pupillary pathways leave the visual pathways in the last third of the optic tracts to reach the pretectal nuclei (Figure 7.27). Afferent pupillary defects do not cause anisocoria (different pupil sizes), but may produce abnormal pupillary light reflexes. Efferent pupillary defects produce anisocoria and are caused by lesions to the motor neurone system, which carries signals from the central nervous system to the iris via the 3rd cranial nerve.

7.9.2 Comparison of tests

Pupil size should be assessed in both bright and dim illumination to investigate any anisocoria. The swinging flashlight test provides a sensitive assessment of any unilateral or asymmetric afferent defects, and has been shown to be superior to the Marcus Gunn test (redilation under sustained illumination) for detecting relative afferent pupillary defects.^{52,53} There is no condition in which the near reflex is defective or lost when the light reflex is normal. Therefore the near reflex need only be checked if the light reflex is abnormal. Patients can show an abnormal light and near pupil reflex or an abnormal light reflex with a normal near reflex (light-near dissociation).

7.9.3 Procedure for pupil assessment

See online video 7.9.

1. Ask the patient to take off their glasses, and look at a letter on the distance visual acuity chart that both eyes can see easily. If the worst



monocular visual acuity is less than about 6/18 (20/60) ask the patient to look at a spot of light on the distance chart.

2. Sit in front and to the side of the patient, so that you can easily observe the patient's pupils, but you are not obscuring fixation of the target.
3. Keep the room lights on and check the size, shape and location of both pupils. Compare the size of both pupils carefully. You can estimate the size of the pupil using the iris as an approximate 12 mm reference scale (Figure 7.28).
4. If the pupil sizes are unequal in bright light conditions, measure the pupil sizes with a millimetre ruler or a hemisphere scale. In addition, dim the room lights but keep the light levels high enough so that you can clearly see the patient's pupils, and measure the size of the patient's pupils again. An ultraviolet lamp, such as a Burton lamp used for contact lens fitting, can be used with patients with dark irides as the lens fluoresces to allow pupil sizes to be measured.

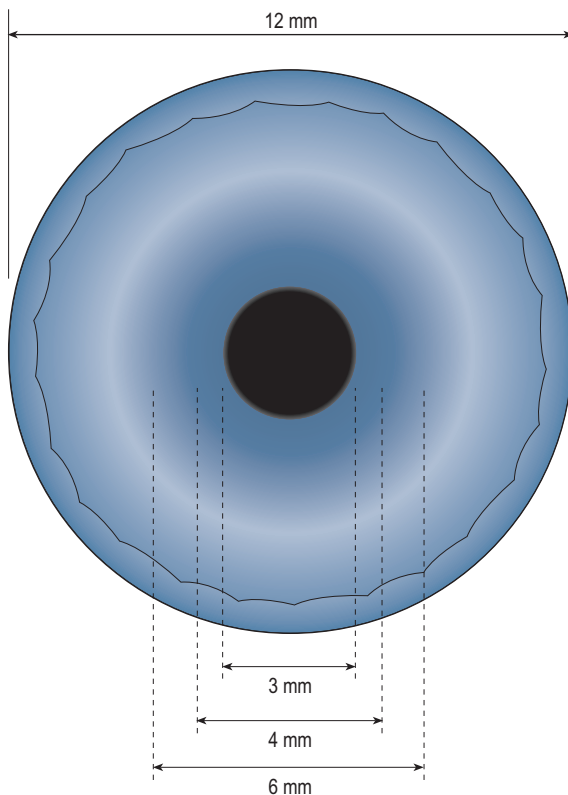


Fig. 7.28 The size of the pupil can be estimated using the iris as a 12 mm reference scale.

5. Direct and consensual light reflexes:
 - (a) Ask the patient to remain fixating a letter or spotlight on the distance chart.
 - (b) Shine a penlight or direct ophthalmoscope into the right pupil from the inferior temporal side from a distance of 5 to 10 cm. Observe the extent and speed of constriction of the right pupil (direct light reflex) and left pupil (consensual reflex). Remove the light and observe the direct and consensual dilation. Check this several times as dramatic fatigue can occur in an abnormal eye that at first shows a normal response.
 - (c) Shine the light into the left pupil from the inferior temporal side from a distance of 5 to 10 cm. Observe the extent and speed of constriction of the left pupil (direct light reflex) and right pupil (consensual reflex). Remove the light and observe the direct and consensual dilation. Check this several times.
6. Swinging flashlight test:
 - (a) Ask the patient to remain fixating a letter or spotlight on the distance chart.
 - (b) Shine a penlight or direct ophthalmoscope into the right eye from below the patient's eyes from a distance of 5 to 10 cm. Pause for 2–3 sec and then quickly switch the light to shine into the left eye.
 - (c) Repeatedly alternate between the two eyes, pausing for 2–3 sec on each eye, and look for any change in pupil size as the light is alternated.
 - (d) A normal response is that both pupils will constrict as the penlight is shone in one eye. As the light is moved off the eye on its way to the fellow eye, both pupils will dilate. As the light reaches the fellow eye, both pupils constrict. After the light has been shone on a pupil for 1–2 seconds, the pupils may redilate slightly, so it is important to observe the pupils at the instant the light first falls on them.
 - (e) An eye with a relative afferent pupillary defect (RAPD) will dilate as the eye is first turned upon it, as the consensual dilation response due to the light moving off the good eye overpowers the poor constriction response from the affected eye.

- (f) The RAPD can be quantified by adding successively increasing neutral density filters to the 'good' eye, until a normal swinging flashlight response is seen.
7. Near reflex: This need only be measured if the light responses are abnormal or sluggish.
 - (a) Ask the patient to remain fixating a letter or spotlight on the distance chart.
 - (b) Ask the patient to then look at a target such as the patient's own thumb about 15 cm from his or her eyes.
 - (c) Observe the extent and speed of pupillary constriction as the patient changes fixation from distance to near.
 - (d) Ask the patient to look back at the distance target and observe the dilation as this occurs.

7.9.4 Recording

Pupil shape and size: Record any irregularity in pupil shape and any anisocoria.

Pupil reflexes: A 0 to 4+ grading system can be used for direct (D) and consensual (C) reflexes where 0 indicates no pupil response, 1+ (or +) indicates a very small, just visible response, 2+ (++) indicates a small, slow response, 3+ (+++) indicates a moderate response and 4+ (+++++) indicates a brisk, large response typical of a healthy young patient. An alternative is to use acronym PERRL (Pupils Equal Round and Respond to Light), but this does not differentiate between a just visible response and a large, brisk one. If the light reflex is abnormal, the near reflex must be checked. Some disorders produce an absent light reflex with a normal near reflex (light-near dissociation).

Also record the result of the swinging flashlight test as +ve RAPD (if an RAPD is indicated) or -ve RAPD (this indicates that there is no problem). If +ve RAPD is found, record which side was defective. If the defect is quantified using a neutral density filter, indicate the filter density in log units.

Examples:

RE 6, LE 6. D and C 4+ R and L, -ve RAPD.
 OD 4, OS 4. D and C 3+ OD and OS, -ve RAPD.
 RE 5, LE 5. PERRL, -ve RAPD.
 OD 4, OS 4. PERRL, +ve RAPD OS, 0.3 ND filter.

7.9.5 Interpretation

Pupils are normally equal in size and typically vary from 3 to 6 mm in diameter in bright light to about 4 to 8 mm in dim light and show slight physiological

fluctuations in size or hippus. The pupil gets smaller with age. Physiological anisocoria is seen in about 20% of normal patients and is generally the same in dim and bright illumination, usually small (<1 mm), shows normal pupil reflexes and has been present for years. If the diagnosis is in any doubt, this can be checked by asking the patient to bring in some old close-up photographs of themselves looking straight ahead. Pathological anisocoria is due to an abnormality in the efferent or motor pupil pathway. Anisocoria that is greatest in bright light will generally show an abnormal direct and consensual light reflex. This indicates a problem in the motor leg of the light reflex pathway, such as in the third nerve, ciliary ganglion (including Adie's tonic pupil) or iris, or could be drug induced.

An abnormal direct light response in a pupil capable of a normal consensual response indicates an afferent (visual pathway) defect. There is generally no anisocoria. The swinging flashlight provides a more sensitive assessment of any unilateral or asymmetric afferent defects. It compares each eye's direct response (reflecting the normality of its visual pathway) with its consensual response (reflecting the normality of the other eye's visual pathway). Symmetrical afferent defects do not show a positive RAPD. Some normal subjects may show a persistent but small RAPD in the absence of detectable pathologic disease. Therefore, an isolated RAPD in the range of 0.3 log unit that is not associated with any other significant historical or clinical finding should probably be considered benign.⁵⁴ Similarly, patients with unilateral cataract may show an RAPD in the non-cataractous eye that is not reflective of visual pathway disease.⁵⁵

7.9.6 Most common errors

1. Using too slow a swing in the swinging flashlight test.
2. Using too low a light level to observe the contralateral eye, especially with a darkly pigmented iris.
3. Blocking the patient's view of the visual acuity chart and stimulating accommodation and subsequent pupil constriction.
4. Forgetting to check pupil reflexes prior to instilling a mydriatic or cycloplegic.

7.10 FUNDUS EXAMINATION, PARTICULARLY THE POSTERIOR POLE

Ophthalmoscopy revolutionised eye examinations by allowing observation of the fundus and replacing

the diagnosis of 'amaurosis' (an outwardly healthy eye with poor vision) with a multitude of others for which an aetiology and treatment could be sought.

7.10.1 Comparison of techniques

Stereoscopic techniques are the clinical standard for fundus examination, and fundus biomicroscopy with a high plus lens is the standard for assessment of the posterior pole, including the disc, macula and vasculature. This indirect technique may also be used for peripheral assessment, and is often employed to enable a more magnified, stereoscopic view of small,

peripheral lesions noted on general assessment with the head-band binocular indirect ophthalmoscope (section 7.12). Some clinicians use this modified technique for routine examination of the entire fundus, including the periphery.

Fundus biomicroscopy

This has many advantages over direct ophthalmoscopy for general assessment of the posterior pole of the fundus (Table 7.4):

- Stereoscopic viewing is possible through dilated and undilated pupils. In addition to a more accurate assessment of the disc and macula region, this allows immediate assessment of any

Table 7.4 Optical and observational characteristics of various fundus examination techniques

Method	Image	Stereopsis?	Diameter (approx.) (mm)	Image mag.*	Mag. in slit lamp (16 ×)	Static field of view*	Extent of fundus visible†
Direct ophthalmoscope	Erect	No	N/A	15×†		~5°†	To equator
Monocular indirect	Erect	No	N/A	5×		~12°	Beyond equator
SuperPupil™	Reversed and inverted	Yes. Detail in stereopsis improves with lower power (higher magnification); best with 'Super' series	15	0.45×	7×	Variable (generally higher with higher powered lenses)	Beyond equator (generally facilitated with higher powered lenses)
Super			25	0.57×	9×		
VitreoFundus™							
SuperField™			30.2	0.76×	12×		
Super66 Stereo			35	1.0×	15×		
Fundus Lens™							
+90D	Reversed and inverted	Yes	19	0.76×	12×	~45°	Entire retinal surface
+78D			29	0.93×	14×		
+60D			30	1.15×	18×		
BIO, +20 D	Reversed and inverted	Yes	48	3×	–	–	Entire retinal surface
Fundus contact lens	Reversed	Yes	–	Variable	Variable	–	Entire retinal surface

*Various manufacturers' claims.

†Through a dilated pupil, with direction of patient fixation to regions to be viewed and with manipulation of the slit lamp.

‡Varies with refractive error.

lesion/feature that requires stereoscopic examination. For example, the neuroretinal rim tissue and the cup-to-disc ratio cannot be evaluated properly without stereoscopic observation of the depression of the cup in relation to the disc structure. Often the depression of the cup extends beyond the area of pallor and this is very difficult to detect without observing the disc stereoscopically.⁵⁶ In addition, non-stereoscopic assessment cannot consistently or accurately determine the presence of more subtle elevations such as oedema of the retina or macula.⁵⁷

- A larger field of view is available compared to direct ophthalmoscopy, even through an undilated pupil.⁵⁸
- The technique is dynamic and all parts of the fundus can be viewed with only minor cooperation from the patient.
- A superior view is obtained through media opacities as compared to direct ophthalmoscopy and this is particularly useful to assess the fundi behind cataract.
- Varied lens diameters and powers are available (Table 7.4). The Super66 stereo is probably the lens of first choice and this lens, the older +78 D and other lower-powered lenses allow more magnification and better stereopsis for viewing details of the optic nerve, macula, and specific lesions. They can all be used with an undilated pupil with practice. The SuperPupil, the older +90 D and other smaller, higher-powered lenses can facilitate examination when the pupil is undilated or otherwise small or provide a better field of view for examination of the peripheral retina.
- Variable magnification settings on the slit lamp allow for varied viewing conditions with the same lens, and a very wide range of magnification options when various lenses are employed.
- The view is relatively independent of ametropia. This is particularly useful in moderate to high myopia, where the high magnification when using direct ophthalmoscopy can limit the field of view substantially. A better estimate of optic disc size can also be obtained. The slit-lamp beam height can be used to increase the accuracy of disc size estimates when used with appropriate magnification factors.⁵⁹
- A red-free filter and various magnification settings facilitate the assessment of the retinal nerve fibre layer.
- A yellow filter attachment facilitates examination of individuals who are photosensitive. Clinicians have varied opinions on whether or not to use a yellow filter as some find the colour rendering properties of the filtered lenses unacceptable and question the necessity in a routine, quick assessment. Students first learning the technique, however, should use a yellow filter to reduce the discomfort and exposure of their subjects.⁶⁰

These advantages outweigh the mild inconvenience of the aerial inverted and reversed image, the interpretation of which is soon learned.

Digital fundus cameras

These can produce stereoscopic photographs of the posterior pole of the fundus through an undilated pupil, that provide an assessment of equal quality to that provided by a dilated fundus examination by a retina specialist.⁶¹ It should be noted that 2-D fundus images provide slightly smaller assessments of cup-to-disc ratio than fundus biomicroscopy, although the reliability of assessments is similar.⁶² The advantages that are brought about by using digital imaging are the speed with which the images can be viewed (which also means that a repeat photograph taken if necessary) and the ability to archive the images in an efficient, long-lasting and flexible fashion using a computer that allows subsequent analysis and comparison. The images can be shown to patients (allowing enhanced patient counselling, section 2.4) and can even be printed out and given to the patient. Computer manipulation also allows for the easy enhancement of images and automated measurements of diagnostic features within images. The 2-D photographs of the posterior pole in Chapter 8 were all taken through non-dilated pupils. Finally, transmission of digital images through computer networks introduces the possibility of 'teleophthalmology' referrals from primary eye care, where the secondary eye care clinician is remote from the patient.⁶³

Direct ophthalmoscopy

This has the advantages of being a simple technique to perform, providing an erect view of the fundus with moderate to high magnification (15× with an emmetrope) and can easily be performed with the patient sitting upright. It uses a hand-held instrument that is easily portable. It can be useful when it is difficult/impossible to use a slit-lamp and for domiciliary (home) visits. It can be used in combination with fundus biomicroscopy and it provides a better retro-illumination picture of cortical and posterior subcapsular cataract and vitreous floaters in an undilated pupil than slit-lamp biomicroscopy and can provide a

useful estimate of a patient's visual dysfunction due to cataract through the observation of the degradation of the fundus image. It can be used to observe spontaneous venous pulsation at the disc (section 8.5.3), which may not be as easily seen with fundus biomicroscopy. The direct ophthalmoscope should not be used to assess the anterior segment as it provides a 2-D, fixed, low magnification view with limited control of illumination. It also requires a very close working distance, which some patients find unsettling (students need to learn to overcome the natural avoidance of invading a patient's 'personal space') and if the examiner or patient is ill it may be necessary for the examiner to wear a surgical mask to prevent the spread of infection. Finally the bending required can lead to strain injury to the back of the examiner over the long term.⁶⁴ For fundus assessment, the extent of the fundus that is visible with direct ophthalmoscopy is limited so that significant fundus lesions can be missed because of the difficulties in scanning the retinal surface with the small field of view provided.^{65,66}

Monocular indirect ophthalmoscopy

This is typically used to provide an assessment of the retina without the necessity of pupil dilation. Its use was therefore higher in the past when fewer countries allowed optometrists to use mydriatic drugs. It is still used in patients where pupil dilation is not possible or advisable, patients who are not tolerant of the brighter light of a binocular technique, young children and special populations (because of the farther proximity from the patient) and basic screenings. It has also been used, instead of direct ophthalmoscopy, by clinicians who are essentially monocular and cannot use their weaker eye with the direct ophthalmoscope. Currently available instruments include the Welch Allyn Pan-Optic and Keeler Wide-Angle Twin Mag, which are marketed as direct ophthalmoscopes with a much larger field of view. In reality they are monocular indirect ophthalmoscopes that provide an erect view of the fundus. The field of view is close to 25° versus the typical direct ophthalmoscope field of view of 5° and the magnification is similar to that of a direct ophthalmoscope at 15×. The Keeler instrument provides a second magnification level of about 22× with a field of view of about 17.5°. The AO/Reichert monocular indirect ophthalmoscope is no longer produced and is not discussed. Although the MIO provides a good view of the majority of the posterior pole, the view of the peripheral fundus and macula is limited. Some MIOs can be focused for an anterior segment assessment and the PanOptic has a +13.3 D add on corneal magnifying lens that is inserted over the objective lens to view the

anterior segment. While this is possible, it is rarely used as the view of the anterior segment with a slit lamp is far superior.

7.10.2 Fundus biomicroscopy procedure

(see summary in [Box 7.2](#))

See online video 7.10. The procedure is the same in undilated or dilated pupils. Maintaining a stable, binocular image is easier when the pupil is larger, but with practice, the ability to maintain excellent views through a small pupil improves.

1. Explain the test to the patient: 'I am going to examine the health of the inside of your eyes with a microscope and a lens held close to your eye. The light will be bright, so please let me know if you would like a break.' If dilation of the patient's pupils is required, follow the informed consent procedure for the instillation of a mydriatic drug ([section 7.8](#)).
2. Set the slit-lamp biomicroscope up for yourself and your patient if this has not already been done, and ask them to remove any glasses. Choose an appropriately powered lens for the

Box 7.2 Summary of fundus biomicroscopy procedure

1. Dilate the patient's pupils (if required and unless contraindicated).
2. Prepare the slit-lamp biomicroscope and clean your lens.
3. Place the illumination system in line with the eyepieces, use a parallelepiped and set the magnification low (~10×). Direct patient fixation.
4. Introduce the lens, ensuring that the light enters the pupil through the lens.
5. Look through the biomicroscope and pull the joystick straight back first noticing the lens itself in focus, then the red reflex of the retina also coming into focus.
6. Increase the magnification and broaden the illumination as required.
7. Evaluate the optic nerve head and its immediate surroundings.
8. Systematically examine the rest of the posterior pole while maintaining lens stability.
9. Examine the light-sensitive macula last.
10. Examine the posterior vitreous by pulling even farther back on the joystick.

type of examination required and make sure that it is clean.

3. Place the illumination system in line with the eyepieces of the biomicroscope (zero degrees displacement). Use a parallelepiped of moderate width, moderate height, and low to medium intensity. Set the magnification to low ($\sim 10\times$), and dim or turn off the room lights. If you are examining the patient's right eye, ask the patient to look at your right ear with their left eye. If you are examining the patient's left eye they should look at your left ear. If the patient is monocular or low-visioned, advise the patient to look in a general straight ahead direction. Most patients can maintain a stable eye position fairly well.
4. Look through the biomicroscope and reduce the height of the slit to the size of the pupil.
5. Either rest your elbow on the biomicroscope table (or on the lens holder placed on the table) or hook your little finger over the forehead rest of the biomicroscope to take the strain off your arm. Holding the lens manually offers more flexibility in manipulation of the lens, and therefore the view, than using one of the available lens mounts.
6. Hold the lens with your thumb and first or second finger. Generally, use your left hand for examination of the patient's right eye and vice versa. The lens should be oriented with the back of the lens facing the patient (i.e. the V of 'Volk' points towards the patient).
7. Introduce the lens into the light path, within 5 mm of the patient's cornea. The optimum lens-to-cornea distance is greater for lower plus lenses (range 5–11 mm); however, being closer and pulling away slightly is preferred to being too far from the eye where the pupil stop prevents a stereoscopic view and reduces the field of view. Make sure that the light enters the pupil through the lens. Rest your other fingers on the patient's cheek and/or bridge of the nose and brow to help stabilise the lens ([Figure 7.29](#)).
8. Once you see the light enter the pupil and the lens is stable, look again through the biomicroscope and pull the biomicroscope joystick straight back. As the slit lamp is being pulled back, the surface of the lens itself will first come into focus, then the blurred red reflex of the retina should be seen. While maintaining lens stability, continue to pull back until the fundus structures come into focus. The extent of this movement varies with the power of the



Fig. 7.29 Holding the condensing lens for fundus biomicroscopy.

condensing lens. The lower dioptric powered lenses will create an image farther from the patient's face so the biomicroscope must be pulled back more than with higher powered lenses. Novices must learn *not* to move the lens back at the same time as the slit lamp is pulled back.

9. Increase the magnification and broaden the illumination as required. Reflections can be reduced by tilting the lens and/or tilting the illumination system.
10. Encourage the patient to blink normally throughout the procedure but to hold their eyes open widely between blinks. Make sure the patient keeps both eyes open and that the eye not being examined has a clearly visible fixation target as this assists the patient in holding the eyes open. If the patient's eyelids are blepharospastic or ptotic, hold the upper eyelid with the fourth finger of the hand that is holding the lens. You can facilitate examination of the photophobic patient by reducing the illumination intensity, beam width and beam height, and by using a yellow filter.
11. Evaluate the optic nerve head and its immediate surroundings ([Figure 7.30](#)). Note whether the disc is particularly large or small and note its shape and colour and the clarity of the disc margins. Make sure you are viewing the cup stereoscopically and estimate the cup-to-disc ratio along the horizontal and vertical meridians

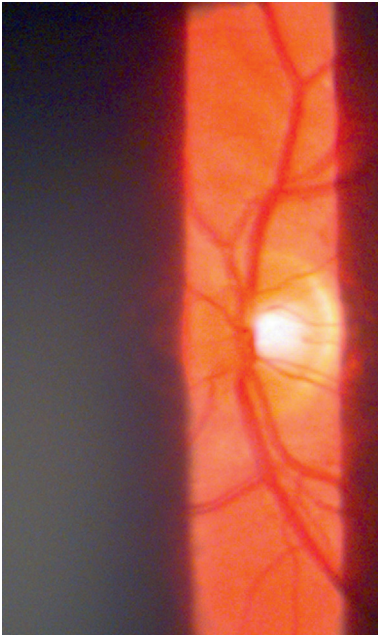


Fig. 7.30 A right optic disc seen with fundus biomicroscopy.

(Figure 7.31) and note the location, slope and depth of the cup. Assess the neuroretinal rim, noting the relative width of the superior, inferior, nasal and temporal rims if possible. Note the presence of any anomalies/ abnormalities of the disc or its immediate surroundings (Figures 8.27–8.38).

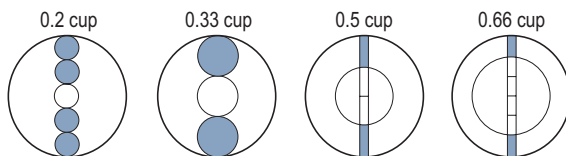


Fig. 7.31 Mathematical relationships that can help to determine the cup/disc ratio.

12. Systematically examine the rest of the posterior pole. Follow the arcades (either inferiorly or superiorly) around the macula, to the opposite arcades and back to the nerve head. As the illumination system of the biomicroscope is moved down with the joystick of the slit lamp through the high plus lens, the light will go up behind the high plus lens to illuminate the superior retina. To maintain the image stability,

as you move the light with the biomicroscope, move or tilt the lens slightly in the same direction as the light source in order that the cone of light from the lens continues to go straight through the pupil. Because the image is inverted and laterally reversed, what appears to be the inferior fundus in the view is actually the superior fundus and vice versa.

13. Note the colour and tortuosity, and any general or focal narrowing or dilation of the blood vessels. Also carefully examine the arterio-venous crossings and look for abnormalities such as venous nipping or right angle crossings (venule deviations due to an overlying hardened arteriole, see Figures 8.46 and 8.48). Estimate the relative width of the arteries and veins between one and three disc diameters from the disc (the AV ratio) as a percentage rather than using the traditional $\frac{2}{3}$ or $\frac{3}{4}$.⁶⁷ At the same time, examine the surrounding fundus and look for any abnormalities.
14. Some practitioners recommend that the light-sensitive macula should be examined last. Note that the after-image produced can make patient fixation of the second eye examined difficult.
15. Examine the posterior vitreous by pulling even farther back on the joystick with the patient's gaze in primary position. The most common and prominent finding is the Weiss ring representing the posterior vitreous that has pulled away from the optic disc (Figure 8.26).
16. If a binocular or adequate view of any part of the fundus and particularly the optic nerve and macula is not obtained, or any lesions are noted or a condition such as glaucoma is suspected, the patient's pupils should be dilated. If a patient refuses mydriasis, counselling on the relative risks should be undertaken and carefully documented.

7.10.3 Peripheral fundus and nerve fibre layer assessment with fundus biomicroscopy

Peripheral views are improved with pupillary dilation. As with headband binocular indirect ophthalmoscopy with a +20 D lens, the patient's gaze is directed toward the sector that the examiner wishes to view. All eight sectors of the fundus are examined in a systematic order (for example: view the superior fundus first, then the superior-nasal, nasal, inferior-nasal, inferior, inferior-temporal, temporal and finally the superior-temporal fundus). To view the superior



Fig. 7.32 Examining the superior fundus using fundus biomicroscopy with a SuperField lens. Note that the patient is looking upwards, and the lens is tilted slightly to maintain coaxial illumination evaluating the superior fundus.

periphery, ask the patient to look up, centre the lens and light to enter the patient's pupil and pull the slit lamp back, as per instructions for the posterior pole assessment. To view farther into the periphery, move the biomicroscope down (the light will be directed up behind the lens) and tilt the lens slightly to maintain coaxial illumination (Figures 7.32 and 7.33). Although the view of the superior retina will be inverted and reversed, it is helpful to remember that, if you are directing the light towards the superior retina with the patient looking upwards, you will be looking at the superior retina.

Examination of the retinal nerve fibre layer (NFL; Figures 8.27–8.33) with the red-free filter is useful, and is especially important in patients in whom you suspect optic neuropathies including glaucoma. As the filter decreases the brightness of the image, the slit-lamp illumination should be increased. A 'bright-dark-bright' pattern is noted in normal individuals, as noted by the light band of white, striated nerve fibres inserting into the superior-temporal and inferior-temporal poles of the disc, and a darker pattern through the macular area. 'Slit' defects appear as slightly darker bands in the striated nerve fibre layer band and are approximately one blood vessel width across. These defects can be normal in some individuals. 'Wedge' defects appear as a darker band that widens as it extends away from the optic disc into the nerve fibre layer. These can be accompanied by a focal loss in the neuroretinal rim tissue. Diffuse loss of the striations of the NFL can also be noted. Note that the fine tertiary

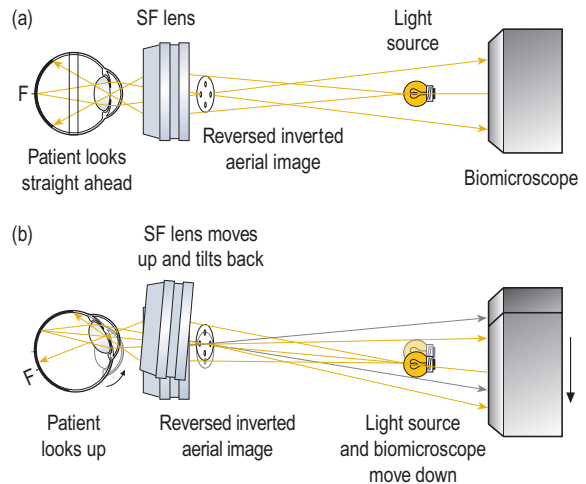


Fig. 7.33 (a) Optics of fundus biomicroscopy with a high-plus lens. The real image is reversed and inverted and lies between the hand-held lens and the observer at the slit lamp. The image is therefore in focus when the slit-lamp biomicroscope is pulled back towards the observer. (b) Observation of the superior fundus is facilitated by having the patient look up.

retinal vessels can be seen more prominently in regions of NFL loss and are less visible within the healthy NFL. Nerve fibre loss with age decreases the robustness of the 'bright-dark-bright' pattern as does media opacity and observation with a lens with a yellow filter.⁶⁸

7.10.4 Direct ophthalmoscopy procedure

See online video 7.11. Familiarise yourself with the controls of the direct ophthalmoscope. Learn how to vary the intensity of the light beam, its size, shape and colour. A green ('red-free') filter increases the contrast of blood vessels and vascular lesions (they appear dark against the light background of the fundus) and therefore can be useful when assessing patients with diabetes or other vascular disease. Some instruments also have settings that will project a target with the light beam such as an eccentric fixation target. A slit aperture is sometimes provided to determine the elevation or depression of a lesion using the monocular cue of the beam bending. A polarising filter and a half circle aperture are often available to help decrease annoying reflections from the corneal surface, although the image with the polarising filter is limited in that the luminance across the image becomes variable (in a



'Maltese cross' pattern due to corneal birefringence). Direct ophthalmoscopes include focusing lenses with ranges that differ depending on the instrument used, but the range is typically from about +30 to -30 D. The power of the lens being used is displayed, with the red numbers indicating minus lenses and the black numbers indicating plus lenses. Some instruments have a second wheel of lenses or a setting for additional lenses that, when used in combination with the first wheel of lenses, allow for higher total dioptric range.

1. Raise the chair to such a position that you can comfortably look into the patient's eye (from the patient's temporal side) by bending over only slightly. This is important to avoid a long-term strain injury to your back.
2. Inform the patient that you are going to examine the health of their eyes.
3. Use the largest aperture beam for patients with large pupils as it provides the largest field of view. For patients with smaller pupils, typically the elderly, the intermediate size aperture is preferred as the field of view is limited by the pupil and the larger aperture creates a larger corneal reflex.
4. Set the lens wheel to about +10 D (if you remove your glasses for this technique, you must take this into account, i.e. a -6 D myopic examiner should start with a +4 D lens). Make sure that any auxiliary lenses are set at zero.
5. Ask the patient to remove their glasses and remove your own. If a patient wears contact lenses, it may be easier to perform direct ophthalmoscopy with the patient wearing the lenses, particularly with highly myopic patients. If you have an unusually large astigmatic or myopic correction it may be necessary to wear glasses or contact lenses while using the direct ophthalmoscope.
6. Dim the room lights. Hold the ophthalmoscope in your right hand and use your right eye to examine the patient's right eye. Your left hand and left eye should be used to examine the patient's left eye. It may take some practice to become comfortable with this, especially with your non-dominant eye and hand. If you have reduced visual acuity in one eye it may be necessary to use your better seeing eye to evaluate both the patient's eyes. This will take some practice to avoid bumping the patient's nose and to obtain an adequate view of the fundus on your affected side.
7. Instruct the patient to look up and temporally (usually at the corner of the room). Some practitioners find this positioning places less strain on the examiner's back than if the patient looks straight ahead at a target.
8. Place the top of the ophthalmoscope against your brow. You should now be able to view through the aperture. Rotate the ophthalmoscope handle approximately 10° to 20° from the vertical to avoid the patient's nose. Position the ophthalmoscope about 15° temporal to the patient's line of sight. Both of your eyes should be kept open to relax your accommodation. It will take some practice to suppress the other image, especially when you are using your non-dominant eye.
9. Place the hand not holding the ophthalmoscope on the back of the examination chair for stability. With the total dioptric power set at about +10 D (Step 2) move closer to the patient until the anterior segment of the eye is in focus (at approximately 10 cm). Now observe the clarity of the media. Opacities will appear as dark areas against a bright red background (the red reflex; Figures 8.20–8.25). You can estimate the location of the opacity by using the principle of parallax motion. Choose a point of focus, e.g., the iris. If the opacity is **Anterior** to the iris, '**Against**' motion will be observed when you move the beam. If the opacity is posterior to the iris, '**with**' motion will be observed when you move the beam. If you note that the opacity is anterior (e.g., on the cornea) ask the patient to blink. If the opacity moves, it is floating in the tears (e.g. mucus or debris). If it does not move, it is a true corneal opacity. Instruct the patient to look up, then left, then down and then right while directing your view in the same direction to view opacities in the lens behind the iris. Cortical lenticular opacities are most commonly found in the inferior nasal aspect of the crystalline lens so care should be taken to inspect this quadrant (section 8.4.3). Anterior segment abnormalities should be assessed in more detail using slit-lamp biomicroscopy.
10. Move in closer to the patient on a line 15° temporal to the patient's visual axis and decrease the dioptric power of the focusing lens as you move closer. By doing this, opacities in the vitreous may be observed, such as floaters, haemorrhage and asteroid bodies. To look more carefully for floaters, ask the patient to look up

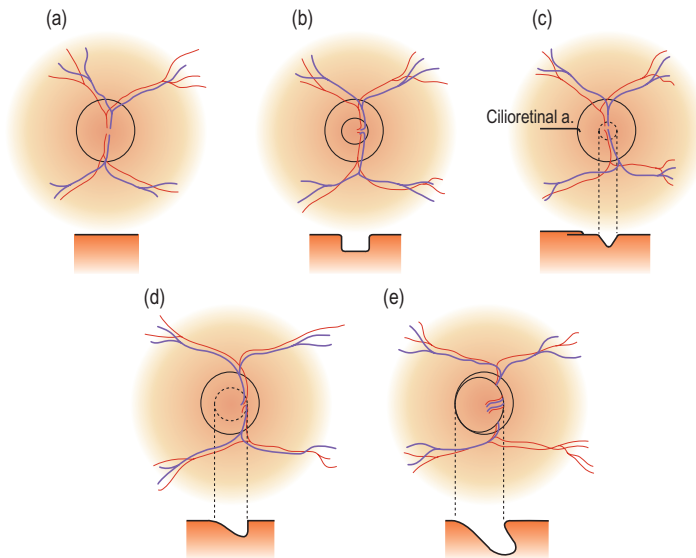


Fig. 7.34 Diagrams of different sizes and types of optic nerve cupping. (a) No cup. (b) 0.4 cup:disc ratio (C:D) in both the horizontal and vertical meridians. Deep, with clearly demarcated edges. (c) Shallow cup with gently sloping edges and a C:D of 0.30 H and 0.25 V. (d) C:D of 0.60 H and 0.50 V, with nasal displacement of the vessels and a gentle slope temporally. (e) Advanced glaucomatous cupping with a C:D of 0.90 and a deep bean pot shape. There is no healthy rim of tissue temporally.

- and down, and watch for any floaters moving in your view.
11. You should now be as close as possible to the patient without touching the patient's eye. This may feel uncomfortably close for both you and the patient but it is important as the farther away you are from the patient, the smaller the field of view you will obtain. Also, if you are closer to the patient the corneal reflex will move further from the viewing axis making the view less obstructed. If you are viewing 15° temporally from the patient's line of sight, the disc or retinal vessels should now be in view.
12. If both you and the patient are emmetropic and your accommodation is relaxed, the dioptric value of the lens wheel should be close to zero. If you and/or the patient are uncorrected and ametropic, the lens power necessary to focus on the fundus (i.e., the power in the lens wheel) will be the sum of the refractive errors and your accommodative state. Some practitioners use this as an approximate estimation of the patient's spherical refractive state.
13. If you do not see the disc straight away but can focus on the vessels, follow the vessels backward towards the disc. The bifurcation of the vessels forms a 'V' and this will point in the direction you should move to get to the disc.
14. Once you see the disc, focus it clearly using the lens wheel. Bracketing several lens positions may be required before deciding on the optimal focus.
15. Determine whether the neuroretinal rim (NRR) follows the ISNT rule and estimate the vertical and horizontal C:D ratios (Figures 7.31 and 7.34; examples 8.27–8.35; online quiz 8.3). The cup margins should be determined by kinking of the vessels as they pass over the margin. Do not assess the cup as the area of pallor, as the cup can extend beyond this area. This is difficult as you are trying to make judgements about a 3D structure with a 2D image. In deep cupping, the bottom of the cup will focus with less plus than the neuroretinal rim tissue and it can appear grey with central mottling (the lamina cribrosa). Slight parallax movements may help in determining the cup. Note the relative position of the vessels to the cup.
16. Evaluate the optic nerve head and its immediate surroundings. Note its shape and colour and the clarity of the disc margins. Observe the veins as they leave the optic cup and look for venous pulsation. Note the presence of any anomalies/abnormalities of the disc or its immediate surroundings.
17. Systematically examine the vascular arcades and rest of the posterior pole. Follow the arcades (either inferiorly or superiorly) around the macula, to the opposite arcades and back to the nerve head. Carefully note any tortuosity and/or focal narrowing of the arterioles. Also examine the arterio-venous crossings and look for abnormalities such as venous nipping or right angle crossings. Estimate the relative

width of the arteries and veins between one and three disc diameters from the disc (the AV ratio) as a percentage rather than using the traditional $\frac{2}{3}$ or $\frac{3}{4}$.⁶⁷ At the same time, examine the surrounding fundus and look for any abnormalities.

18. Examine the retina more peripherally. Ask the patient to look into various positions of gaze (up, up and right, right, down and right, down, down and left, left and up and left) and systematically examine the retina with a moderately wide beam of light. You must look in the same direction as the patient. For example, when the patient looks up, you must position the ophthalmoscope slightly below the pupil and aim the ophthalmoscope beam upwards, towards the superior retina. It is important to be careful, as moderately large abnormalities can be missed easily due to the direct ophthalmoscope's high magnification and narrow field of view. When the patient is looking down it will be necessary to gently hold up the upper eyelid to view the inferior retina.
19. Finally, evaluate the macula using the smallest aperture. This observation is performed at the end so that the patient has a chance to adapt to the light; however, many patients still find the light uncomfortably bright, therefore dimming the illumination may be required to get an adequate view of the macula. The macula is located slightly below centre and approximately 2 DD temporal to the disc. You can either move the light in this direction or ask the patient to look directly into the light. You will often note a bright reflection from the cornea that obscures the view of the macula. This is minimised by using the smallest aperture beam and/or changing the shape of the light beam (a half circle shape is available with some ophthalmoscopes), changing your angle of observation and/or getting as close to the eye as possible.
2. Inform the patient that you are going to examine the health of their eyes.
3. Ask the patient to remove their glasses. You should be able to continue to wear your own glasses for this technique but it is recommended that you remove them. Now dim the room lights.
4. Look through the PanOptic with your thumb on the dynamic focusing wheel and focus on an object in the room that's at least 3 to 4 metres away so that it's clear and sharp.
5. Make sure that the aperture dial is set to the small aperture position. This setting is marked with a green indicator line on the dial. It's the ideal setting for a typical non-dilated pupil.
6. Turn the PanOptic on and adjust the light intensity rheostat to its maximum position.
7. Explain to your patient that the eyecup will touch their brow. Instruct them to try not to move their head and to look straight ahead.
8. Position yourself about 15 cm away at a 15 to 20 degree angle on the temple side of the patient. To keep your patient's head steady, you may want to rest your left hand on the patient's forehead.
9. Shine the light at the patient's eye and look for the red retinal reflex. Slowly follow the red reflex toward the patient and into the pupil.
10. The eyecup should be compressed about half its length to maximize the view. At this point, a large view of the entire optic disc and surrounding vessels should be visible.
11. After examining the right eye, repeat the procedure for the left eye.

7.10.5 PanOptic procedure

1. Seat the patient comfortably in the examination chair with their head held upright and not back against the headrest. The chair should be raised to such a position that you can comfortably look into the patient's eye (from the patient's temporal side) by bending over only slightly. This is important to avoid a long-term strain injury to your back.

7.10.6 Keeler wide-angle twin mag procedure

Familiarise yourself with the controls of the ophthalmoscope. The apertures and filters available are a wide angle beam which illuminates a large area of the fundus and is most useful with a dilated pupil, an intermediate beam that is useful for use with an undilated pupil and in the paediatric examination, a macular beam for use in viewing the macula, a slit, a cup disc graticule, a semi circle and red-free and cobalt blue filters.

1. Position the spectacle rest, located at the user end of the instrument. When it is in position there will be a click. Pull out the spectacle rest if you are not wearing glasses.
2. Remove the dust cover and store in dust cover holder.

3. Position the brow rest into place.
4. Set the magnification lever to LO and select the small or intermediate aperture by rotating the graticule/aperture/filter selector. Look through the eyepiece and focus the instrument on an object by sliding the focus adjuster up or down.
5. Turn on the lamp by rotating the light intensity adjuster anti-clockwise until the desired intensity is achieved.
6. Position yourself at approx 60 cm from the patient and view the eye to be examined along the visual axis to observe the red reflex. Move towards the patient and refocus the instrument on a fundus feature. The posterior pole will be in view. The field of view will increase as you move closer, to a maximum when you are 15 mm from the patient's cornea. Position your hand on the patient's forehead to steady the instrument.
7. If you are using the brow rest, move the instrument towards the patient until the brow rests on the patient's forehead.
8. The large beam produces a 25 degree field of view and is used for general examinations. It provides 15× magnification. By flipping the magnification lever to HI the field of view decreases to 17.5 degrees and provides 22.5× magnification.
9. Corneal examination procedure: administer fluorescein dye to the patient's eye and attach the corneal lens at the front of the instrument. It attaches magnetically. Select the blue filter from the graticule/aperture/filter selection wheel. View the cornea from a distance of 1.5 cm from the front of the instrument.

7.10.7 Recording

Photograph any abnormalities if possible and store the image for future comparisons. Otherwise record as follows:

Lens (with direct ophthalmoscopy): If there are no opacities record 'clear'. Sketch any cataracts as shown (Figure 7.13). The undilated pupil can be recorded as a dashed line on this diagram.

Vitreous: If no abnormalities are detected, record 'clear' or 'No abnormalities detected' (NAD). Note that only the posterior vitreous is examined with fundus biomicroscopy and the anterior vitreous is examined with the slit lamp without an auxiliary lens.

Fundus biomicroscopy: Keep in mind that the image is real, inverted and aerial, so vertical and lateral

directions must be reversed for recording. Two methods may be employed for documentation of the findings with indirect fundus biomicroscopy with a high plus lens. The first involves mentally reversing and inverting the image before drawing the findings. This requires a significant amount of practice and is prone to errors in interpretation. The second and often more accurate method is to place the examination form upside down to compensate for the reversed inverted image, and draw exactly what is seen in the lens.

Optic nerve head

See online quiz 8.3. Record the following:

1. Distinctness of the optic disc margins.
2. Optic nerve head size and shape. Indicate whether the optic disc size is small, average or large.
3. The size, configuration and location of any peripapillary chorioretinal atrophy, both zone alpha and zone beta.
4. The health of the neuroretinal rim (NRR) tissue by its colour, thickness and uniformity. Whether or not the 'ISNT' rule is followed should be documented.
5. The optic cup size. Draw the shape, size and location of the physiological cupping on a diagram of the disc. Include a horizontal cross section of the cupping showing the depth and shape, and a vertical one if necessary. Record the size of the optic cup as a decimal fraction of the optic nerve in both the horizontal and vertical dimensions. The disc is considered one unit and the cup is a fraction of that unit and should be recorded in 0.05 steps, e.g. 0.60 horizontally and 0.65 vertically. In general, when the cup is smaller than $\frac{1}{3}$ of the overall optic nerve head, the cup can be visually superimposed on the rims to determine the ratio, and certain mathematical relationships hold. For a 0.20 cup, four more of the same sized cups should be able to fit into the available rim tissue (Figures 7.31 and 7.34), although not necessarily symmetrically. For a 0.25 cup, three more should be able to be superimposed on the rims. For a 0.33 cup, the cup would be the same size as equally sized rims (Figure 7.31). A 0.30 cup is slightly smaller than $\frac{1}{3}$ of the optic disc, whereas a 0.35 cup is slightly larger than $\frac{1}{3}$. The assessment of larger cups is often considered more challenging. In larger cups where the rims are smaller than the width of the cup, the rims can be superimposed

on the cup to help to determine the ratio. With a 0.50 cup, both of the rims can be superimposed onto the cup and add up perfectly to the cup size. For a 0.65 cup, both rims superimposed within the cup add up to half of the total cup (Figures 7.31 and 7.34).

6. Note the presence of the lamina cribrosa and spontaneous venous pulsation.
7. In the same diagram include all anomalies/ abnormalities of the disc such as coloboma, crescents, drusen, disc swelling, haemorrhages, myelinated nerve fibres, pallor, pits and disc tilting. The differential diagnosis of drusen in the disc can be helped by using cobalt blue light and a yellow filter as they autofluoresce.

Example: The recording of a normal optic nerve head would include text such as:

Margins – distinct, NRR – healthy (follows ISNT rule), C:D 0.35 H, 0.40 V. Your recording could also include a plan and cross-sectional diagram of the disc.

Nerve fibre layer: Record the relative brightness and width of the pattern in the superior-temporal and inferior-temporal nerve fibre layer. Note any diffuse loss, as well as any slit- or wedge-type defects. Patients with a more darkly pigmented retinal pigment epithelial layer often have a more prominent appearance of the nerve fibre layer than those with less pigment.

Blood vessels: If no abnormalities are detected, record 'No abnormalities detected' (NAD) or 'Negative', or equivalent and record the relative size of the arteries and veins between one and three disc diameters from the disc (AV ratio) as a percentage.⁶⁷ Record any abnormality of the blood vessels (e.g., attenuation or dilation, emboli, broadened reflex or copper/silver wiring or vascular sheathing), the artery-vein crossings (90° degree crossings, venule nipping) and any tortuosity of the arterioles (often congenital) and venules (often acquired). Indicate the location of all findings in a diagram.

Fundus (posterior pole, equator and periphery): If no abnormalities are detected, record 'No abnormalities detected' (NAD) or 'Negative', or equivalent. Record this separately for the posterior pole and the periphery/mid-periphery. Note the size, shape, location, colour, elevation and depth of any abnormality. Specify the size of a lesion and its location with respect to the disc in terms of disc diameters (DD). For example, the lesion may be 2 DD × 1 DD wide and located 4 DD at 4 o'clock

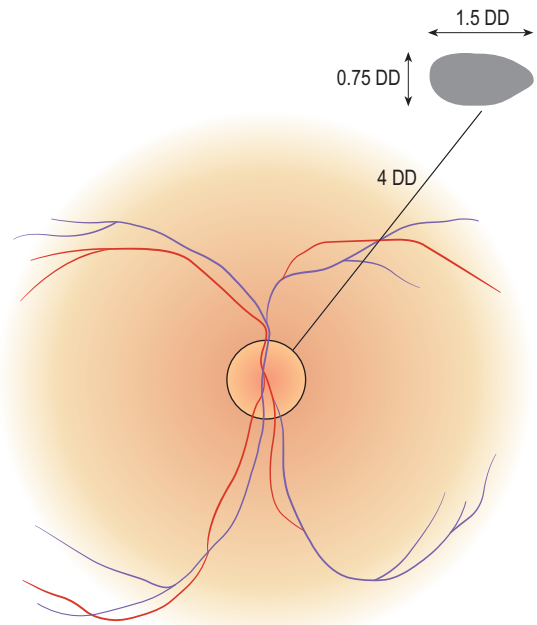


Fig. 7.35 Diagrammatic representation of a choroidal naevus located 4 disc diameters (DD) at 1 o'clock from the disc. Its size is 1.5 DD by 0.75 DD.

from the disc (Figure 7.35). Determining the appropriate anterior-to-posterior location in the peripheral fundus can be facilitated by certain normal landmarks.

Macula: If no abnormalities are detected, record 'No abnormalities detected' (NAD) or 'Negative', or equivalent. Pertinent negative findings should be recorded in certain situations; e.g. 'No clinically significant macular oedema' in those patients who are diabetic. Record any findings or abnormalities noted at the macula such as drusen, pigmentation changes, haemorrhages, exudates, cotton wool spots, subfoveal neovascular membranes and thickening (oedema).

7.10.8 Interpretation

ISNT rule

The optic nerve head should have a pink rim of tissue surrounding the physiological cupping. The neural retinal rim (NRR) tissue should be approximately 1.5–2.0 times wider superiorly and inferiorly than temporally. The mnemonic **'ISNT'** is often used and indicates that in most normal discs the thickest part of the rim is the **Infero-temporal**, followed by the

Supero-temporal, then **Nasal** and the thinnest is the **Temporal**. The thickness of the temporal NRR is variable and of limited clinical use. In glaucoma, the NRR often becomes thinner at the superior and inferior (temporal) poles first and a 'notch' indicates the localised loss of the NRR. If this occurs, the NRR will not obey the ISNT rule. This preferential damage to the superior and inferior (temporal) poles of the NRR in glaucoma causes the vertical C:D ratio to increase, which means that the vertical C:D ratio is more important clinically.⁶⁸

7.10.9 Most common errors

Fundus biomicroscopy

1. Misaligning the indirect optical system causing a poor view and a view with only one eye (no stereopsis). Stability of the lens is critical.
2. Holding the lens too far from the cornea, causing the pupil stop to limit the view and/or a view with only one eye (no stereopsis). You need to learn *not* to move the lens back from the eye when the slit lamp is pulled back from the eye.
3. Holding the lens too close such that the patient's lashes touch the lens. Patients may be concerned about the lens touching their eye so may either blink frequently or may pull back from the headrest. You may also get condensation on the lens surface, which will obscure your view.

Direct ophthalmoscopy

1. Not getting close enough to an older patient (with a small pupil) when performing the technique, particularly when attempting to view the macula.
2. Putting your hand on the patient's shoulder or the top of their head when doing direct ophthalmoscopy. Steady yourself by putting your hand on the back of the examination chair or nearby wall.
3. Using the cup pallor instead of the deflection of the blood vessels as the determinant of the edge of the cupping.
4. Not having the patient view in different directions of gaze to obtain a better view of the non-central retina.

Monocular indirect ophthalmoscopy

1. Not getting close enough to optimise the view.
2. Not matching the aperture stop to the pupil diameter. It is best to have the aperture stop less

than wide open to avoid reflection from the edge of the pupil.

7.11 OPTICAL COHERENCE TOMOGRAPHY

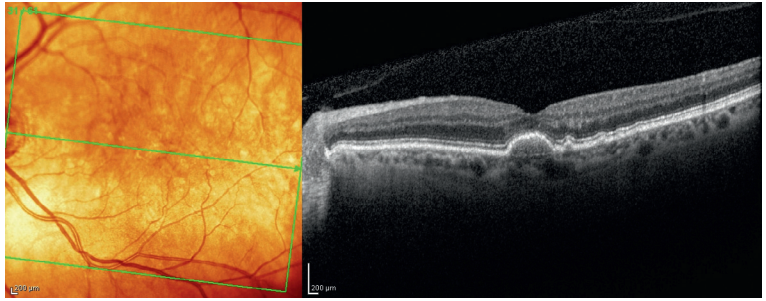
Optical coherence tomography (OCT) is the most common technology used for the routine, high resolution, digital imaging of the retina and optic nerve (ON). For a review of the optical principles and their application to the eye, see Drexler and Fujimoto⁶⁹ and Fujimoto and Huang.⁷⁰ OCT enables the high resolution, cross-sectional imaging of the retina by measuring the reflectance and relative delay of light as it journeys through the ocular tissues. The relative interference caused by the optical properties of the retinal and ON tissues following comparison with a known reference, are analysed using Fourier techniques, and interpreted to provide a detailed image of the retinal layers. Initial instruments operated in the time domain, which at their best permitted 400 A-scans per second with a theoretical axial (depth) resolution of 10 microns. In 2006 the first spectral domain (SD) OCT was introduced (RTVue), which permits very rapid data acquisition, currently up to 53,000 A-scans per second, and less than 5 microns of axial resolution and 10 microns of lateral resolution. SD-OCT is now the standard form of clinical OCT imaging.

Standardised test patterns are used for imaging the macula and retina for retinal lesions, and the retina and ON for glaucoma. It is capable of documenting subtle lesions of the retina, with high levels of repeatability, and should be considered in all suspected maculopathies, including age-related macular degeneration, diabetic eye disease, and detachments.⁷¹ It is also capable of monitoring progression or resolution of a lesion or area of oedema. SD-OCT should be considered for all patients with glaucoma, where it can evaluate the nerve fibre layer (NFL) and/or ganglion cell complex, the ON and provide measures of early progression. SD-OCT is also used for evaluation of the cornea and anterior segment for corneal lesions, refractive surgery and glaucoma, and has been adapted for ocular biometry.

7.11.1 Comparison of tests

Time domain OCT is capable of imaging retinal lesions and evaluating NFL and retina thickness, but is limited in its ability to analyse serial images and therefore monitor progression. It is prone to eye movement errors and is of lower resolution. The principles of scanning patterns and analysis are similar to the

Fig. 7.36 OCT showing a detached pigment epithelium in the macula, with drusen to the right and disruption of the overlying outer plexiform and outer nuclear layers. The patient was 75 years old, with a history of ARMD including confluent drusen and recent VA drop from 6/6 to 6/9. (Spectralis SD-OCT).



SD-OCTs, but it will not be considered further. The SD-OCT instruments differ in acquisition speed. Most current SD-OCTs acquire 26,000 or 27,000 A-scans per second (Topcon 3D OCT-2000, Optovue RTVue and Zeiss Cirrus). The Heidelberg Spectralis acquires 40,000 A-scans per second. The Spectralis is also different in that it employs an active eye tracking system that ensures, in real time, that data are acquired without the artefacts caused by eye movements and blinking. The same principle ensures that follow-up images are acquired in the same location as the baseline image, minimising the errors associated with serial imaging. The other SD-OCTs use mainly post-processing to reduce the artefact caused by eye movements. The Topcon 3D OCT-2000 is unique in that it incorporates a 12.3 megapixel colour, digital fundus camera to generate its reference images. Other instruments use infrared scanning laser imaging or lower resolution, en-face reference images.

7.11.2 Retinal imaging

Typical retina imaging includes single line scans of relatively high lateral resolution (Figure 7.36); raster scans of varying lateral resolution, e.g. the Cirrus 5 line scan or Spectralis 7 line scan; radial patterns, usually centred on the fovea and scanning the four lines along the major and minor meridians; circular patterns, usually centred on the fovea, and averaged for better image quality, cross/cross-hair patterns that can be centred on a lesion of interest or on the fovea; and 3D volume scanning, a series of B-scans combined to create a retinal cube. The 3D scans vary considerably in resolution with typical scans of 100×512 (RTVue), 128×512 and 200×200 (Cirrus), and anything up to 1024×1024 , enough scans to give an equal horizontal and vertical pixel resolution of 11 microns (Spectralis). Some models of the Spectralis also enable fundus autofluorescence imaging by incorporating a blue laser source (488 nm). The number and type of scans will depend upon the lesion to be imaged.

7.11.3 Glaucoma imaging

Glaucoma imaging includes circle scans, centred on the ON and segmented to quantify the NFL thickness (Figure 7.37); 3D ON volume scans; and 3D macula/posterior pole volume scans. It is common to perform both the NFL scan and 3D ON scan on patients with glaucoma. However, it is becoming increasingly popular to also acquire a 3D macular scan (see section 7.11.6).⁷²

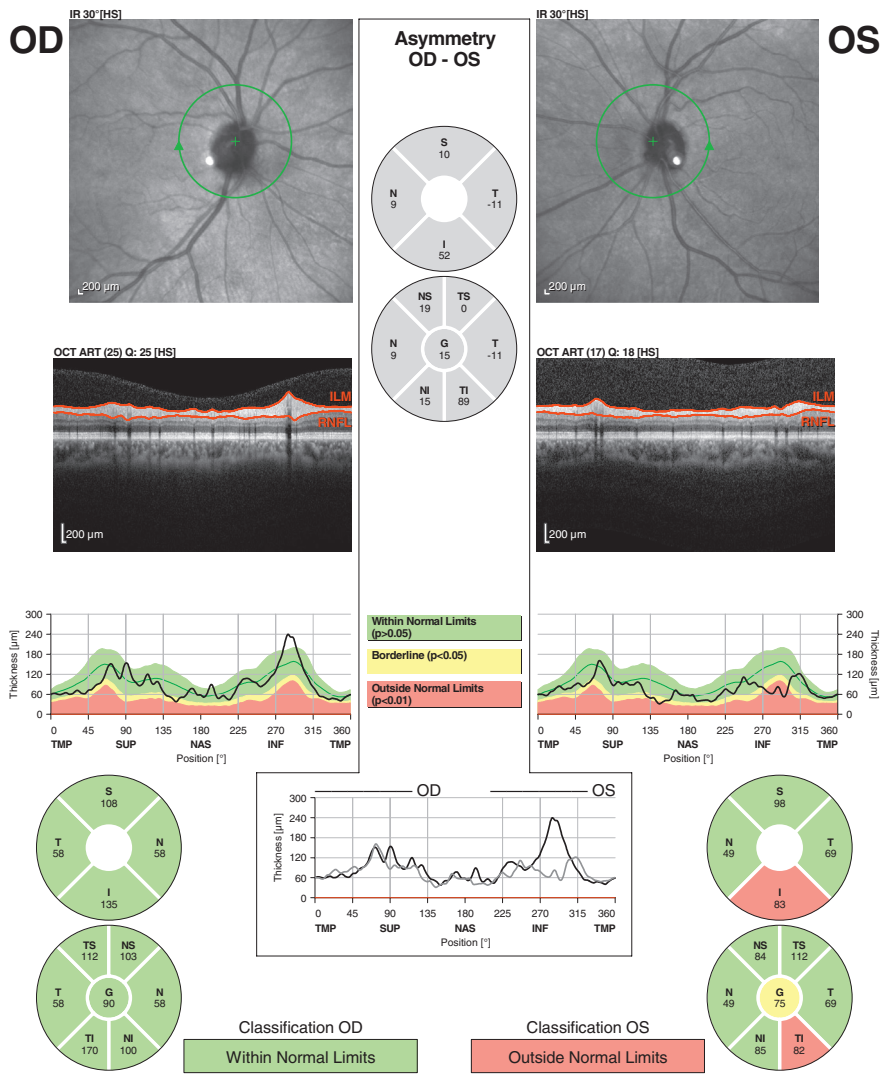
7.11.4 Procedure for OCT

When performing OCT imaging pupils should be 3 mm or greater, whenever possible.

1. Explain the test and the reasons for performing the assessment to the patient.
2. Turn on the instrument, clean the chin rest, forehead rest and, if necessary, the camera lens.
3. Seat the patient at the instrument and adjust the height of the instrument to ensure they are comfortable.
4. Enter patient name using the surname first, date of birth (often formatted as month-day-year), patient file number if appropriate, and keratometry measurements as radius of curvature. It is often useful to enter the refractive error and relevant diagnostic code.
5. Select the eye to be tested.
6. Select the scan type you require, whether for retina or glaucoma and select the desired resolution and number of repetitions, if relevant.
7. Choose a fixation target, either internal or external.
8. Ensure that the camera head is positioned back away from the headrest, then place the patient's head in the headrest. Explain the procedure and the fixation targets to the patient.

RNFL Single Exam Report OU with FoDi™
SPECTRALIS® Tracking Laser Tomography

Patient:	DOB: Nov/01/1941	Sex: F
Patient ID:	Exam.: Mar/12/2012	
Diagnosis: ---	Comment: ---	



Notes:

Date: 3/12/12

Signature:

Fig. 7.37 Circular NFL scan and analysis. The circular scan is not ideally positioned, being slightly too high on the right eye, and both high and nasal in the left eye. The left eye inferior quadrant and inferior temporal segment are considered outside of normal limits. The global NFL thickness is considered borderline. Note the artefactually thick NFL in the inferior temporal sector of the right eye due to the scan coinciding with the crossing of a major arteriole and venule. The patient was 70-year-old diagnosed with primary open angle glaucoma, with an upper arcuate visual field defect in the left eye and possible early inferior nasal step in the right eye. (Spectralis SD-OCT RNFL scan.)

9. Slowly move the camera toward the patient's eye and adjust the position (up and down; side to side) until the image is centred and approximately 1.5 cm from the eye. Adjust the focus and position of the camera to ensure an even illumination, a focused image and an OCT scan that is oriented correctly (erect) with minimum tilt and within the necessary acquisition window. Also ensure that the image quality is within the desired range.
10. Press the button to acquire the images.
11. Monitor the OCT scan and encourage the patient throughout the test.
12. Select the next scan type and repeat.
13. Image the second eye and save all scans if not stored automatically.
14. Inspect all scans and ensure that scan patterns are centred appropriately and were recorded without artefact.
15. Repeat scans as necessary then request that the patient sit back and relax.

7.11.5 Recording

Select the scans of your choice. Ensure that automated segmentations were successful and accurate and, if not, adjust and re-save. Ensure that 3D volume scans are appropriately centred. Print the results or save to electronic files and, if the scans were acquired for both eyes, print both eyes together (Figure 7.37).

7.11.6 Interpretation

Retina

Ensure that scans are complete and without eye movement or pupil edge artefact before trying to interpret them. Assessment of the retina is somewhat more qualitative than the assessment for glaucoma and you may need to work with an experienced colleague before you will be able to fully interpret the layers of the retina and ageing changes including drusen, the shadows cast by blood vessels or reflective lesions and blood in the retina. The vitreous is normally seen as black, although floaters can give a cloudy appearance. White (or, if choosing the colour scale, bright colours, red to white) corresponds to high reflectivity and horizontal structures such as the NFL, plexiform layers, and RPE are highly reflective. Adjacent structures that have very different refractive indices are highly reflective at their boundaries. Dark colours, indicating minimal reflectance, can be fluid within the retina. If there is vitreoretinal separation, the posterior hyaloid face may be visible as a reflective line. 3D volume

scans and radial scans will give retinal thickness maps, which you should compare to age matched normal data. There will also be asymmetry analysis, both between eyes and between the upper and lower hemifields. 3D volume scans can also be viewed by individual B-scan, within the context of the image cube. There are specific analysis tools to enable mapping of retinal atrophy and the size or height of lesions. Progression analysis permits analysis of change in thickness, area and height of lesions.

Glaucoma

Circular NFL scans will show the NFL thickness around the ON and compare to normal age matched data. This is usually for global measures, quadrants and sectors. There is also asymmetry analysis across eyes and within eyes across hemifields. 3D ON scans can be viewed as image cubes. Most OCTs will automatically analyse the ON for rim tissue and asymmetry. 3D macula scans are generally segmented to give retinal thickness, NFL thickness or ganglion cell complex thickness. The ganglion cell complex consists of the NFL, ganglion cell layer and inner plexiform layer and has been proposed as an efficient method for detecting early glaucomatous damage.⁷² It was first introduced by Optovue but a similar method has since been implemented on the Cirrus. The Spectralis uses full retinal thickness but has introduced posterior pole thickness maps and asymmetry analysis.⁷³

7.11.7 Most common errors

1. Not aligning the patient properly.
2. Not optimally focusing the image.
3. Using poor centration, particularly for circle scans.
4. Analysing poor quality images.

7.12 FUNDUS EXAMINATION, PARTICULARLY THE PERIPHERAL RETINA

Stereoscopic techniques are the clinical standard for fundus examination and headband binocular indirect ophthalmoscopy (BIO) with a plus lens is the standard for assessment of the peripheral retina.

7.12.1 Comparison of tests

There are many fundus abnormalities in the peripheral retina that are missed with direct or indirect monocular ophthalmoscopy through an undilated or dilated

pupil, including but not limited to retinal holes/tears and retinal detachments, intraretinal haemorrhages, exudates and infarcts, neovascularisation, retinal degenerations, vitreoretinal traction, naevi and tumours.^{65,66,74} BIO provides simultaneous viewing of approximately eight disc diameters (about 35°) of the fundus compared to less than two disc diameters with the direct ophthalmoscope. Other advantages include a quick assessment of the entire fundus periphery and vitreous (Table 7.4), with subsequent easy localisation of most lesions due to the very large field of view. This can be especially useful when examining the fundus in cyclopleged children and special populations. Different lenses can be used to create different magnifications. The +20 D or +22 D aspheric lenses are recommended for routine use. Lower-powered lenses (+14 D or +15 D) provide higher magnification and may be used if the patient is bedridden or in a reclined wheelchair such that fundus biomicroscopy is not an option. They are somewhat more difficult to manipulate as they must be raised farther from the patient's eye to get an image and of course have a smaller field of view. Smaller, higher-powered lenses (+28 D or +30 D) provide a larger field of view but are rarely used because of their low magnification. They may be considered by a clinician who has small hands and difficulty manipulating the larger +20 D lenses, during scleral indentation due to easier lens manipulation around the scleral indenter and when the patient has small pupils. Scleral indentation can be used in conjunction with BIO to further evaluate peripheral areas of the fundus such as the ora serrata in a dynamic manner. The main disadvantages of BIO are the reversed and inverted image (making interpretation and recording a challenge to learn initially), the recommended supine position of the patient, need for mydriasis and the lower magnification provided (~3× compared to 9×–18× with fundus biomicroscopy and 16× slit-lamp magnification, and 15× with direct ophthalmoscopy). Finally, the potential exists for light toxicity with prolonged exposure.⁶⁰ Yellow condensing lenses or yellow filters attached to clear lenses may be used and are recommended for students. They can also reduce patient glare and discomfort.

With the 3-mirror Universal lens the patient can remain at the biomicroscope and does not need to be placed into a supine position and with established slit-lamp skills, the technique is easier to learn than scleral indentation. The 'thumbnail' mirror (angled 59° to 64° from the horizontal plane) is used for gonioscopy (section 7.6), but can also be used to view the far peripheral fundus through a well-dilated pupil. The rectangular mirror (angled at approximately 66°) is

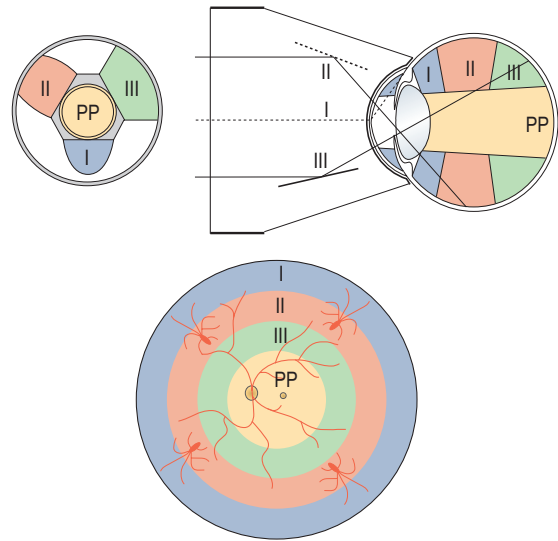


Fig. 7.38 Diagrammatic representation of the Goldmann 3-mirror contact lens demonstrating the central lens for examining the posterior pole (PP); the thumbnail-shaped mirror angled at 60° and used for gonioscopic assessment of the anterior chamber angle as well as examination of the far-peripheral fundus in a dilated eye (I); the rectangular-shaped mirror angled at 66° and used to assess the peripheral fundus (II) and the trapezoidal-shaped mirror angled at 76° and used for examination of the equatorial fundus (III).

used to examine more posteriorly to the thumbnail, but still in the fundus periphery. The third mirror is trapezoidal in shape (angled at approximately 76°) and is used to examine the equatorial fundus (Figures 7.21 and 7.38). Because of the limited field of view, the 3-mirror lens is not used for general assessment. Instead, it is employed when lesions are detected with other techniques such as BIO or indirect fundus biomicroscopy. This lens allows a stereoscopic view that is different from the indirect techniques. Note also that the central lens is an excellent tool for assessment of the macula (and disc), especially when fine stereopsis detail is critical (e.g. macula oedema). Other disadvantages of the 3-mirror lens include the need for corneal anaesthesia and the lack of a dynamic view so that layer separation is not possible and there is greater difficulty in lesion localisation.

Wide field images of the retina can also be obtained without the need for mydriasis in many cases with the Optos, a scanning laser retinal imaging system (Figure 7.39). This provides a 200° image or 'optomap' of the retina using red and green lasers. Optos images can be

taken quickly and relatively easily by clinical assistants and as the image is provided within seconds, it can be reviewed and the need for further images determined. The images can also be seen in red-free or green-free formats, which allows you to differentiate between retinal (seen in green-free) and choroidal (seen in red-free) abnormalities and the instrument shows good resistance to the effects of cataract. However, although optomaps provide reasonable specificity, they miss treatable conditions in both the mid-peripheral (moderate sensitivity) and particularly the far peripheral retina (low sensitivity) when compared with a dilated fundus examination.^{75,76} Other disadvantages are the need for some manipulation of the patient's position to get their eye in a correct position, the loss of part of the image due to the patient's eyelashes (Figure 7.39); this can be improved using eyelid retraction with a cotton bud) and the image colour, in

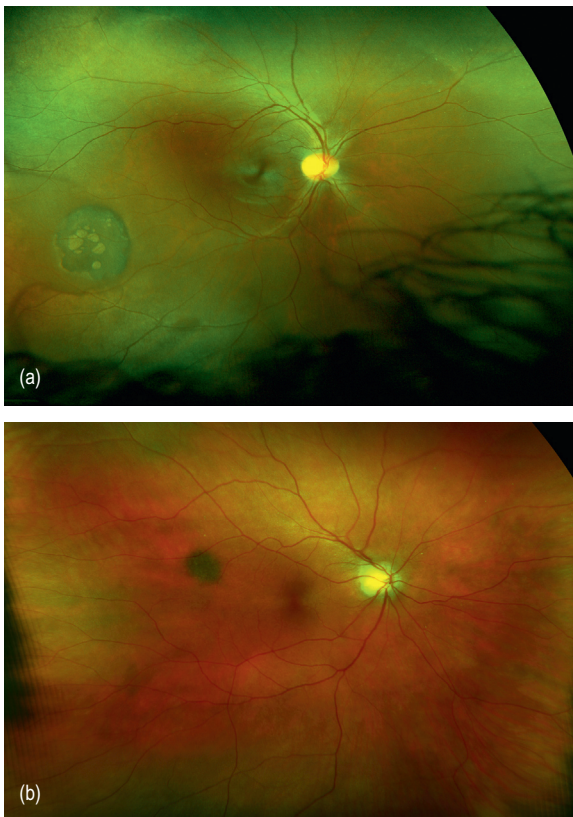


Fig. 7.39 Optomaps of (a) a CHRPE with lacunae (section 8.6.7) and (b) choroidal naevus (section 8.6.5). The intrusion of the patient's eyelashes on the images can be reduced by lid retraction with a cotton bud.⁷⁶

that the fundus does not look the same as it does in the white light of ophthalmoscopy.⁷⁶

7.12.2 Procedure for head-band BIO (summary in Box 7.3)

See online video 7.12.



1. Explain the test to the patient. For example: 'I am going to examine the health of the inside of your eyes with light from the head unit and a lens held close to your eye.' Obtain informed consent and instil an appropriate mydriatic (section 7.8).
2. Adjust the back and top of the headband of the instrument to allow for a comfortable fit. The fit may need to be readjusted as the eyepieces are adjusted.
3. Plug the instrument into the battery pack and turn it on. Release the lock on the headset and swing the housing unit down in front of your eyes until the eyepieces are as close as possible and approximately perpendicular to your line of sight (Figure 7.40). The closer the eyepieces are to the eyes, the larger the field of view.
4. Direct the ophthalmoscope light at your thumb or at a wall at arm's length, and adjust the eyepieces for your interpupillary distance so that the spot of light is exactly centred in the

Box 7.3 Summary of head-band BIO procedure

1. Dilate the patient's eyes.
2. Recline the patient to approximately hip level.
3. Adjust the headband.
4. Adjust the eyepieces and mirror vertically so the spot of light is in the upper half of the field of view.
5. Adjust the illumination intensity.
6. Dim or turn off the room lights.
7. Ask the patient to look straight up to the ceiling.
8. Align the two reflections from the condensing lens with middle of the pupil.
9. Gradually pull the lens directly toward you until the fundus detail fills the entire lens.
10. Examine the fundus in a systematic, predetermined order (usually clockwise), filling the condensing lens as much as possible.



Fig. 7.40 Side view of the head-band binocular indirect ophthalmoscope.

field of view for each eye. Adjust the mirror vertically until the spot of light is situated in the upper half of the field of view ($\pm 4^\circ$ adjustment arm). This allows the illumination beam to pass above the observation beam to minimise reflections during patient examination. Most instruments possess this adjustment.

5. Adjust the illumination intensity to low to medium-low and the illumination beam to the largest spot size that can be used for the patient's pupil size. For a dilated pupil, use the largest spot size. A smaller spot size may be considered if the pupils are not fully dilated.
6. Ask the patient to remove any glasses, and explain that you are going to recline the chair as at a visit to the dentist. Adjust the chair to the reclining position, so that the patient is at approximately hip level. The supine position allows you to stand approximately opposite the area of the fundus being viewed, optimising stereopsis and the extent of viewing area while minimising back strain. Examination with the patient seated upright can also be performed if reclining is not possible. The inferior and superior fundi are more difficult to examine with a seated patient as the light source must be well above the patient's head to view the inferior peripheral fundus, and towards the patient's lap to see the superior peripheral fundus.
7. Dim or turn off the room lights.
8. Pick up the aspheric condensing lens with the white or silver edge of the lens casing toward the patient to minimise reflections and optical

aberrations. Hold the lens between the index finger and the thumb. The little (or the third) finger can be used to retract the upper eyelid and allow for stable extension of the lens away from the patient's eye, while at the same time acting as a pivot, enabling the observer to tilt the lens in all planes merely by rocking the lens system. The other eyelid may be retracted with the thumb of the opposite hand. Alternatively, the little (or the third) finger of the opposite hand may be employed so that this second index finger can also be used to help stabilise the lens. The lens can be moved with critical control closer or further from the eye by increasing or decreasing the extension of the little finger stabilising on the patient's eyelids. Ambidexterity should be practised and is required for scleral indentation.

9. Novices will want to view the recognisable posterior pole first, so should ask the patient to look straight up to the ceiling if in supine position or over your shoulder if seated upright.
10. Direct the BIO light source so that it is centred on the patient's pupil. Introduce the condensing lens close to the patient's eye (2 to 4 cm) such that the external eye can be seen through the lens and with slight magnification. Centre the pupil in the condensing lens (observe the red reflex), and align the two reflections from the +20 D lens surfaces with each other and in the middle of the pupil. Gradually move the lens away from the patient's eye (towards you) and fundus detail will become progressively magnified until the red reflex fills the entire area of the lens.
11. Keep the pupil centred in the lens at all times or the fundus view will be lost. Only slight misalignment of any part of the optical system will cause shadows, distortion, or complete loss of the view. Stabilisation of the lens with a finger from the second hand helps to minimise this fluctuation. When loss of the image occurs, move the lens towards the eye again, until the pupil can be recognised and centred, and pull the lens back toward you again to maximise the image in the lens.
12. Keep the headband unit at arm's length to the lens. When the examiner moves closer to the lens, difficulties with accommodation, convergence and loss of binocularity may occur, as will a smaller field of view.
13. If reflections from the condensing lens block visualisation of the fundus, displace the

reflections by tilting the lens slightly. Excessive tilting, however, induces astigmatism and will distort the fundus image.

14. To view the different regions of the fundus, change position around the patient and tilt the lens so that the optical system formed by the patient's pupil and fundus, the condensing lens, and your pupils remain aligned along the widest part of the patient's pupil. To examine the superior fundus, for example, ask the patient to look upwards while you direct the illuminating beam toward the superior fundus. A 'full' lens image in this position will show approximately 8 DD of the fundus near the superior equator. Examine farther into the peripheral fundus by moving the light source anteriorly (toward the ora serrata), making sure the elements of the optical system remain in alignment so that the image continues to fill the lens as much as possible. To do this, you must bend along the line of sight but in the opposite direction (i.e. toward the patient's feet). Because the image is reversed and inverted, attempting to shift the field of view in one direction will cause the image to move in the opposite direction. It helps to remember here that only the lens view is reversed and inverted; that is, if you wish to see more temporally, direct the light in that direction; more superiorly, direct the light towards the superior fundus and so on.
15. Stereopsis is achieved by imaging both of the examiner's pupils within the patient's pupil. This is facilitated by a large patient pupil with maximum dilation. During the examination of the patient's periphery, the patient's fixation is directed toward the sector that is to be examined. The pupil relative to the examiner's perspective is oval, with the long axis of this pupil perpendicular to the patient's line of sight. To maximise stereopsis in these situations, keep your two pupils aligned with this long axis. If the patient's pupil is very large or they are not looking too far off axis, stereopsis is still possible without this alignment with the long axis, but it is less likely and less consistently achieved.
16. It is advised that you examine the fundus in a systematic, predetermined order. Some clinicians elect to examine the regions of the equatorial and peripheral fundus before the posterior pole to allow the light-sensitive patient time to adapt (unless the posterior pole has just been examined with fundus

biomicroscopy anyway). Direct the patient gaze toward each individual sector until all eight sectors of the fundus have been examined (plus the posterior pole). Moving clockwise in each eye is a good initial method.

7.12.3 Additional techniques: Scleral indentation and Goldmann 3-mirror fundus examination

Scleral indentation with BIO provides a dynamic assessment of the peripheral fundus allowing tissue separation and facilitating the detection of previously undetected retinal tears. The technique also allows further examination of lesions detected with other methods, e.g. retinal breaks for the presence of fluid cuffs; lattice degeneration for the presence of breaks; vitreoretinal traction, etc. Rarely the clinician may elect to perform scleral indentation in all sectors if risk factors warrant a closer look when first examination with BIO noted no breaks. Generally, however, indentation is targeted to a previously identified lesion.

Procedure for scleral indentation with BIO

1. Perform binocular indirect ophthalmoscopy or dynamic fundus biomicroscopy of all sectors and determine the area(s) of the periphery requiring indentation. Note both the clock position and the anterior-to-posterior position (relative to the equator and ora serrata).
2. Explain the specific reasons for scleral indentation to the patient. For example: 'I am now going to apply a slight pressure to the outside of the eye to better view a region of the inside of the eye. You may note mild discomfort or a pressure-like sensation during the procedure'. Topical anaesthetic may be considered.
3. Recline the patient. Seated examination is not recommended.
4. Ask the patient to look in the opposite direction to the area to be viewed. Place the indenter tip on the fold of the eyelid (just beyond the tarsal plate) at the clock position on the globe where the lesion was localised. The indenter may be placed with the curve following or opposite the globe depending on patient anatomy.
5. Direct the patient fixation back toward the indenter and as the patient moves their eye, have the indenter follow the globe back into the orbit. The indenter should be placed approximately 7 mm posterior to the limbus to indent the ora serrata, and 13–14 mm to indent

the equator. If the orbital anatomy is obstructing the placement of the indenter, tilt the patient's head slightly to facilitate manipulation of the instrument. For example, if the brow is prominent and in the way, tilt the head back somewhat. Maintain indenter position without pressure on the globe. Tangential pressure only is required.

6. Introduce the BIO light source. Note that 'on axis' indenter positioning can be determined in advance of introducing the condensing lens by noting a shadow in the red reflex in the pupil. When the lens is introduced, the optical system formed by the indented region of the fundus, the patient's pupil, the condensing lens and your pupils must be perfectly on axis to observe the indented retina. Do not apply pressure but gently roll the indenter laterally and forward and back. If the indenter is not seen, move the lens away in order to re-orient your view. You may need to alter the orientation so that the light is aimed directly at the indenter tip. Also check the anterior to posterior positioning of the indenter. If the elevated area is seen but not in the proper position, move the indenter in the opposite direction expected (away from the centre of the lens) as the view is reversed and inverted. Another way to obtain gross orientation is to remember that when the patient is looking into an extreme position of gaze and you direct your light source directly into their pupil, the equator should be in view. To extend the final 4–5 disc diameters between the equator and the ora serrata, you must bend away from the area being examined and direct the light up under the iris.
7. Observe all areas in question. For the more difficult temporal and nasal areas, the superior eyelid may be drawn downward or the inferior eyelid drawn upward with the indenter. If this is unsuccessful, the indenter may be disinfected and placed directly on the anaesthetised conjunctiva.

Procedure for Goldmann 3-mirror examination

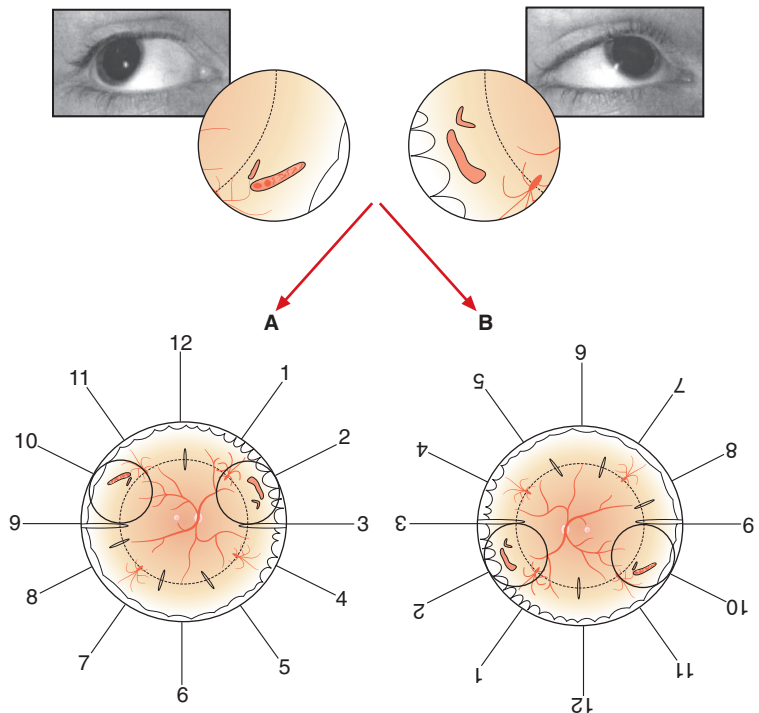
1. Explain the specific reasons for using the lens. Inform the patient that it is a contact lens used with local anaesthetic and a cushioning fluid between the lens and the eye. Explain that they may feel some pressure from the lens and will likely feel the lens on the eyelids, but will feel no discomfort with the instillation of anaesthetic. Obtain informed consent and dilate the patient's pupils ([section 7.8](#)).
2. Having determined the anterior-to-posterior positioning of the lesion to be evaluated, choose the mirror most likely to detect the lesion; that is, for a lesion at the ora serrata, use the thumbnail mirror; for a lesion in the peripheral retina, use the rectangular mirror; and for the midperiphery or equatorial fundus, use the trapezoidal mirror.
3. Prepare the patient at the slit lamp and prepare the lens for insertion. Apply the lens to the eye. Usually, the patient can maintain a primary gaze position for the examination of most areas of the fundus.
4. Rotate the lens such that the chosen mirror is positioned 180° from the lesion. To examine the posterior pole, use the central contact lens.
5. With the biomicroscope in a 'full-back' position, direct the slit-lamp light into the mirror of choice. Move the slit lamp forward until the fundus is in focus, then rotate and tilt the lens to locate the lesion. If the lesion is more posterior to that portion of the fundus which is being viewed, tilt the lens away from the mirror; if more anterior (i.e. more peripheral), tilt the lens towards the mirror.
6. Once the lesion has been fully examined, remove the lens.

7.12.4 Recording

The fundus image viewed through the BIO condensing lens is a real image created between the patient and the examiner and the image is reversed and inverted. Therefore, when viewing the posterior pole, what is seen to be superior in the view is actually inferior, nasal is temporal and temporal is nasal. When viewing the peripheral fundus, the area of the image that appears closest to you in the condensing lens (i.e. towards your thumb) is actually more anterior (peripheral) in the fundus. For example, when the patient is looking up above their head, the more peripheral retina will be seen at the bottom of the lens, and whatever appears to be located to your right within the lens is actually located to the left on the fundus. However, although the view of the superior fundus will be inverted and reversed, if you direct the light towards the superior fundus with the patient looking upwards, you will be looking at the superior fundus.

The most useful way to record fundus findings is with a sketch accompanied by brief explanatory notes. By convention, fundus details are recorded with two

Fig. 7.41 Demonstration of recording methods for BIO and other indirect techniques. The top portion of the figure demonstrates the patient's position of gaze and diagrammatic representation of the view in the binocular indirect lens (+20D). Option A represents mentally reversing and inverting the image seen and recording on the patient's chart. Asymmetric and complicated lesions are more difficult to interpret and document properly in this manner. Option B demonstrates how the examiner may draw the lesion exactly as it was seen and in the proper clock position, but with the recording paper turned upside down.



circles, one within the other. The inner circle represents the equator and the larger one surrounding it represents the ora serrata (Figure 7.41). Note that although the outside circle is larger, the circumference of the ora serrata is actually less than the equator, the widest part of the globe. To draw a lesion, some examiners mentally reverse and invert the image as seen in the lens and then draw it in the correct location. Others place the examination form upside down to compensate for the reversed inverted image, and draw exactly what they see in the lens (while considering where the patient was looking and therefore the proper clock position; Figure 7.41). Both methods take some practice to master. Determining the appropriate anterior-to-posterior location in the fundus can be facilitated by certain normal landmarks in the fundus (Figure 7.42).

7.12.5 Interpretation

The various landmarks of the peripheral retina are rarely included in a fundus drawing but assist in identifying and documenting the location of any noted findings. There are many changes that can be noted in the peripheral retina, some of which are benign and others that have quite a significant risk to vision if left undetected. Benign ocular findings include peripheral cystoid degeneration, which is

present in essentially all patients over the age of 8 years. Disorders such as posterior vitreous detachment, white without pressure, lattice degeneration, vitreoretinal traction tufts, commotio retinae, pars planitis, retinal breaks, retinal detachment and others may be sight threatening and may go undetected without a dilated examination with BIO and possibly scleral indentation. Findings such as malignant melanoma can be life threatening. Retinal degenerations, breaks and shallow detachments are much more obvious with indentation. The contrast of a break is enhanced as the edge of the torn retina appears more whitened while the tear itself appears to open and become more red. Subtle breaks and traction may be missed without this technique. Fluid cuffs surrounding breaks are representative of sub-clinical or progressive retinal detachment and observation is facilitated with scleral indentation.

7.12.6 Most common errors

1. Not adjusting the instrument properly, leading to diplopia, eyestrain or compromised stereopsis.
2. Not reducing the intensity of the light source or using a yellow filtered lens to minimise patient photosensitivity.

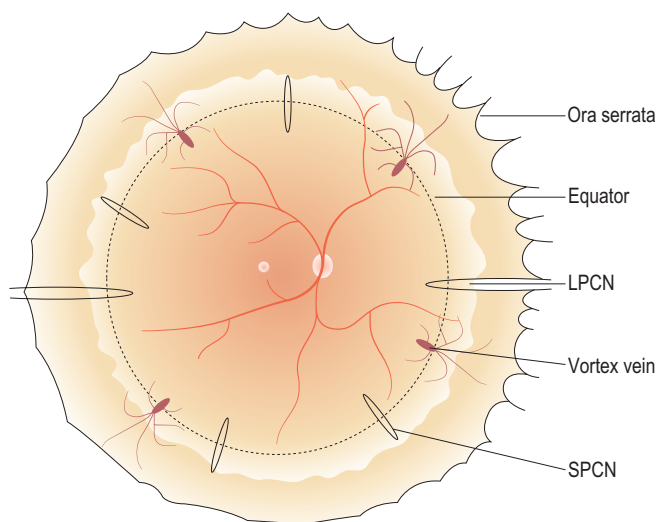


Fig. 7.42 Fundus drawing indicating peripheral landmarks. Ora serrata marks the termination of the retina (and the beginning of the pars plana); equator is the widest part of the eye (represented here with a dotted circle) and is represented by the vortex vein ampullae. Other landmarks in the peripheral fundus include the long posterior ciliary nerves (LPCN) and arteries at the 3- and 9-o'clock positions of the fundus. The short posterior ciliary nerves (SPCN) are located approximately at the equator and may, like the vortex vein ampullae, be asymmetrical in each hemisphere.

3. Starting the examination of a sector while already in the bent position. This not only limits the view of the periphery, but will cause you to miss sections of the equatorial fundus.
4. Getting confused regarding where a lesion is. Understanding and drawing the inverted and reversed image seen with BIO must be practised.
5. Moving the indenter in the opposite direction to that which is needed to facilitate the view due to the reversed and inverted image orientation.

REFERENCES

1. Classé JG, Rutstein RP. Binocular vision anomalies: an emerging cause of malpractice claims. *J Am Optom Assoc* 1995;66:305–9.
2. Jabs DA, Nussenblatt RB, Rosenbaum JT, et al. Standardization of uveitis nomenclature for reporting clinical data. Results of the First International Workshop. *Am J Ophthalmol* 2005;140:509–16.
3. Chylack LT, Wolfe J, Singer D, et al. The Lens Opacities Classification System III. *Arch Ophthalmol* 1993;111:831–6.
4. Efron N, Morgan P, Katasara S. Validation of grading scales for contact lens complications. *Ophthalmic Physiol Opt* 2001;21:17–29.
5. Moss SE, Klein R, Klein BE. Prevalence of and risk factors for dry eye syndrome. *Arch Ophthalmol* 2000;118:1264–8.
6. Ang RT, Dartt DA, Tsubota K. Dry eye after refractive surgery. *Curr Opin Ophthalmol* 2001;12: 318–22.
7. Nichols KK, Foulks GN, Bron AJ, et al. The international workshop on meibomian gland dysfunction: executive summary. *Invest Ophthalmol Vis Sci* 2011;52:1922–9.
8. 2007 Report of the International Dry Eye Workshop (DEWS). *Ocul Surf* 2007;5:65–204.
9. Korb DR, Herman JP, Blackie CA, et al. Prevalence of lid wiper epitheliopathy in subjects with dry eye signs and symptoms. *Cornea* 2010;29:377–83.
10. Slusser TG, Lowther GE. Effects of lacrimal drainage occlusion with nondissolvable intracanalicular plugs on hydrogel contact lens wear. *Optom Vision Sci* 1998;75:330–8.
11. Morgan P, Maldonado-Codina C. Corneal staining: do we really understand what we are seeing? *Cont Lens Ant Eye* 2009;32:48–54.
12. Bandamwar K, Garrett Q, Papas E. Mechanisms of superficial micropunctate corneal staining with sodium fluorescein: the contribution of pooling. *Cont Lens Ant Eye* 2012;35:81–4.
13. Machado L, Castro R, Fontes B. Staining patterns in dry eye syndrome: rose bengal versus lissamine green. *Cornea* 2009;28:732–4.
14. Bron A. Diagnosis of dry eye. *Surv Ophthalmol* 2001;45:S221–6.
15. Manthorpe R. Sjögren's syndrome criteria. *Ann Rheum Dis* 2006;61:482–4.
16. Cho P. Schirmer test 1. A review. *Optom Vision Sci* 1993;70:152–6.
17. Farrell J, Patel S, Grierson DG, Sturrock RD. A clinical procedure to predict the value of temporary occlusion therapy in keratoconjunctivitis sicca. *Ophthalmic Physiol Opt* 2003;23:1–8.

18. Pult H, Murphy PJ, Purslow C. A novel method to predict the dry eye symptoms in new contact lens wearers. *Optom Vision Sci* 2009;86:1042–50.
19. Yamaguchi M, Kutsuna M, Uno T, et al. Marx line: Fluorescein staining line on the inner lid as an indicator of meibomian gland function. *Am J Ophthalmol* 2006;141:669–75.
20. Little SA, Bruce AS. Repeatability of the phenol-red thread and tear thinning time tests for tear film function. *Clin Exp Optom* 1994;77:64–8.
21. Bron AJ, Evans VE, Smith JA. Grading of corneal and conjunctival staining in the context of other dry eye tests. *Cornea* 2003;22:640–50.
22. Madden RK, Paugh JR, Wang C. Comparative study of two non-invasive tear film stability techniques. *Curr Eye Res* 1994;13:263–9.
23. Fukuda M, Wang H. Dry Eye and closed eye tears. *Cornea* 2000;19 (Suppl 1):S44–S48.
24. Cho P, Douthwaite W. The relation between invasive and noninvasive tear break-up time. *Optom Vision Sci* 1995;72:17–22.
25. Tucker NA, Codere F. The effect of fluorescein volume on lacrimal outflow transit time. *Ophthalm Plast Reconstr Surg* 1994;10:256–9.
26. Foster PJ, Devereux JG, Alsbirk PH, et al. Detection of gonioscopically occludable angles and primary angle closure glaucoma by estimation of limbal chamber depth in Asians: modified grading scheme. *Br J Ophthalmol* 2000;84:186–92.
27. Pandit RJ, Taylor R. Mydriasis and glaucoma: exploding the myth. A systematic review. *Diabet Med* 2000;17:693–9.
28. Wong TY, Foster PJ, Johnson GJ, Seah SK. Refractive errors, axial ocular dimensions, and age-related cataracts: the Tanjong Pagar survey. *Invest Ophthalmol Vis Sci* 2003;44:1479–85.
29. Johnson GJ, Foster PJ. Can we prevent angle-closure glaucoma? *Eye* 2005;19:1119–24.
30. Browning DJ, Scott AQ, Peterson CB, et al. The risk of missing angle neovascularization by omitting screening gonioscopy in acute central retinal vein occlusion. *Ophthalmology* 1998;105:776–84.
31. Harper RA, Reeves BC. Glaucoma screening: the importance of combining test data. *Optom Vision Sci* 1999;76:537–43.
32. Heijl A, Leske MC, Bengtsson B, et al. Reduction of intraocular pressure and glaucoma progression: results from the Early Manifest Glaucoma Trial. *Arch Ophthalmol* 2002;120:1268–79.
33. Johnson M, Kass MA, Moses RA, Grodzki WJ. Increased corneal thickness simulating elevated intraocular pressure. *Arch Ophthalmol* 1978;96:664–5.
34. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. *Surv Ophthalmol* 2000;44:367–408.
35. Ehlers N, Bramsen T, Sperling S. Applanation tonometry and central corneal thickness. *Acta Ophthalmol* 1975;53:34–43.
36. Brandt JD, Beiser JA, Kass MA, Gordon MO. Central corneal thickness in the Ocular Hypertension Treatment Study (OHTS). *Ophthalmology* 2001;108:1779–88.
37. Park SJK, Ang GS, Nicholas S. The effect of thin, thick and normal corneas on Goldmann intraocular pressure measurements and correction formulae in individual eyes. *Ophthalmology* 2012;119:443–9.
38. Tonnu PA, Ho T, Newson T, et al. The influence of central corneal thickness and age on intraocular pressure measured by pneumotonometry, noncontact tonometry, the Tono-Pen XL, and Goldmann applanation tonometry. *Br J Ophthalmol* 2005;89:851–4.
39. Emara BY, Tingey DP, Probst LE, Motolko MA. Central corneal thickness in low-tension glaucoma. *Can J Ophthalmol* 1999;34:319–24.
40. Shaikh NM, Shaikh S, Singh K, Manche E. Progression to end-stage glaucoma after laser in situ keratomileusis. *J Cataract Refract Surg* 2002;28:356–9.
41. Herndon LW. Measuring intraocular pressure-adjustments for corneal thickness and new technologies. *Curr Opin Ophthalmol* 2006;17:115–9.
42. Cook JA, Botello AP, Elders A, et al. Systematic review of the agreement of tonometers with Goldmann applanation tonometry. *Ophthalmology* 2012;119:1552–7.
43. Vernon SA, Jones SJ, Henry DJ. Maximising the sensitivity and specificity of non-contact tonometry in glaucoma screening. *Eye* 1991;5:491–3.
44. Whitacre MM, Stein R. Sources of error with use of Goldmann-type tonometers. *Surv Ophthalmol* 1993;38:1–30.
45. Classé JG. A review of 50 malpractice claims. *J Am Optom Assoc* 1989;60:694–706.
46. Nucci P, de Pellegrin M, Brancato R. Atlantoaxial dislocation related to instilling eyedrops in a patient with Down's syndrome. *Am J Ophthalmol* 1996;122:908–10.
47. Mapstone R. Dilating dangerous pupils. *Br J Ophthalmol* 1977;61:517–24.

48. Classé JG. Mydriasis: an eye-opening problem. *J Am Optom Assoc* 1992;63:733–41.
49. Gaynes BI. Monitoring drug safety; cardiac events in routine mydriasis. *Optom Vision Sci* 1998;75:245–6.
50. Celebi S, Aykan U. The comparison of cyclopentolate and atropine in patients with refractive accommodative esotropia by means of retinoscopy, autorefractometry and biometric lens thickness. *Acta Ophthalmol* 1999;77:426–9.
51. Twelker JD, Mutti DO. Retinoscopy in infants using a near noncycloplegic technique, cycloplegia with tropicamide 1%, and cycloplegia with cyclopentolate 1%. *Optom Vision Sci* 2001;78:215–22.
52. Levatin P. Pupillary escape in disease of the retina or optic nerve. *Arch Ophthalmol* 1959;62:768–79.
53. Enyedi LB, Dev S, Cox TA. A comparison of the Marcus Gunn and alternating light tests for afferent pupillary defects. *Ophthalmology* 1998;105:871–3.
54. Kawasaki A, Moore P, Kardon RH. Long-term fluctuation of relative afferent pupillary defect in subjects with normal visual function. *Am J Ophthalmol* 1996;122:875–82.
55. Lam BL, Thompson HS. A unilateral cataract produces a relative afferent pupillary defect in the contralateral eye. *Ophthalmology* 1990;97:334–8.
56. Varma R, Steinmann WC, Scott IU. Expert agreement in evaluating the optic disc for glaucoma. *Ophthalmology* 1992;99:215–21.
57. Grey RH, Hart JC. Screening for sight threatening eye disease. Stereoscopic viewing of the retina needed to identify maculopathy. *Br Med J* 1996;312:440–1.
58. Raasch T. Funduscopy systems: a comparison of magnification. *Am J Optom Physiol Opt* 1982;59:595–601.
59. Garway-Heath DF, Ruben ST, Viswanathan A, Hitchings RA. Vertical cup/disc ratio in relation to optic disc size: its value in the assessment of the glaucoma suspect. *Br J Ophthalmol* 1998;82:1118–24.
60. Bradnam MS, Montgomery DM, Moseley H, Dutton GN. Quantitative assessment of the blue-light hazard during indirect ophthalmoscopy and the increase in the 'safe' operating period achieved using a yellow lens. *Ophthalmology* 1995;102:799–804.
61. Chow SP, Aiello LM, Cavallerano JD, et al. Comparison of nonmydriatic digital retinal imaging versus dilated ophthalmic examination for nondiabetic eye disease in persons with diabetes. *Ophthalmology* 2006;113:833–40.
62. Hrynychak P, Hutchings N, Jones D, Simpson T. A comparison of cup-to-disc ratio evaluation in normal subjects using stereo biomicroscopy and digital imaging of the optic nerve head. *Ophthalmic Physiol Opt* 2003;23:51–9.
63. Hanson C, Tennant MT, Rudnisky CJ. Optometric referrals to retina specialists: evaluation and triage via teleophthalmology. *Telemed J E Health* 2008;14:441–5.
64. Kitzmann AS, Fethke NB, Baratz KH, et al. A survey study of musculoskeletal disorders among eye care physicians compared with family medicine physicians. *Ophthalmology* 2011;119:213–20.
65. Siegel BS, Thompson AK, Yoltan DP, et al. A comparison of diagnostic outcomes with and without pupillary dilatation. *J Am Optom Assoc* 1990;61:25–34.
66. Parisi ML, Scheiman M, Coulter RS. Comparison of the effectiveness of a non-dilated versus dilated fundus examination in the pediatric population. *J Am Optom Assoc* 1996;67:266–72.
67. Wolffsohn JS, Napper GA, Ho SM, et al. Improving the description of the retinal vasculature and patient history taking for monitoring systemic hypertension. *Ophthalmic Physiol Opt* 2001;21:441–9.
68. Jonas JB, Budde WM, Panda-Jonas S. Ophthalmoscopic evaluation of the optic nerve head. *Surv Ophthalmol* 1999;43:293–320.
69. Drexler W, Fujimoto JG. State-of-the-art retinal optical coherence tomography. *Prog Ret Eye Res* 2008;27:45–88.
70. Fujimoto JG, Huang D. Introduction to optical coherence tomography. In: Huang D, Duker JS, Fujimoto JG, et al, editors. *Imaging the Eye from Front to Back with RTVue Fourier-Domain Optical Coherence Tomography*. New Jersey: SLACK Inc.; 2012. pp. 1–22.
71. Hatef E, Khwaja A, Rentiya Z, et al. Comparison of time domain and spectral domain optical coherence tomography in measurement of macular thickness in macular edema secondary to diabetic retinopathy and retinal vein occlusion. *J Ophthalmol* 2012;354783.
72. Tan O, Li G, Lu AT, et al. Mapping of macular substructures and optical coherence tomography for glaucoma diagnosis. *Ophthalmology* 2008;115:949–56.
73. Um TW, Sung KR, Wollstein G, et al. Asymmetry in hemifield macular thickness as an early indicator of glaucomatous change. *Invest Ophthalmol Vis Sci* 2012;53:1139–44.

74. Batchelder TJ, Fireman B, Friedman GD, et al. The value of routine dilated pupil screening examination. *Arch Ophthalmol* 1997;115:1179–84.
75. Mackenzie PJ, Russell M, Ma PE, et al. Sensitivity and specificity of the optos optomap for detecting peripheral retinal lesions. *Retina* 2007;27:1119–24.
76. Cheng SC, Yap MK, Goldschmidt E, et al. Use of the Optomap with lid retraction and its sensitivity and specificity. *Clin Exp Optom* 2008;91:373–8.
77. Albietz JM. Prevalence of dry eye subtypes in clinical optometry practice. *Optom Vision Sci* 2000;77:357–63.
78. Ansari-Shahrezaei S, Maar N, Biowski R, Stur M. Biomicroscopic measurement of the optic disc with a high-power positive lens. *Invest Ophthalmol Vis Sci* 2001;42:153–7.
79. Atkinson PL, Wishart PK, James JN, et al. Deterioration in the accuracy of the pulsair non-contact tonometer with use: need for regular calibration. *Eye* 1992;6:530–4.

8

VARIATIONS IN APPEARANCE OF THE NORMAL EYE

DAVID B. ELLIOTT AND KONRAD PESUDOV'S

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The vast majority of patients examined in optometry practice have normal, healthy eyes. This chapter presents information about some of the subtle variations that occur in the normal eye and presents changes that commonly occur with normal ageing. To discriminate between ocular disease and the normal eye, it is essential to be familiar with the range of presentations that is considered to represent 'normal'. A brief description and collection of photographs of these normal variations is presented here, to supplement the information provided in atlases of ocular disease. In addition, more photographs, online quizzes and video-clips are provided on the accompanying website. The variations in younger adult eyes are mainly caused by differences in ocular size and pigmentation and the occasional presence of embryological remnants. We thank Lisa Prokopich and John Flanagan for some of the photographs.

8.1 ANTERIOR EYE VARIATIONS

See online quiz 8.1 and additional online photographs 8.1i–8.5i. Concretions and pinguecula can be found in young adults, but are more common in older patients and are discussed in [section 8.2](#).

8.1.1 Epicanthus

Bilateral inner canthal nasal folds are common in Caucasian infants and Asians. It can make the child appear strabismic.

8.1.2 Congenital conjunctival melanosis

Relatively common, bilateral, benign, flat, pigmented areas of conjunctiva, typically near the limbus in young, heavily pigmented eyes ([Figure 8.1](#) and online). The pigmentation is darkest at the limbus with decreasing intensity away from it. It is sometimes simply called complexion-associated conjunctival pigmentation to differentiate it from primary acquired melanosis, which are flat, speckled, brown lesions occurring in patients with European ancestry, do not diminish as they move away from the limbus and can rarely lead to conjunctival melanoma.¹

8.1.3 Pigment spots

Can be seen beneath the conjunctiva at the point of scleral canal emissaries, particularly arteries, in heavily pigmented eyes (online figures 8.1iii, iv.).

8.1.4 Palisades of Vogt

Limbal epithelial folds that run radially. They are more easily seen in young heavily pigmented eyes and are most prominent in the lower limbus ([Figure 8.2](#) and online). They house limbal epithelial stem cells, which produce epithelial cells to maintain the normal corneal epithelium or replace it in the event of injury.²

8.1.5 Pigment changes in the iris

Little or no pigment gives 'blue eyes'. With increasing amounts of pigment, the iris is seen as green, hazel or brown. People with blue irides have greater light scatter than those with more pigmented irides and may suffer more from disability glare in situations such as driving at night.³ Variations in pigment can produce wedge-shaped sections of hyper or hypo-pigmentation (heterochromia, [Figure 8.3](#) and online) in one or both eyes. Hyperpigmented spots (naevi or 'iris freckles', [Figure 8.4](#) and online) are common, but should be monitored using photography for changes due to the slight risk of malignant melanoma.

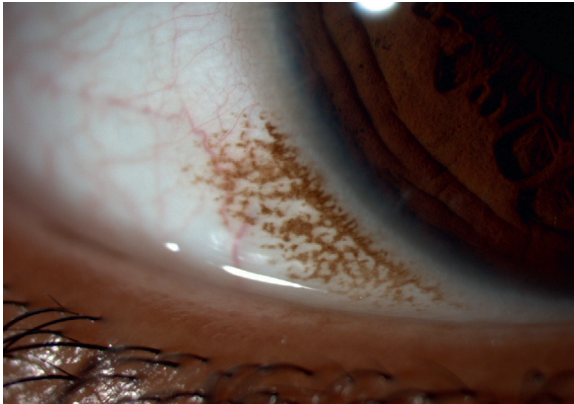


Fig. 8.1 Conjunctival melanosis.

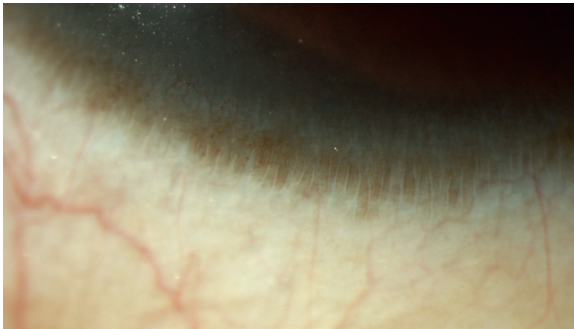


Fig. 8.2 Limbal palisades.

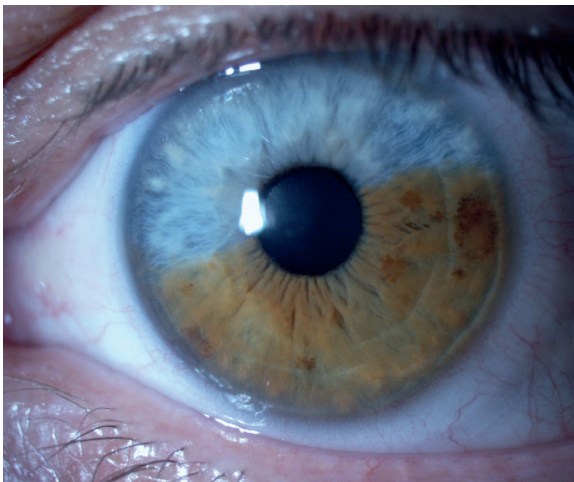


Fig. 8.3 A large section of iris hyperpigmentation (heterochromia).

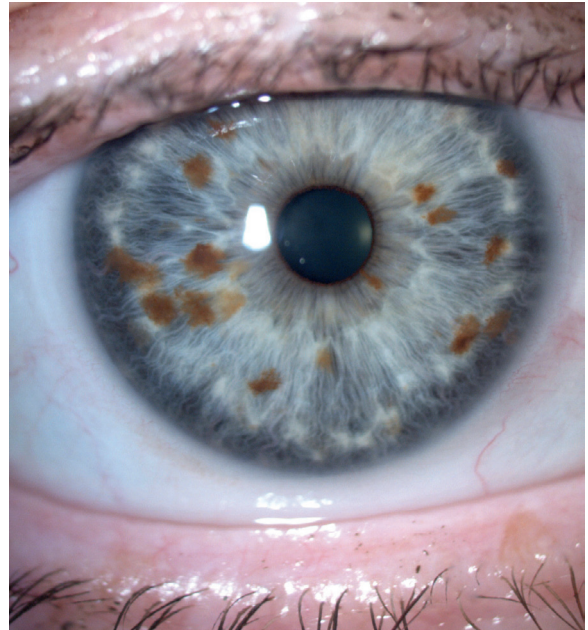


Fig. 8.4 Iris naevi.

8.1.6 Persistent pupillary membrane

These are strands of the embryonic pupillary membrane that remain into adulthood. One end of the strand inserts into the iris colarette and the other is either attached to the anterior lens capsule or floats in the anterior chamber ([Figure 8.5](#) is a common example, while [Figure 8.6](#) is rare; also online figures).

8.2 ANTERIOR EYE CHANGES IN OLDER PATIENTS

See online quiz 8.1 and additional online photographs 8.7i–8.16ii. With increasing age, there is progressive loss of tone and bulk of the eyelids, a loss of tear film stability, a reduction in corneal sensitivity and decreased cell density and increased variation in cell size (polymegethism) and shape (pleomorphism) in the corneal endothelium. In the iris, the crypts disappear, especially near the pupil and the pupillary ruff appears eroded and, as novice retinoscopists and ophthalmoscopists will readily confirm, the pupil gets smaller with age (pupillary miosis).

8.2.1 Dermatochalasis

Benign, bilateral drooping of upper lid tissue over the septum or lid margin with age (online figures 8.7i,ii).

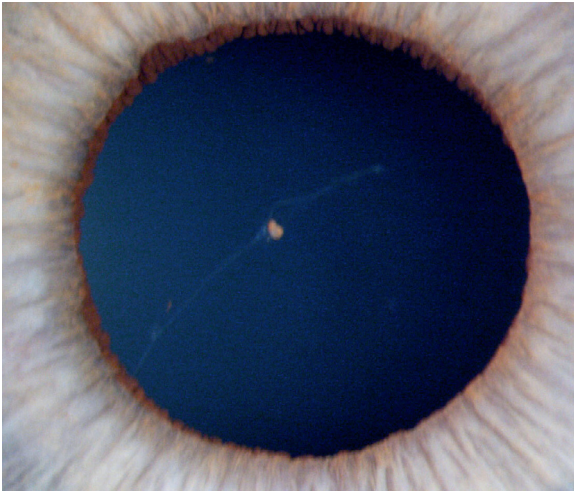


Fig. 8.5 Persistent pupillary membrane.

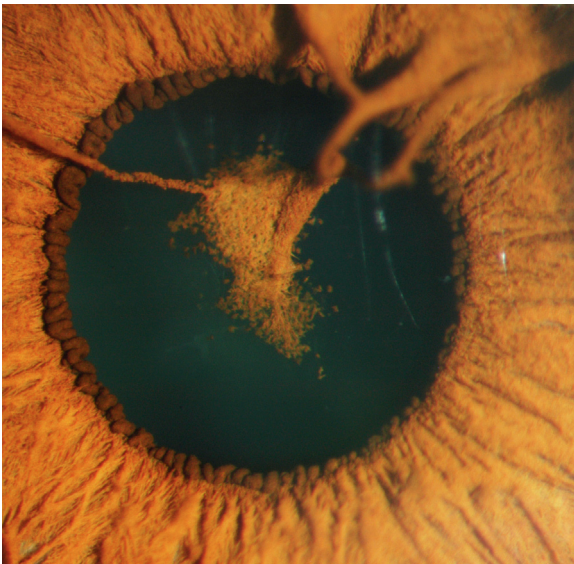


Fig. 8.6 A large persistent pupillary membrane.

Cosmetic surgery is sometimes requested. Blepharoplasty or blepharoptosis repair can improve functional vision and may be recommended if the patient reports problems.⁴

8.2.2 Ectropion and entropion

The eyelid is either turned outward (ectropion) or **in**ward (**en**tropion) due to loose lids so that the inferior lid margin or puncta are not in contact with the

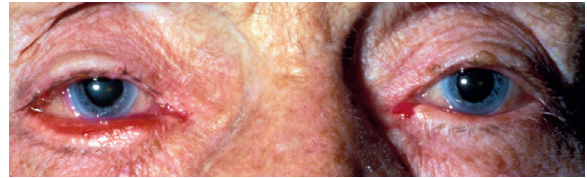


Fig. 8.7 Ectropion with rose Bengal staining (section 7.1).

eye. The patient may complain of epiphora or be symptomless. It is a common complaint, found in about 3% (ectropion, **Figure 8.7**) and 2% (entropion) of elderly patients.⁵

8.2.3 Seborrheic keratosis

One of the most common benign eyelid tumours in the elderly.^{6,7} Hyperkeratinised, waxy, light grey-brown plaques found over the eyelids and face and appearing to be stuck onto the skin. Typically benign, but should be monitored for changes in size, shape, pigmentation, edge erosion, recurrent infection or inflammation and can be removed for cosmetic reasons. You should reassure the patient and monitor the lesion, ideally using photography.⁸

8.2.4 Papilloma

The most common benign lesion of the eyelid and often known as a 'skin tag'.⁷ They are avascular, epithelial lesions of variable size, shape and colour (amelanotic to black) with a roughened surface reflecting the redundant epithelial cell growth (online figure 8.7.iii). Over time, they grow and become attached to the eyelid surface by a stalk (pedunculated), so that the papilloma can be moved back and forth. You should reassure the patient and photograph the cyst, which can be removed for cosmetic reasons.

8.2.5 Sebaceous cysts

Common, benign, yellowish, 'cheesy' cyst of variable size (typically 2–5 mm). Superficial cysts are covered by a thin layer of epithelial cells. Multiple small sebaceous cysts are often called milia. Subcutaneous or deep sebaceous cysts are larger (variable, but up to 20 mm) and slightly movable and covered by normal skin. They are caused by blockages to the sebaceous glands, with the blocked pore subsequently becoming filled with the oily sebum (**Figure 8.8** and online). You should reassure the patient and photograph the cyst, which can be removed for cosmetic reasons.



Fig. 8.8 Subcutaneous sebaceous cyst.



Fig. 8.9 Xanthelasma.

8.2.6 Xanthelasma

Bilateral, flat, light brown/yellow, triangular lipid masses with a nasal base, typically found on the inner upper eyelids of elderly patients and especially females (Figure 8.9 and online). They usually have a familial aetiology, but can be linked with atherosclerosis and

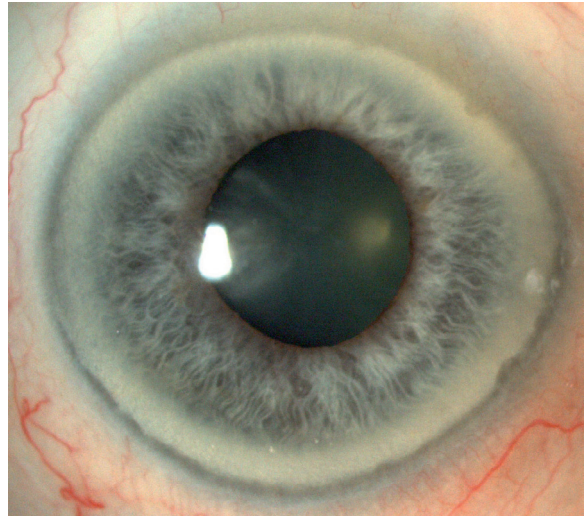


Fig. 8.10 Complete corneal arcus and cortical cataract viewed in direct diffuse illumination.

high cholesterol and any initial diagnosis of xanthelasma should be referred for further investigation. They often reoccur if removed, so the patient should be warned of this if considering cosmetic removal.⁹

8.2.7 Corneal arcus (previously arcus senilis)

A commonly found, bilateral, 1.0–1.5 mm wide, greyish-white ring or part ring occurring in the periphery of corneas of older patients that is separated from the limbus by a thin ring of clear cornea, the lucid interval of Vogt (Figure 8.10 and online). It is called a corneal arcus rather than a corneal ring as it initially presents as arcs in the inferior and superior poles of the perilimbal cornea before spreading to form a complete ring. The inner edge is typically more diffuse than the sharper outer edge. Its prevalence increases significantly with age after 50 years.¹⁰ It is caused by lipid being deposited in the corneal stroma, having permeated from the limbal blood vessels, which become more permeable with age. Corneal arcus may be a sign of systemic hyperlipidaemias if seen in younger adults and any patient with arcus who is below the age of 50 years should be referred for further investigation.

8.2.8 Concretions

Typically asymptomatic, small (1–3 mm), yellow-white calcium lesions found in the palpebral conjunctiva of the upper and lower eyelid.¹¹ They can be found in young adults, but are more common in elderly



Fig. 8.11 Solitary hard concretion in the lower palpebral conjunctiva.

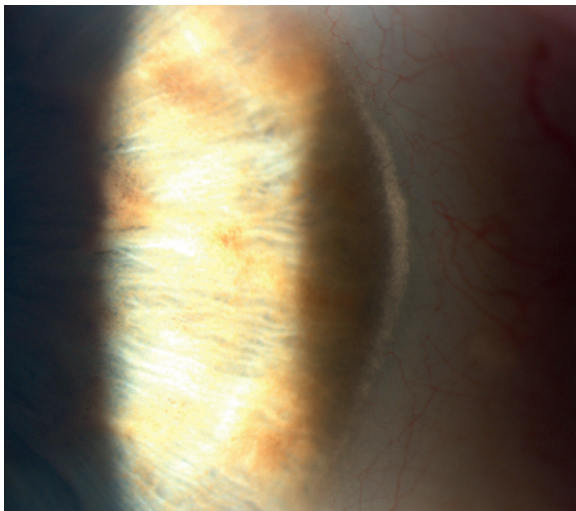


Fig. 8.12 Limbal girdle of Vogt seen in indirect illumination.

patients. The majority are superficial, hard and single (Figure 8.11 and online).¹¹ A small percentage of concretions can cause symptoms, likely due to corneal irritation.

8.2.9 Limbal girdle of Vogt

Common, bilateral degenerative condition producing a narrow band of white, crystal-like opacities along the nasal or temporal limbus, typically found in older female eyes (Figure 8.12 and online). Two types are described: type I has a perilimbal clear zone similar to

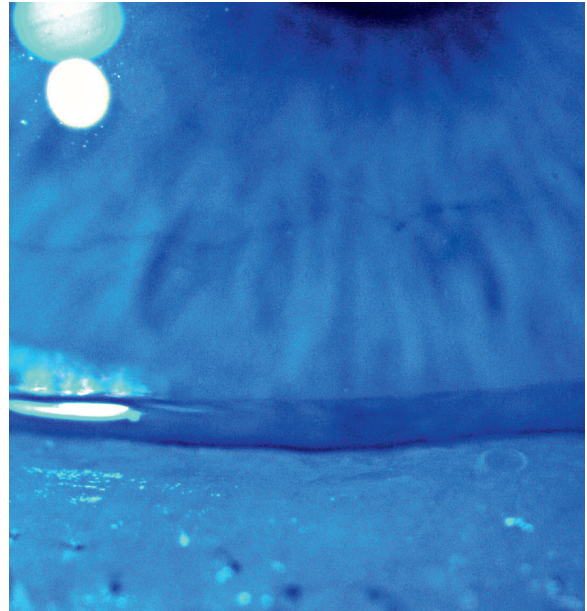


Fig. 8.13 A Hudson-Stähli line.

corneal arcus and contains numerous holes, while type II has neither holes nor a clear zone.

8.2.10 Hudson-Stähli line

Common, corneal orangey-brown iron deposition line found close to where the lid margins meet when blinking. The line is generally horizontal, possibly with a slight V-shape in the middle. It can be continuous or segmented and although some texts suggest that the prevalence typically matches the age of the patient, many Hudson-Stähli lines are faint and difficult to see under white light so that this high prevalence seems unlikely. However, they become more visible in cobalt blue (Figure 8.13 and online) or ultra-violet light.¹² For this reason you may first notice it during a slit-lamp examination using fluorescein and cobalt blue illumination. Its aetiology is unclear, with the iron possibly arising from the tears, perilimbal blood supply and/or caused by UV radiation and the line/vortex pattern being linked with the position of eyelid closure or the growth and repair patterns of the corneal epithelium.¹² Corneal iron deposition can occur in orthokeratology patients and the iron deposition pattern and position appears to change after refractive surgery.^{13,14}

8.2.11 Crocodile shagreen

This is a polygonal pattern of white or grey opacity in the cornea that is visible on direct illumination (Figure

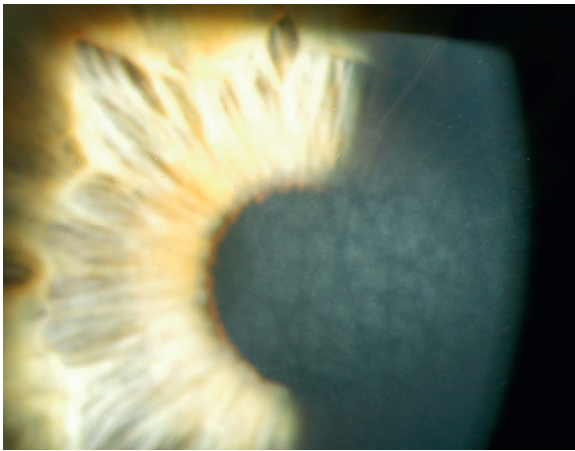


Fig. 8.14 Crocodile shagreen.

8.14). It takes its name from the pattern of roughly tanned hides that follow the papillae of animals' skin. Peripheral crocodile shagreen is the most common with a reported clinical incidence of 13.4%.¹⁵ The pattern is probably related to the arrangement of corneal fibrils allowing opacities to preferentially occur in some locations. Peripheral shagreen tends to progress towards but never reaching the central cornea. It can vary from faint to striking, and while the latter may be of concern, vision seems unaffected. No treatment is required, and referral is not appropriate.

8.2.12 Corneal guttata

These are small excrescences of abnormal basement membrane and collagen fibrillar material from distressed corneal endothelium. They occur in the periphery of all corneas where they are termed Hassall-Henle bodies or 'warts' and the prevalence of frank central corneal guttata in those aged over 55 is about 9%, with smoking doubling their likelihood.¹⁶ Guttata are often accompanied by a fine pigment dusting, and the endothelial layer is said to take on a beaten metal appearance when viewed with specular reflection or retro-illumination (Figure 8.15). Identification of central corneal guttata may be important in patients undergoing refractive surgery, as mild corneal guttata has been associated with increased risk of complications post surgery.¹⁷ The transition from a simple observation of corneal guttata to a diagnosis of Fuchs' endothelial dystrophy occurs when the guttata are accompanied by corneal thickening as evidenced by signs of oedema: striae, folds or clouding. Corneal guttata are a benign clinical finding, as is early Fuchs' endothelial dystrophy.

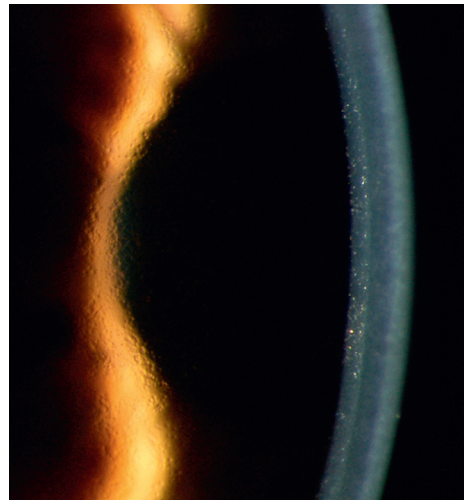


Fig. 8.15 Corneal guttata seen on the right in direct illumination as white dots of increased backscatter in the corneal endothelium and on the left as a 'beaten copper metal' appearance in retro-illumination against the iris.

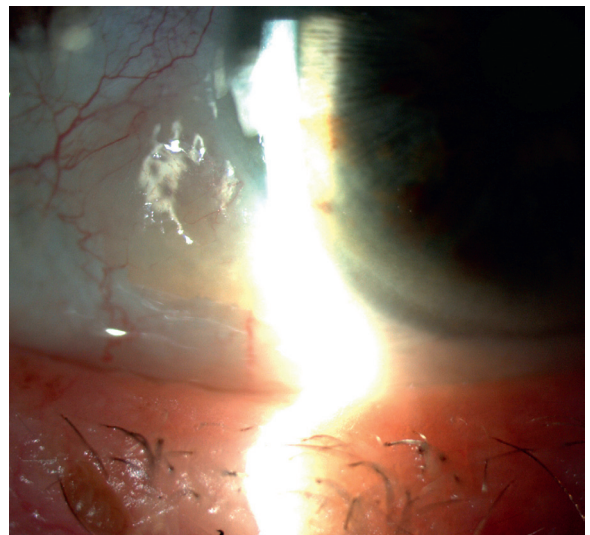


Fig. 8.16 A pinguecula seen to the left of the slit-beam in indirect illumination. A small papilloma is also visible on the lower lid.

8.2.13 Pinguecula

A degenerative thickening of the bulbar conjunctiva adjacent to the limbus and often found nasally (Figure 8.16 and online). Although it is seen in adult patients who work outdoors and do not wear



Fig. 8.17 Mittendorf dot (the black dot seen slightly superior nasally from the pupil centre).

sunglasses, its prevalence increases with age and it is very common in the elderly.¹⁸ Pingueculae can lift the lids away from the surrounding conjunctiva, leading to a local area of drying and hyperaemia for which artificial tears can be helpful. Given their minimal impact on the patient, and a likelihood to recur, surgical excision is rarely considered. Pinguecula can increase in size with age, so the mainstay of treatment is preventative with UV blockers in spectacles and/or sunglasses.

8.3 LENS AND VITREOUS VARIATIONS

Vitreous floaters can be found in young adults, particularly the large eyes of moderate to high myopes, but are more common in older patients and are discussed in [section 8.4](#).

8.3.1 Mittendorf dot

Seen as a small black dot in fundal retro-illumination ([Figure 8.17](#) and online) and a white dot on the posterior capsular surface in direct illumination. It is usually displaced nasally or inferior-nasally and it is a remnant of the attachment of the hyaloid canal to the posterior lens surface. The hyaloid artery provides nutrients to the developing lens in the growing foetus and is typically fully regressed before birth (but see video 8.1

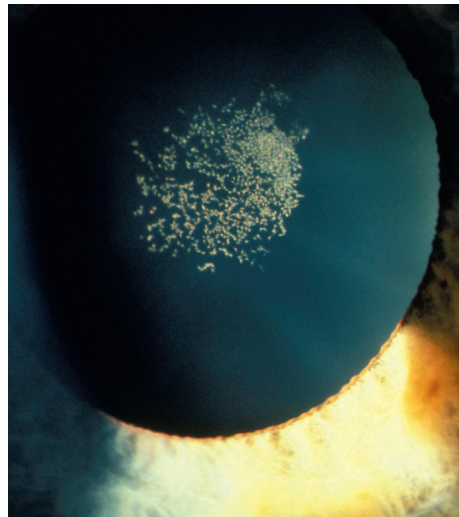


Fig. 8.18 Epicapsular stars.

which shows a full hyaloid artery in a young adult). It runs from the ophthalmic artery at the optic disc to the crystalline lens where it spreads over both surfaces of the lens in a capillary net or tunica vasculosa lentis.

8.3.2 Epicapsular stars

Small, light brown or tan star shaped deposits on the anterior lens surface ([Figure 8.18](#) and online) that are remnants of the tunica vasculosa lentis ([section 8.3.1](#)). They can be bilateral or unilateral and single or multiple.

8.3.3 Zones of discontinuity

The slit-lamp appearance of the normal adult lens shows a series of zones of clear media in both the anterior and posterior lens cortex delineated by a curved line of scattered light ([Figure 8.19](#) and online). These zones are made up of lens fibre layers with different scattering properties, likely due to different refractive indices in the continually growing lens cortex. Koretz and colleagues suggested that an adult lens typically contains three zones that originate from lens growth at approximate ages of 5, 10 and 20 years, with a fourth zone often appearing after the age of 40.¹⁹

8.3.4 Y-sutures

The lens is formed by the meeting of fibres that arch over the lens equator and join with other fibres to form branching suture lines which take on an upright 'Y' appearance anteriorly and an inverted 'Y'

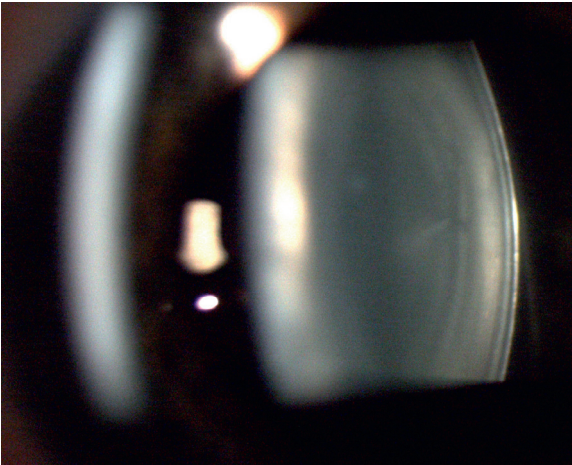


Fig. 8.19 Zones of discontinuity and a Y-suture in a posterior lens section.

appearance posteriorly (Figure 8.19 and online) in the foetal lens. The sutures are visible because of the large amount of light scatter caused by the non-uniform shape and size of the lens fibre ends. These lens sutures become progressively more complex during distinct periods of lens growth. In early childhood, simple star sutures are formed. In adolescence and adulthood, star (9 branches) and complex star (12 branches) sutures are formed, but these are much more difficult to see.²⁰

8.4 LENS AND VITREOUS CHANGES IN OLDER PATIENTS

See online quiz 8.2 and additional online photographs 8.20i–8.26iv. The lens continues to grow and thicken with age, leading to a gradual reduction in the anterior chamber. There is increased light scatter due to an increased number of cortical layers and the production of large aggregates in the lens nucleus. Chromophores that absorb blue wavelength light also increase with age, leading to progressive lens yellowing. In addition, the prevalence of cataract increases substantially.

8.4.1 Posterior subcapsular (PSC) cataract

PSC cataract presents at the back of the lens just in front of the posterior capsule. In the age-related type, vacuoles are found in the early stages (Figure 8.20 and online). Later, there is a posterior migration of epithelial cells from the lens equator to the posterior

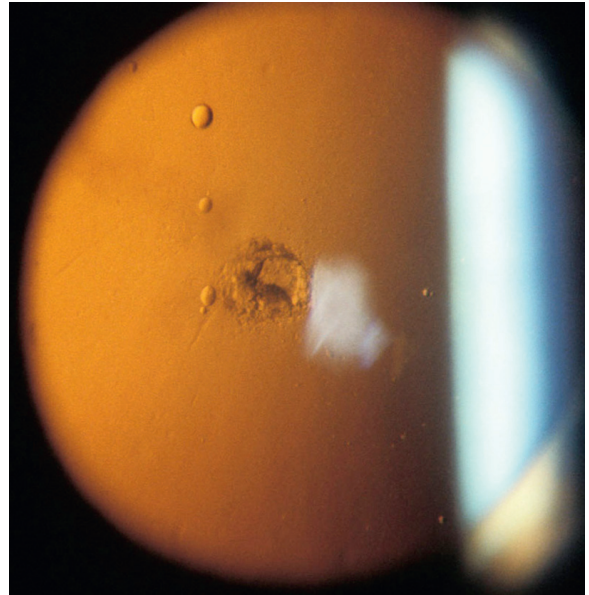


Fig. 8.20 A small posterior subcapsular cataract and several vacuoles seen in fundal retro-illumination.

pole, where they form the balloon or bladder cells of Wedl. Large particle scattering is increased by the many organelles in the epithelial cells. To categorise a cataract as PSC, an optical section technique is required, although PSC cataract is best viewed through a dilated pupil using retro-illumination from the fundus.

PSC cataract typically presents earlier than the other morphological types, at about age 55 years, and are associated with diabetes, other ocular diseases such as retinitis pigmentosa and uveitis, after ocular trauma and are found as a side effect of systemic drugs such as oral corticosteroids.²¹ PSC cataracts can cause a dramatic reduction in vision with pupil constriction because they are generally centrally positioned within the pupil. These cataracts can hide behind the corneal and lens reflexes when viewed through an undilated pupil and be missed (Figure 8.21 and online). Clinicians have been successfully sued for missing PSC cataracts in patients with no symptoms at the time of the eye examination but whom subsequently had holidays ruined due to poor vision in a brighter, sunnier climate.

8.4.2 Nuclear cataracts

These present as a homogenous increase in light scatter in the lens nucleus and can be associated with an increased yellowing turning to brunescence

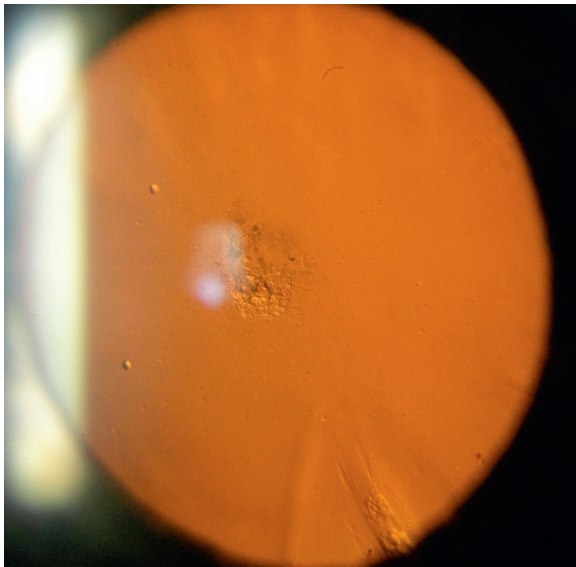


Fig. 8.21 A small posterior subcapsular cataract that could be hidden behind corneal reflexes in an undilated lens examination and missed.

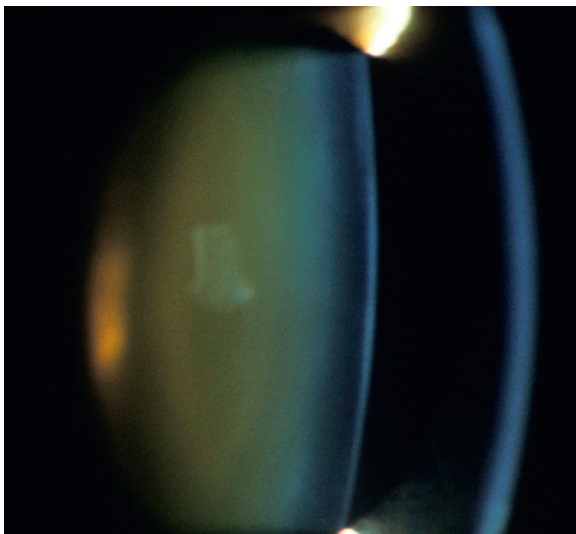


Fig. 8.22 Nuclear cataract seen by optical section. The blurred blue arc to the right is the out-of-focus cornea.

(Figure 8.22 and online), which is indicative of blue wavelength-dependent light absorption. The use of a slit-lamp optical section technique is the only accurate way of detecting and assessing nuclear cataract and it is best performed with a dilated pupil, although is still possible undilated.

8.4.3 Cortical cataract

Cortical cataracts are wedge shaped opacities found in the anterior and/or posterior lens cortex. Vision is only affected if the cortical spokes enter the pupillary area and vision therefore varies depending on pupil size. Cortical opacities are most often found in the inferior-nasal part of the lens, which may reflect ultra-violet B radiation involvement in their aetiology.²² Opacification is due to the scattering of light when it meets irregular interfaces between regions of different refractive index. Cortical opacities are best seen using retro-illumination from the fundus, when the cortical opacities appear black against the red fundal glow (Figure 8.23 and online). The brightest reflection from the fundus is obtained when the illuminating beam strikes the optic nerve head, so that typically the illumination system is placed on the temporal side of the biomicroscope. The slit-lamp illumination beam size, shape and position can be altered to avoid the cortical opacities on its way to the fundus. Some slit lamps allow a half-moon shape illumination beam that can be placed inside the edge of the pupil. In some cases you may need to view the opacities with the illumination in two positions (Figures 8.23 and 8.24). Retro-illumination gives an overall view of the cataract, although note that the depth of focus is usually not sufficient to provide an assessment of both the anterior and posterior lens at the same time, particularly with higher magnification, so that separate assessments are required. The cataracts appear white in direct illumination and are often associated with water clefts, which are optically clear wedges that can be seen with slit-lamp biomicroscopy. Using optical sections to view cortical cataracts is much less useful as it can show large amounts of light scatter due to backward light scatter and reflections that do not cause vision loss and an overall view of the cataract is only possible by mentally combining the views of the many optical sections.

8.4.4 Intra-ocular lenses and posterior capsular remnants

Given the very high rate of cataract surgery in the developed world, you will often examine a pseudophakic patient with an intra-ocular lens and an intact posterior capsule. This capsule can thicken, or form a scaffold for residual lens cell proliferation. If posterior capsular opacification encroaches on the pupillary area and causes visual problems, referral for YAG laser capsulotomy should be suggested. After YAG capsulotomy, a hole in the capsular remnants will be

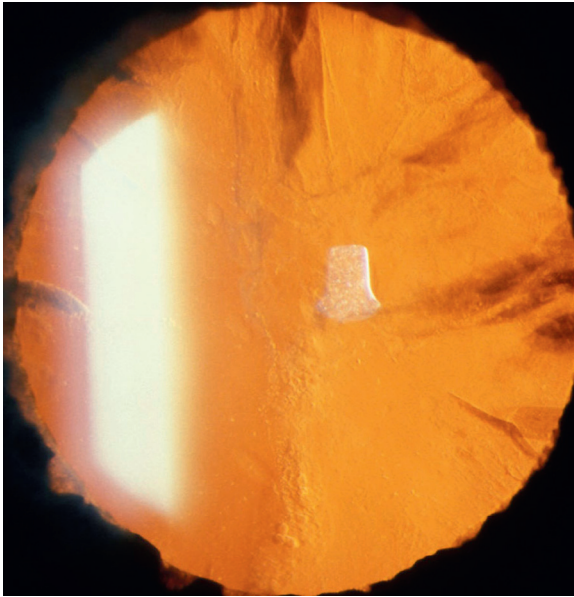


Fig. 8.23 Cortical cataract seen in fundal retro-illumination.

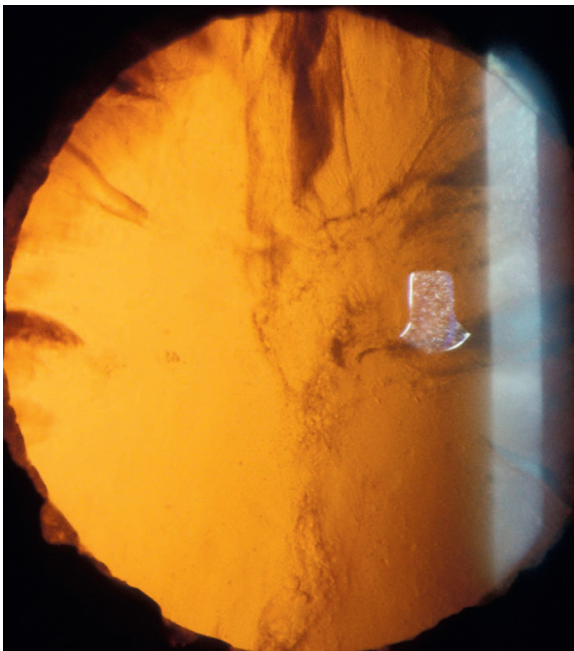


Fig. 8.24 The same cortical cataract as in [Figure 8.23](#) with the illumination beam now on the right side of the pupil. Notice the difference in appearance of the same cataract in the two photographs.

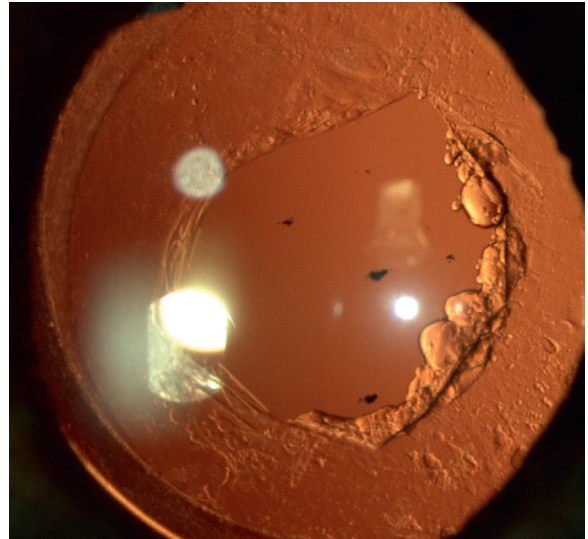


Fig. 8.25 An intra-ocular implant with peripheral posterior capsular remnants after YAG capsulotomy has removed central capsular remnants.

visible ([Figure 8.25](#) and online). As for PSC cataracts, capsular remnants are best seen using retro-illumination from the fundus.

8.4.5 Vitreous floaters

See online video 8.1. Vitreous floaters cast a shadow on the retina and are most obvious to the patient in bright light conditions and when the patient is looking at white walls, snow, etc. Patients typically report seeing black flecks floating in their vision. Some patients mistake them for flies or spiders moving out of the corner of their eye and are very relieved when these symptoms are explained. Vitreous floaters can often be most easily seen with the retro-illumination view provided by a direct ophthalmoscope. Otherwise use the slit-lamp biomicroscope and direct illumination through a dilated pupil to view the anterior vitreous and fundus biomicroscopy to view the posterior vitreous. To look more carefully for floaters, it can be useful to ask the patient to look up, down and then straight ahead and watch for any floaters moving in your view.

8.4.6 Posterior vitreous detachment (PVD)

With ageing, liquefaction and shrinkage (syneresis) occur and this leads to posterior vitreous detachment (PVD). PVD is common after the age of 50, with the prevalence being similar to the patient's age, with even

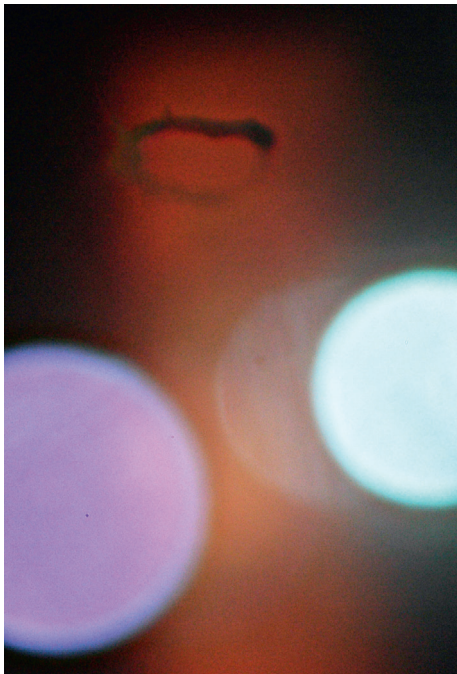


Fig. 8.26 A Weiss ring photographed using fundus biomicroscopy.

greater prevalence after cataract surgery. Detachment of the vitreous from the retina is a slow process, so when the patient is examined the PVD may be complete or incomplete. Determination of whether a PVD is complete or incomplete can only be done with binocular indirect ophthalmoscopy through a dilated pupil. Eventually, all PVDs progress to complete detachment of the vitreous from the sensory retina with collapse of the gel. Many PVDs are asymptomatic, but symptoms are classically a sudden onset of flashes of light, due to tugging on the vitreo-retinal adhesion, and floaters.²³ After the vitreous detaches from the optic nerve head, it can be seen as a ring-like vitreous floater known as a Weiss ring (Figure 8.26 and online).

8.5 OPTIC NERVE HEAD VARIATIONS

See online quiz 8.3 and additional online photographs 8.31i–8.38ii.

8.5.1 Optic nerve head size and shape

The optic nerve head or disc comes in a variety of shapes and sizes (Figures 8.27–8.30 and online quiz 8.3; note that relative size is affected by the degree of

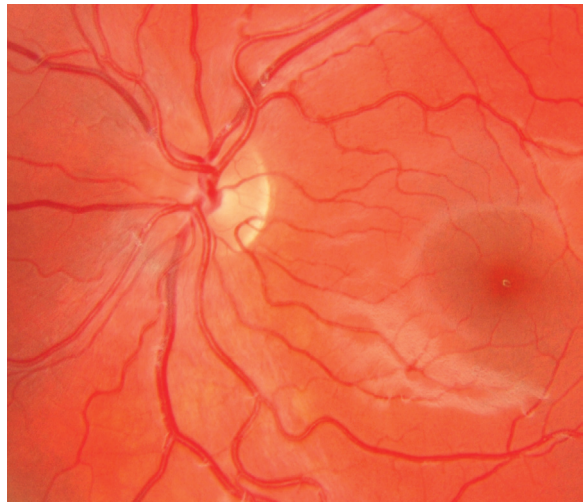


Fig. 8.27 Small optic disc with minimal cupping of a young Caucasian patient. Note the relative difficulty of detecting parts of the disc margin (compare with figure 8.28).

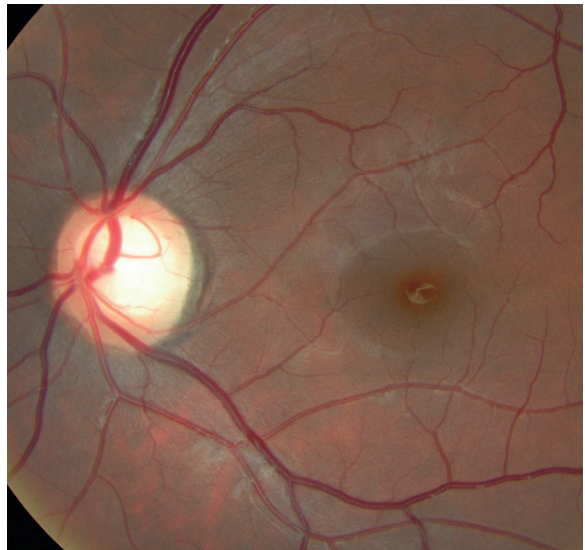


Fig. 8.28 Large optic disc and large cupping (CD ratio ~0.60), a visible nerve fibre layer and macular pigmentation of a young, slightly myopic Asian patient.

magnification of the book figures). Discs have been shown to be smaller in Caucasians, and progressively larger in Mexicans, Asians and African Americans.²⁴ Disc size is larger in myopes beyond –8 D and smaller in hyperopes greater than +4 D.²⁵ Oval discs are often found with corneal astigmatism and the direction of

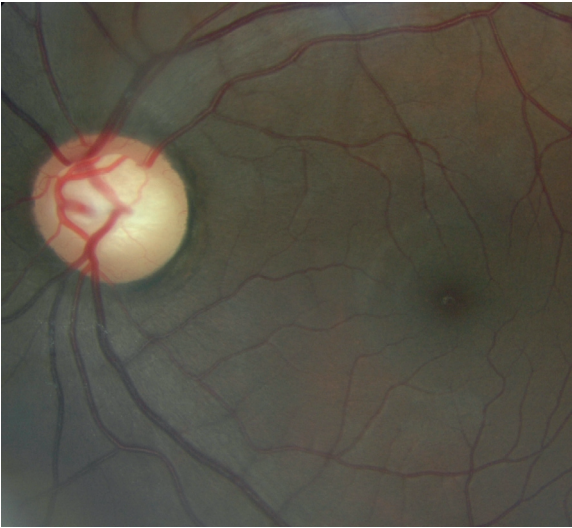


Fig. 8.29 Large optic disc and large cupping (CD ratio ~ 0.60) and a visible nerve fibre layer of a young emmetropic African-Caribbean patient.



Fig. 8.30 An oval optic disc of a young Asian patient. Note the visible nerve fibre layer and macular pigment.

the longest optic disc diameter can indicate the axis of astigmatism (Figure 8.30).²⁶

8.5.2 Optic cupping

The central proportion of the nerve head usually contains a depression called the 'cup'. This is often

associated with an area of pallor due to the lamina cribrosa reflecting through in the absence of axons and their associated capillaries. However, in some cases the cup can extend beyond the area of pallor, so that this should not be used as an indicator of cup size during 2D evaluations such as provided by direct ophthalmoscopy. Rather the kinking of blood vessels as they pass over the edge of the cup should be used as an estimate of the cup position. As discussed above, discs can vary considerably in size, yet approximately the same number of axons (about one million) leave the eye via the optic nerve head. Therefore, large optic discs typically have larger cupping because of the absence of axons in the middle of the disc as the neurons leave the retina in the larger rim tissue of larger discs. The physiological cup-to-disc ratio (CDR) is normally less than 0.60, but is relative to the size of the disc so that smaller cupping should be seen in a small-sized disc and larger cupping is expected in large discs (Figures 8.27–8.29 and online quiz 8.3). For this reason, a 0.30 CDR in a small disc may be more indicative of glaucoma than a 0.70 CDR if it is in a large-sized disc, highlighting the importance of assessing disc size.²⁷ The vertical CDRs indicated for the photographs presented here are based on the 2-D diagrams. The optic nerve heads and cups of the two eyes are typically mirror images of each other and differential diagnosis of many optic nerve head anomalies is provided by an inter-eye comparison.

8.5.3 Spontaneous venous pulsation

See online video 8.2. Present in about 90% of adult eyes with careful observation and most obvious at the point of entry of the central retinal vein into the optic nerve.²⁸ It is caused by the intracranial pressure pulse which acts on the central retinal vein as it passes through the subarachnoid space where it leaves the optic nerve.²⁹ It can be useful to record its presence as its cessation is a sensitive marker of raised intracranial pressure and can help in the differential diagnosis of true papilloedema (it is absent) from pseudopapilloedema (it is present).²⁸ Venous pulsation is best seen with high magnification (15 $\times$ with direct ophthalmoscopy or fundus biomicroscopy using lenses and slit-lamp settings to gain a similar magnification) and mydriasis.²⁸

8.5.4 Lamina cribrosa

Seen in about 30% of eyes as grey dots at the bottom of the optic cup (Figure 8.31, 8.40 and online).³⁰ It is a sieve-like connective and glial tissue that is continuous

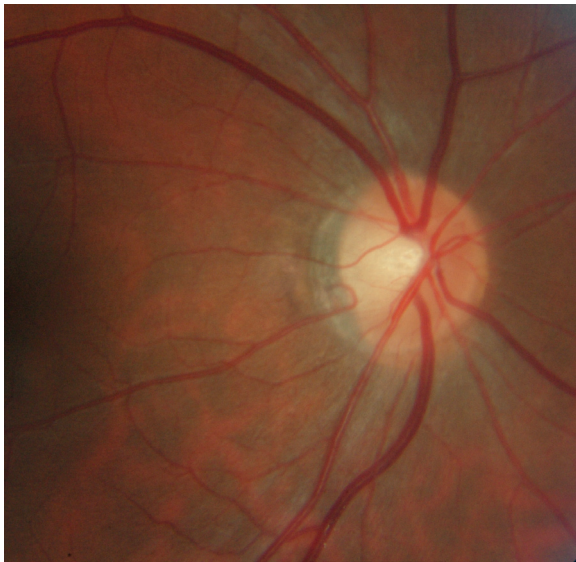


Fig. 8.31 A deep cup with visible lamina cribrosa (C:D ratio ~0.25), a choroidal crescent, visible nerve fibre layer and cilio-retinal artery of a young myopic Caucasian patient.

with the scleral canal. It is more visible in larger discs and larger cups.³⁰

8.5.5 Cilio-retinal artery

Found in about 15–20% of normal eyes as an artery that hooks out of the temporal edge of the disc and runs towards the macula (Figure 8.31 and online). Its shape gives it the nickname of the ‘Shepherd’s crook’. It is derived from the short posterior ciliary system or choriocapillaris rather than the central retinal artery and it becomes most relevant after a central retinal artery occlusion, when it saves the retina around its distribution. Of course, the cilio-retinal artery can itself become occluded.

8.5.6 Nerve fibre layer striations

These are brightest at the superior and inferior poles, where the nerve fibre layer is thickest, and are best seen in young patients, particularly those with heavily pigmented fundi (Figure 8.27–8.33). The striations are caused by the tubes of astrocytes that surround the retinal ganglion cell axon. Fundus photography, particularly digital, may provide a better assessment of the nerve fibre layer than fundus biomicroscopy.³¹ Nerve fibre layer striations are best seen with the green (red-free) filter as the lower wavelengths do not

penetrate the nerve fibre layer and are more readily reflected back.

8.5.7 Tilted discs and optic disc malinsertion

The tilt can be seen with the 3D view of fundus biomicroscopy. With direct ophthalmoscopy it is seen as an oval disc whose edges may not be exactly focussed simultaneously. Optic disc malinsertion is a simple insertion of the optic nerve at an acute angle and without the appearance of rotation of the optic nerve, nasal staphyloma or situs inversus. The malinsertion is almost always bilateral and the malinserted discs are mirror images of each other, typically elevated nasally, tilting downwards temporally and with a temporal scleral and/or choroidal crescent. Photographs from the right and left eyes of a patient with malinserted discs are shown in Figures 8.32 and 8.33 and online.

Tilted disc syndrome is more rare, with the disc or discs commonly tilted inferior nasally with a nasal staphyloma (bulging of the sclera) and situs inversus, where the temporal blood vessels first course towards the nasal retina before sharply changing course (tilted disc syndrome in Figure 8.34 and a normal disc in the fellow highly myopic eye in Figure 8.35). Tilted discs are thought to be caused by an incomplete closure of the embryonic foetal fissure, similar to the aetiology of a coloboma.³² The condition is benign, although the area of nasal staphyloma can produce a temporal visual field defect. Tilted discs are associated with corneal astigmatism and myopia and the direction of the longest optic disc diameter can indicate the axis of corneal astigmatism.²⁶

8.5.8 Peripapillary atrophy (PPA)

PPA can be categorised into zone alpha and beta.³³ Zone **B**eta PPA is found adjacent (**B**ordering) to the disc and is present in about 15% of normal eyes (Figure 8.36 and online). The RPE and choriocapillaris are lost and all that is visible are the large choroidal vessels and sclera. Zone alpha is present in nearly all normal eyes and is characterised by irregular hyper and hypopigmented areas in the RPE, either on their own or surrounding zone beta PPA. PPA is most commonly found at the temporal edge of the disc. It should be differentially diagnosed from high myopic atrophy and malinserted optic discs.

8.5.9 Myelinated nerve fibres

Found in about 1% of patients and represents myelin sheathing of the optic nerve fibres that extends beyond



Fig. 8.32 Tilted disc with the nasal side raised and blood vessels nasally displaced. There is a temporal choroidal crescent, slightly tessellated fundus and visible nerve fibre layer.



Fig. 8.33 Fellow eye of [Figure 8.32](#) showing a tilted disc.

the lamina cribrosa and presents a superficial, white, feathery opacification which hides any underlying retinal blood vessels. They are usually continuous with the optic nerve head ([Figure 8.37](#) and online), although small discrete patches of myelinated nerve fibres can appear and may mimic a cotton wool patch. They are typically benign, although may cause visual field loss at threshold. In most cases, myelinated nerve

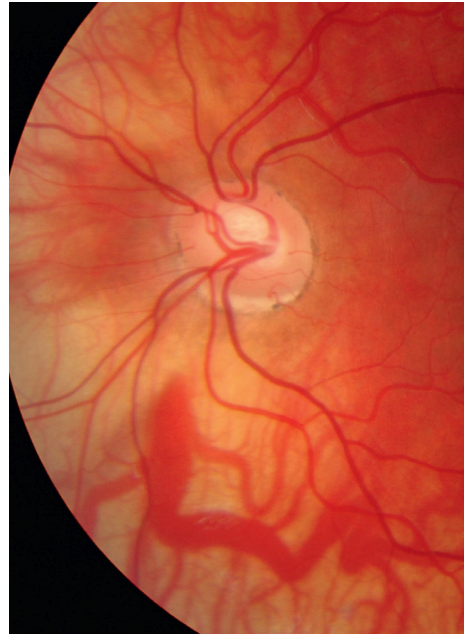


Fig. 8.34 Tilted disc syndrome and highly visible choroidal blood vessels in a young, highly myopic and astigmatic Caucasian patient. The disc is tilted inferior nasally with situs inversus.



Fig. 8.35 Fellow eye of [Figure 8.34](#) showing a normal disc and highly myopic Caucasian fundus.

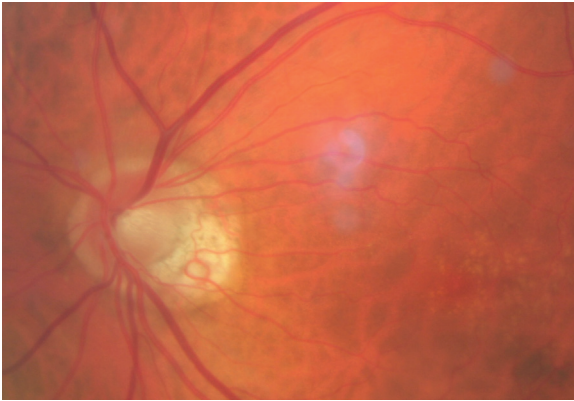


Fig. 8.36 Peripapillary atrophy. There appears to be a ring of beta zone, with temporal alpha zone. The image is slightly more washed out compared to those from younger patients due to light scatter from early cataract. Drusen are visible in the macular region.



Fig. 8.37 Myelinated nerve fibres. There is a purplish reflection between the macula and disc, likely from dust in the camera system.

fibres remain unchanged over time. However, loss of myelinated nerve fibres may occur due to a central demyelinating process or the result of direct axonal destruction or nerve fibre layer ischaemia.³⁴

8.5.10 Drusen of the disc

A familial, typically bilateral condition, found in about 0.3% of patients, which becomes more obvious with

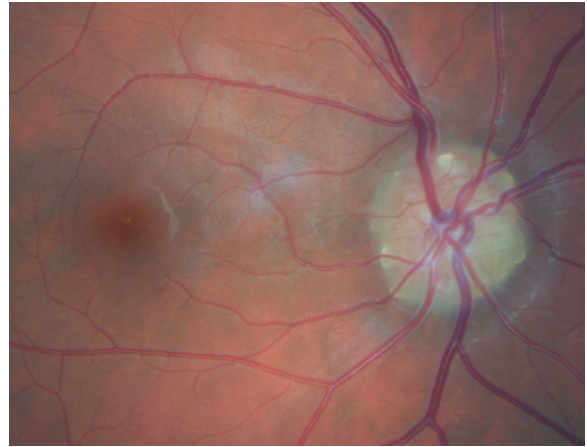


Fig. 8.38 Drusen in the optic nerve head.

age.³⁵ In children, they may be buried in the nerve head and not seen and the disc appears swollen, so that the condition is sometimes called pseudopapilloedema. They are golden, autofluorescent, glowing, calcific globular deposits that sit in front of the lamina cribrosa (Figure 8.38 and online). They are typically found in small discs with little or no cupping and this appearance can mask signs of early glaucoma. Although typically benign they can shear blood vessels and/or nerve fibres, leading to haemorrhages (2–10%) and visual field loss (~75%), some of which can be progressive, so that visual field monitoring is essential.³⁵

8.6 FUNDUS VARIATIONS

The colour of the fundus is determined by the choroidal blood supply and the amount of pigmentation in the choroid and overlying retinal pigment epithelium (RPE). The retinal veins are typically dark red/purple and the retinal arteries are about $\frac{2}{3}$ the thickness and a brighter red, with a slight reflex along the centre of the vessel. The arterioles and venules should have a smooth course and cross at oblique angles without nipping or compressing the venule.

8.6.1 Fundus pigmentation

Fundus pigmentation typically mimics skin pigmentation. Compare the Asian and African-Caribbean fundi in Figures 8.28–8.30 to the Caucasian fundus in Figure 8.27. With a lightly pigmented or thin (typically myopic) RPE, the choroidal vessels and choroidal pigmentation can be seen (Figures 8.34 and 8.35).



Fig. 8.39 Very tortuous retinal arteries and visible macular pigment in a young Caucasian patient. Some reflections can be seen in a broken ring outside the macular region, just above the ring and beside some of the blood vessels.

8.6.2 Macular pigmentation

The macula lutea area contains a yellow-brown pigment, although the amount is highly variable between individuals, and is most obvious in highly pigmented eyes (Figures 8.30, 8.39 and online). A bright reflex may be seen at the foveola in younger patients, as the ophthalmoscope light is reflected back from the foveal pit.

8.6.3 Congenital vascular tortuosity

Most commonly bilateral and involving both arteries and veins and all quadrants (Figure 8.39 and online). Acquired tortuosity, particularly of veins, is less common than the congenital condition, but should be considered as it is connected with a variety of ocular and systemic diseases. For this reason, eyes with very tortuous vessels should ideally be photographed and monitored.

8.6.4 Tessellated or tigroid fundus

A thin RPE allows the red choroidal vessels and heavily pigmented choroid to be seen and can give a tiger stripe appearance (Figures 8.40 and 8.41). It is more commonly seen with the thin retina of myopic patients.³⁶

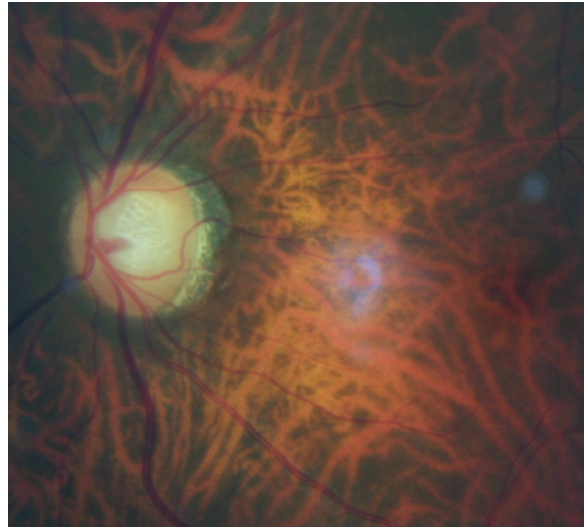


Fig. 8.40 A tigroid fundus with a large optic disc and cup (CD ~0.55), visible lamina cribrosa and choroidal crescent in a young myopic patient.

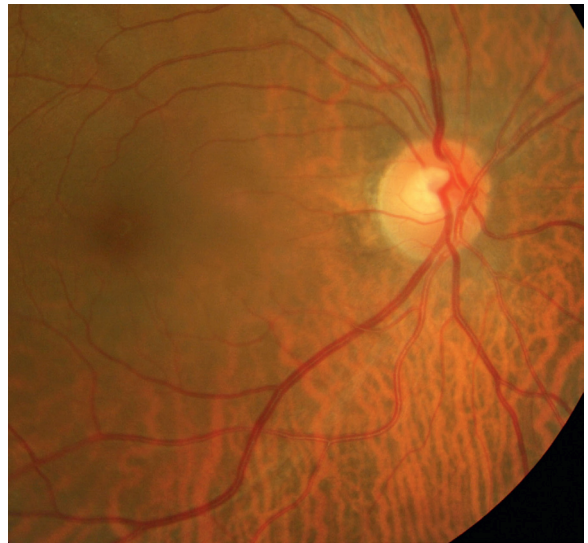


Fig. 8.41 A tessellated fundus from a moderately myopic patient.

8.6.5 Choroidal naevus

A commonly found localised area of choroidal pigmentation, also known as a benign choroidal melanoma. They can be described to patients as a freckle on the back of their eye. They have a prevalence up to 30%, although they can be easily missed with

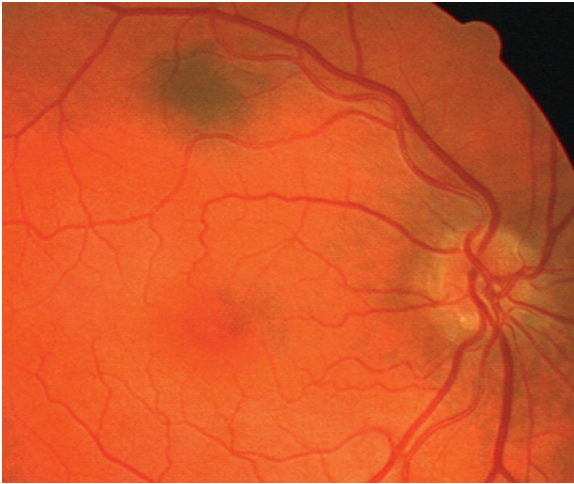


Fig. 8.42 A choroidal naevus, ~1 DD in size, about 3 DD from the disc between 10 and 11 o'clock. The disc is small and flat.

the direct ophthalmoscope given its limited field of view. They appear grey as your view of a choroidal naevus is filtered through the RPE and sensory retina (Figure 8.42 and online). Naevi can be flat or raised, with drusen often appearing on the surface with age. They vary in size, although the vast majority are less than two disc diameters. All naevi should be routinely monitored, preferably using photography, as they can rarely transform into a malignant melanoma.

8.6.6 RPE window defect

A fairly common, benign, yellow-white, well-circumscribed dot or circle (Figure 8.43) found throughout the retina, but particularly in the mid-peripheral fundus (2 disc diameters either side of the equator of the eye). It is caused by the absence of melanin in the RPE in a localised area. It is typically not associated with surrounding RPE hyperplasia (increase in the number of RPE cells) as would be seen with a chorioretinitis. It is easily differentiated from the red-brown retinal hole, which often has a surrounding cuff of retinal oedema or RPE hyperplasia. RPE window defects can enlarge with age, but this is of no concern.

8.6.7 Congenital hypertrophy of the retinal pigment epithelium (CHRPE)

Pronounced as 'chirpy', these are congenital, unilateral, flat, typically round or oval patches of pigment

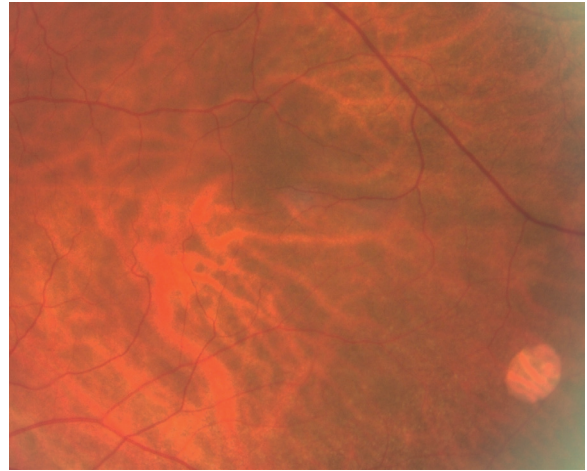


Fig. 8.43 An RPE window defect.

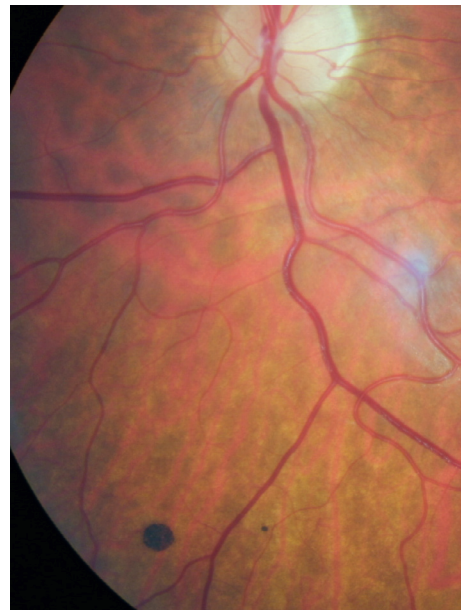


Fig. 8.44 CHRPE.

(‘birthmarks’) found in the peripheral retina (Figure 8.44). They are typically darker than naevi (although they can be grey, brown or black) with sharply defined edges and consist of a layer of hyperpigmented RPE cells over a thickened Bruch’s membrane. They are found in about 1.2% of the optometric population (although many would not be seen with the limited view provided by a direct ophthalmoscope) with about one-half having a depigmented halo just inside the border (this gives rise to the alternative name of halo

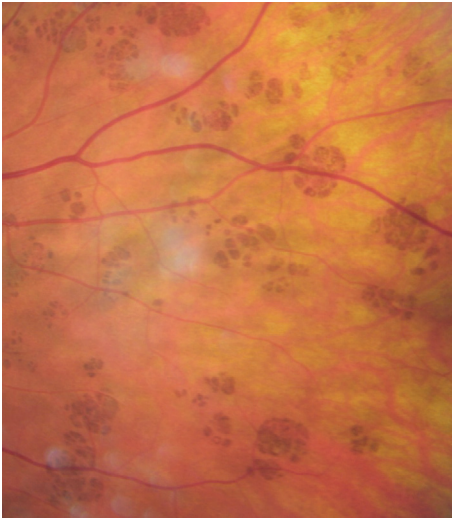


Fig. 8.45 Bear tracks in the peripheral retina.

naevi) and about one-half containing hypopigmented lacunae, which are areas of chorioretinal atrophy.³⁷ Increasing atrophy may lead to slight enlargement of the lesion. A group of small pigment patches in an isolated quadrant of the peripheral fundus are known as 'bear tracks' (Figure 8.45) given their characteristic clustering. Although commonly referred to as a type of CHRPE, bear tracks do not show haloes or lacunae and are histopathologically different to CHRPE.³⁸ Both are benign features and cause no problem other than the possible loss of the overlying retinal receptors with associated visual field loss. As with choroidal naevi, CHRPE need to be differentially diagnosed from malignant melanoma and require regular monitoring and documentation. With age, the central pigment of a CHRPE can be lost ('sunburst' effect). The lesion should preferably be photographed or otherwise drawn with an approximation of its size and position.

8.7 FUNDUS CHANGES IN OLDER PATIENTS

8.7.1 Macular pigmentary changes

Pigmentary changes occur at the macula with age, with increased disorganisation of the RPE and areas of depigmentation and pigment clumping (Figure 8.46, compare with maculae from young adults, Figures 8.27–8.30). These changes need not cause losses of visual function, but can progress to early age-related maculopathy.

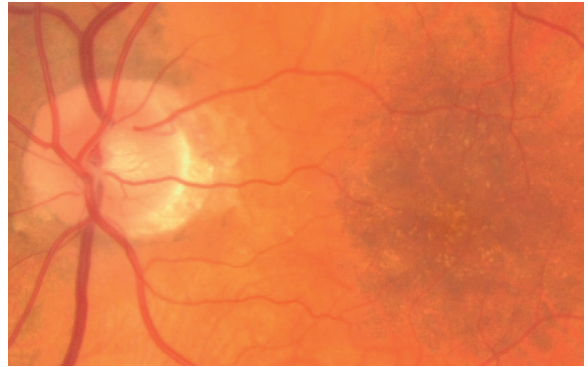


Fig. 8.46 Zone beta PPA with pigmentary changes and drusen in the macular area.

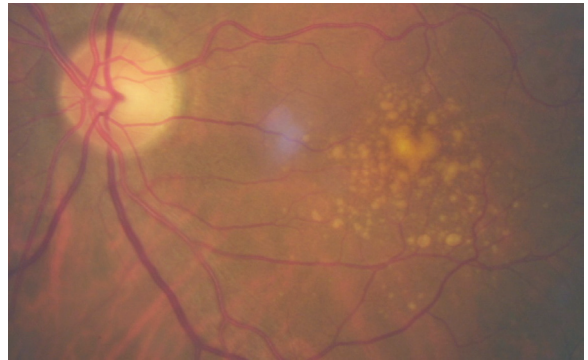


Fig. 8.47 Drusen in the macular area. The photograph includes some light scatter spot artefacts.

8.7.2 Drusen

Small, circular yellow or yellow-white dots, commonly seen around the macula (Figure 8.47), disc (Figure 8.38) and more peripherally. They consist of deposits lying between Bruch's membrane and the basement membrane of the retinal pigment epithelium. Large drusen should arouse a greater level of concern as they indicate a greater level of RPE compromise and are associated with the development of exudative age-related maculopathy.

8.7.3 Retinal blood vessels

Changes to the retinal blood vessels can occur with normal ageing or can indicate early signs of hypertensive retinopathy.³⁹ The more significant the changes at an early age, the more likely the changes are early hypertensive changes. Arteriolar narrowing and

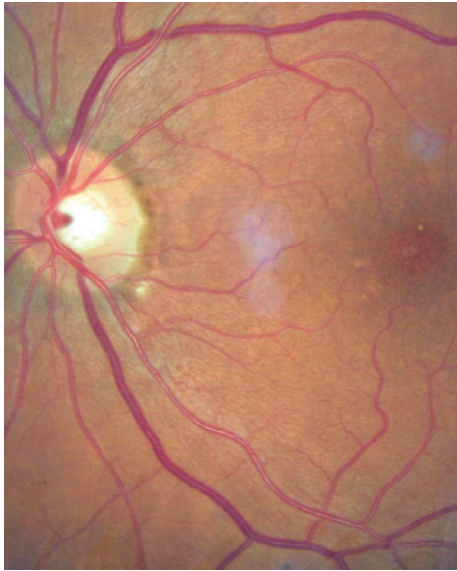


Fig. 8.48 Venous nipping of both temporal veins and drusen at the macula.

hardening of the arteries occurs with increasing age and can cause a slight broadening of the reflex on the arterioles. Arteriosclerotic changes can lead to changes to the veins at artery–vein crossings, with 90-degree crossings and nipping of the vein on the distal side of the artery (Figures 8.46 and 8.48), becoming increasingly common.

8.8 PERIPHERAL FUNDUS VARIATIONS

The posterior pole is bordered by the superior and inferior temporal vascular arcades and includes the macula and optic nerve head. The mid-periphery extends anteriorly from the vascular arcades to the equator, which is defined by the posterior border of the vortex vein ampullae. The periphery extends anteriorly from the equator to the ora serrata, which is 4 to 5 DD beyond the equator, at the termination of the choroid and retina.

8.8.1 Vortex vein ampullae

The ampullae are the dilated sacs of the vortex veins, which receive blood from the tributaries of the vortex system, and are red-orange octopus or spider shaped, often surrounded by pigment. The ampullae are found at the equator, with at least one per quadrant, typically in the four oblique meridians, and up to ten in each eye. They are most easily seen in a lightly pigmented eye (Figure 8.49).

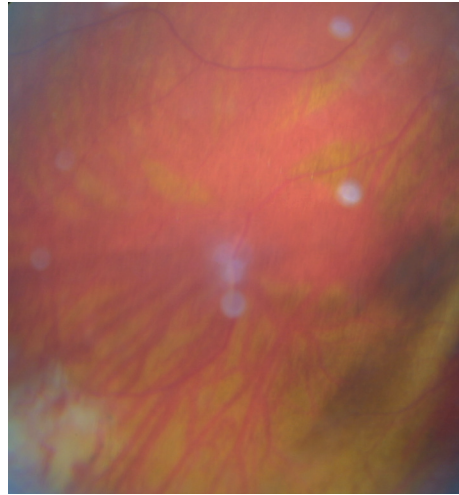


Fig. 8.49 Vortex vein ampullae in the retinal periphery. There are light scatter artefacts likely due to dust in the camera system.

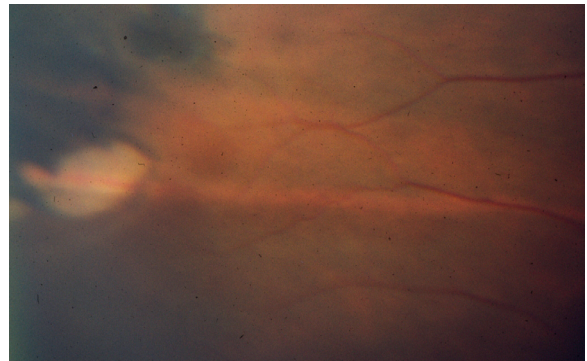


Fig. 8.50 A long posterior ciliary nerve runs across the photograph with pavingstone degeneration on the left.

8.8.2 Ciliary nerves and arteries

Two long posterior ciliary nerves bisect the superior and inferior fundus at the 3 and 9 o'clock positions in the fundus periphery and 10–20 short posterior ciliary nerves can be seen away from the horizontal meridian. They appear as faint, yellow-white short lines (Figure 8.50), often with pigmented borders. The long posterior ciliary arteries run below the corresponding ciliary nerve in the temporal retina and above it in the nasal retina. The short posterior ciliary arteries may have pigmented margins.

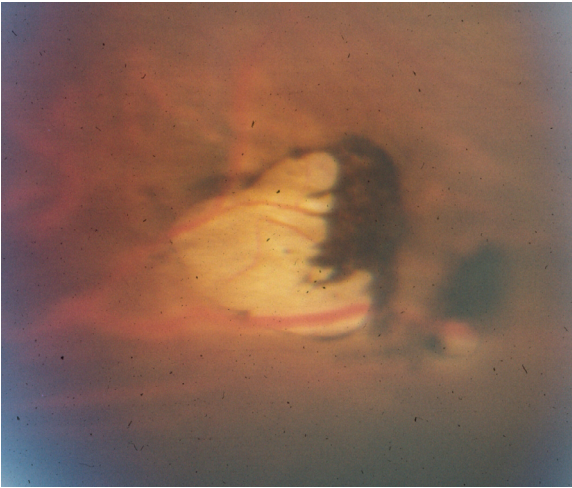


Fig. 8.51 Pavingstone degeneration.

8.8.3 Peripheral cystoid degeneration

The most prevalent of the benign peripheral retinal conditions whose extent increases with age. The cystoid area appears as a hazy grey zone of thickened retina near to the ora serrata and can extend to the equator. Red dots may appear with the cystoid degeneration and strands in the vitreous may appear above it.

8.9 PERIPHERAL FUNDUS CHANGES IN OLDER PATIENTS

8.9.1 Pavingstone degeneration

This primary chorioretinal atrophy, with depigmented areas surrounded by RPE hyperplasia, is found in about 25% of patients over 20 (Figure 8.50), but increases with age. If the lesions coalesce, the underlying choroidal vessels may be seen (Figure 8.51). It is often bilateral with about 75% of lesions being found in the inferior nasal quadrant. It is thought to be caused by occlusion of some of the peripheral choriocapillaris vessels.

8.9.2 Peripheral pigmentary or tapetochoroidal degeneration

A granular pigment appearance between the equator and ora serrata that occurs in about 20% of patients after the age of 40 and becoming more prominent with age. It often has a honeycomb appearance and is associated with peripheral drusen. If the pigment takes on a reticular or bone spicule appearance, differentiation

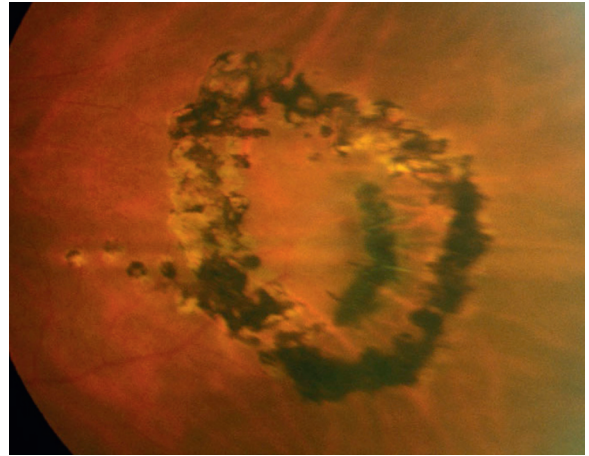


Fig. 8.52 An area of lattice degeneration ringed by thermal burns from prophylactic laser.

from retinitis pigmentosa is required. It is a degenerative condition of the RPE, possibly associated with vascular compromise.

8.10 MYOPIC EYES

The majority of myopia is due to an increased axial length, so myopic eyes are big eyes. Pathological myopia is well-recognised, but non-pathological myopic eyes also show typical changes.⁴⁰ The anterior angle is typically deeper in myopes and the vitreous is more liquefied and degenerative the higher the myopia. Therefore, there is a higher prevalence of vitreous floaters and a greater likelihood of posterior vitreous detachment at an earlier age. If the RPE is pulled away from the disc in long myopic eyes, a crescent-shaped section of the choroid (choroidal blood vessels and pigment) can be seen (Figures 8.31–8.33). If both the RPE and choroid are pulled away from the disc, a white scleral crescent can be seen. These crescents are typically seen along the temporal edge.³⁶ The optic disc is typically larger in high myopia (greater than -8 D) often with a larger cup-to-disc ratio.²⁵ The retina of the large myopic eye is relatively thin. This leads to a greater prevalence of tessellated/tigroid fundi (Figures 8.40, 8.41), visible choroidal vessels (Figures 8.34, 8.35) and lattice degeneration (Figure 8.52).³⁶

REFERENCES

1. Gloor P, Alexandrakis G. Clinical characterization of primary acquired melanosis. *Invest Ophthalmol Vis Sci* 1995;36:1721–9.

2. Dua HS, Azuara-Blanco A. Limbal stem cells of the corneal epithelium. *Surv Ophthalmol* 2000;44: 415–25.
3. Nischler C, Michael R, Wintersteller C, et al. Iris color and visual functions. *Graefes Arch Clin Exp Ophthalmol* 2013;251:195–202.
4. Cahill KV, Bradley EA, Meyer DR, et al. Functional indications for upper eyelid ptosis and blepharoplasty surgery: a report by the American Academy of Ophthalmology. *Ophthalmology* 2011;118: 2510–7.
5. Damasceno RW, Osaki MH, Dantas PE, Belfort R Jr. Involutional entropion and ectropion of the lower eyelid: prevalence and associated risk factors in the elderly population. *Ophthalm Plast Reconstr Surg* 2011;27:317–20.
6. Chi MJ, Baek SH. Clinical analysis of benign eyelid and conjunctival tumors. *Ophthalmologica* 2006; 220:43–51.
7. Deprez M, Uffer S. Clinicopathological features of eyelid skin tumors. A retrospective study of 5504 cases and review of literature. *Am J Dermatopathol* 2009;31:256–62.
8. Kersten RC, Ewing-Chow D, Kulwin DR, Gallon M. Accuracy of clinical diagnosis of cutaneous eyelid lesions. *Ophthalmology* 1997;104:479–84.
9. Rohrich RJ, Janis JE, Pownell PH. Xanthelasma palpebrarum: a review and current management principles. *Plast Reconstr Surg* 2002;110:1310–4.
10. Vurgese S, Panda-Jonas S, Saini N, et al. Corneal arcus and its associations with ocular and general parameters: the Central India Eye and Medical Study. *Invest Ophthalmol Vis Sci* 2011;52: 9636–4963.
11. Haicl P, Jankova H. Prevalence of conjunctival concretions. *Cesk Slov Oftalmol* 2006;61:260–4.
12. Every SG, Leader JP, Molteno AC, et al. Ultraviolet photography of the in vivo human cornea unmasks the Hudson-Stahli line and physiologic vortex patterns. *Invest Ophthalmol Vis Sci* 2005;46: 3616–22.
13. Rah MJ, Barr JT, Bailey MD. Corneal pigmentation in overnight orthokeratology: a case series. *Optometry* 2002;73:425–34.
14. Vonthongsri A, Chuck RS, Pepose JS. Corneal iron deposits after laser in situ keratomileusis. *Am J Ophthalmol* 1999;127:85–6.
15. Ansons AM, Atkinson PL. Corneal mosaic patterns – morphology and epidemiology. *Eye* 1989;3: 811–5.
16. Zoega GM, Fujisawa A, Sasaki H, et al. Prevalence and risk factors for cornea guttata in the Reykjavik Eye Study. *Ophthalmology* 2006;113:565–9.
17. Moshirfar M, Feiz V, Feilmeier MR, Kang PC. Laser in situ keratomileusis in patients with corneal guttata and family history of Fuchs' endothelial dystrophy. *J Cataract Refract Surg* 2005;31: 2281–6.
18. Rashima A, Ramesh SVE, Lokapavani V, et al. Prevalence and associated factors for pterygium and pinguecula in a South Indian population. *Ophthalmic Physiol Opt* 2012;32:39–44.
19. Koretz JF, Cook CA, Kuszak JR. The zones of discontinuity in the human lens: development and distribution with age. *Vision Res* 1994;34:2955–62.
20. Kuszak JR, Peterson KL, Sivak JG, Herbert KL. The interrelationship of lens anatomy and optical quality. II. Primate lenses. *Exp Eye Res* 1994;59: 521–35.
21. Vasavada AR, Mamidipudi PR, Sharma PS. Morphology of and visual performance with posterior subcapsular cataract. *J Cataract Refract Surg* 2004;30:2097–104.
22. Graziosi P, Rosmini F, Bonacini M, et al. Location and severity of cortical opacities in different regions of the lens in age-related cataract. *Invest Ophthalmol Vis Sci* 1996;37:1698–703.
23. Hikichi T, Trempe CL. Relationship between floaters, light-flashes, or both, and complications of posterior vitreous detachment. *Am J Ophthalmol* 1994;117:593–8.
24. Jonas JB, Budde WM, Panda-Jonas S. Ophthalmoscopic evaluation of the optic nerve head. *Surv Ophthalmol* 1999;43:293–320.
25. Jonas JB. Optic disk size correlated with refractive error. *Am J Ophthalmol* 2005;139:346–8.
26. Jonas JB, Kling F, Grundler AE. Optic disc shape, corneal astigmatism, and amblyopia. *Ophthalmology* 1997;104:1934–7.
27. Garway-Heath DF, Ruben ST, Viswanathan A, Hitchings RA. Vertical cup/disc ratio in relation to optic disc size: its value in the assessment of the glaucoma suspect. *Br J Ophthalmol* 1998;82: 1118–24.
28. Jacks AS, Miller NR. Spontaneous retinal venous pulsation: aetiology and significance. *J Neurol Neurosurg Psychiatry* 2003;74:7–9.
29. Morgan WH, Lind CR, Kain S, et al. Retinal vein pulsation is in phase with intracranial pressure and not intraocular pressure. *Invest Ophthalmol Vis Sci* 2012;53:4676–81.
30. Healey PR, Mitchell P. Visibility of lamina cribrosa pores and open-angle glaucoma. *Am J Ophthalmol* 2004;138:871–2.
31. Blumenthal EZ, Weinreb RN. Assessment of the retinal nerve fiber layer in clinical trials of

- glaucoma neuroprotection. *Surv Ophthalmol* 2001;45: S305–312.
32. Sowka J, Aoun P. Tilted disc syndrome. *Optom Vision Sci* 1999;76:618–23.
33. Jonas JB, Budde WM. Diagnosis and Pathogenesis of Glaucomatous Optic Neuropathy: Morphological Aspects. *Prog Ret Eye Res* 2000;19:1–40.
34. Williams AJ, Fekrat S. Disappearance of myelinated retinal nerve fibers after pars plana vitrectomy. *Am J Ophthalmol* 2006;142:521–3.
35. Aumiller MS. Optic disc drusen: complications and management. *Optometry* 2007;78:10–6.
36. Tekiele BC, Semes L. The relationship among axial length, corneal curvature, and ocular fundus changes at the posterior pole and in the peripheral retina. *Optometry* 2002;73:231–6.
37. Coleman P, Barnard NAS. Congenital hypertrophy of the retinal pigment epithelium: prevalence and ocular features in the optometric population. *Ophthalmic Physiol Opt* 2007;27:547–55.
38. Regillo CD, Eagle RC, Shields JA, et al. Histopathologic findings in congenital grouped pigmentation of the retina. *Ophthalmology* 1993;100:400–5.
39. Hurcomb P, Wolffsohn J, Napper G. Ocular signs of systemic hypertension: A review. *Ophthalmic Physiol Opt* 2001;21:430–40.
40. Saw SM, Gazzard G, Shih-Yen EC, Chua WH. Myopia and associated pathological complications. *Ophthalmic Physiol Opt* 2005;25:381–91.

PHYSICAL EXAMINATION PROCEDURES

PATRICIA HRYNCHAK

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9.1 DIFFERENTIAL DIAGNOSIS INFORMATION FROM OTHER ASSESSMENTS

The case history and ocular health assessments in particular can provide significant information about a patient's general health and can help you decide whether physical examination procedures will aid in the differential diagnosis process.

9.1.1 Observations and symptoms

- (a) Simple observation of the patient's physical features can be useful. For example, obesity is a risk factor for hypertension and carotid artery disease.
- (b) A palpable preauricular node can be helpful information in determining the cause of a red eye. In addition, differential diagnosis of the cause of the red eye can begin in the case history with questions regarding the duration, recurrence and laterality of the red eye, any discomfort and type of discharge.
- (c) While mild to moderate hypertension does not cause headache, the presence of pulsating, suboccipital headaches that subside during the day, particularly in an older patient, may suggest acute hypertension and thus the need for sphygmomanometry.¹
- (d) Episodes of transient loss of vision (amaurosis fugax) may be present in carotid artery stenosis which requires further investigation. Amaurosis fugax is a sudden onset, painless loss of vision in one eye that is described as a curtain coming down over the vision. The vision loss generally lasts longer than one minute.²

9.1.2 General medical history and family history

The medical history in a patient with a red eye may be important in the differential diagnosis. For example, a history of a recent upper respiratory tract infection and contact with another person with a red eye could be suggestive of viral origin to the red eye, the history of a urogenital infection could be suggestive of *Chlamydia*, a history of cold sores is suggestive of herpes simplex virus conjunctivitis and a history of allergy with intensive itching is suggestive of allergic conjunctivitis.³

A history of hypertension, cardiovascular disease, cerebrovascular disease, obesity, physical inactivity, heavy alcohol intake, smoking, diabetes mellitus and hyperlipidaemia are important when considering if blood pressure measurement is indicated. When there is a positive family history the risk of developing hypertension is increased two to four times.⁴ The patient's medical history should also include the current medical care for systemic conditions, frequency of monitoring for the conditions, previous and planned investigations for the conditions, medications prescribed and compliance with medication use. For example, if a patient has been diagnosed as hypertensive, is taking medication regularly and having their blood pressure regularly monitored, then there would be little need for optometric testing. If, however, the patient was previously diagnosed with hypertension, stopped taking their medication 6 months ago due to an adverse reaction and has not seen their physician to follow up, it would be prudent to take a blood pressure reading and advise the patient accordingly even in the absence of abnormalities on the ocular fundus examination.

When considering if carotid artery assessment is indicated, a history of hypertension, hyperlipidaemia, diabetes mellitus, coronary artery disease and smoking can be significant. If a patient has had one or more episodes of amaurosis fugax, it is important to determine if he has already sought medical care and if and what investigations have already been done or are being planned. It is not uncommon to determine that the patient has already seen his physician and that a carotid ultrasound or other investigations are being

Table 9.1 Simplified classification of hypertensive retinopathy as proposed by Wong and Mitchell⁷

Grade of retinopathy	Retinal signs	Systemic associations
None	No detectable signs	None
Mild	Generalised arteriolar narrowing, focal arteriolar narrowing, arteriovenous nicking, opacity ('copper wiring') of arteriolar wall, or a combination of these signs	Modest association with risk of clinical stroke, subclinical stroke, coronary heart disease, and death
Moderate	Haemorrhage (blot, dot, or flame-shaped), microaneurysm, cotton-wool spot, hard exudate, or a combination of these signs	Strong association with risk of clinical stroke, subclinical stroke, cognitive decline, and death from cardiovascular causes
Malignant	Signs of moderate retinopathy plus swelling of the optic disc	Strong association with death

arranged. The patient is then presenting to determine if any additional information can be gained through a dilated fundus examination.

9.1.3 Slit-lamp biomicroscopy assessment

Various aspects of slit-lamp assessment can also help in differential diagnosis of a red eye, including the pattern of conjunctival injection (e.g., circumlimbal injection suggests anterior uveitis, segmental injection suggests episcleritis), flare and cells in the anterior chamber (present in anterior uveitis), the presence and quality of any discharge (e.g., watery suggests allergic conjunctivitis, mucopurulent suggests bacterial conjunctivitis). Other features to investigate are conjunctival chemosis (e.g., allergic conjunctivitis), palpebral conjunctival papillae or follicles (papillae suggest bacterial or allergic and follicles suggest viral conjunctivitis), lid swelling (e.g., allergic conjunctivitis and epidemic keratoconjunctivitis) and corneal abnormalities (e.g., corneal ulcers). The intraocular pressure is helpful in suspected cases of angle closure glaucoma and anterior uveitis when it would be elevated or decreased, respectively.

9.1.4 Fundus examination

Ocular fundus features suggesting hypertension and the possible need for sphygmomanometry are discussed in [section 9.3](#) and [Table 9.1](#). Ocular risk factors for significant carotid artery stenosis include emboli (Hollenhorst plaques), retinal vascular occlusions, peripheral retinal haemorrhages with dilated and

tortuous veins (hypoperfusion retinopathy), microaneurysms, iris transillumination defects, ocular ischaemic syndrome, anterior ischaemic optic neuropathy, normal tension glaucoma and asymmetric diabetic retinopathy which is less advanced ipsilateral to the stenosis.^{5,6}

9.2 LYMPHADENOPATHY IN THE HEAD-NECK REGION

The presence of lymphadenopathy in the head and neck region can provide information about the differential diagnosis of a red eye and this technique should be performed on every red eye work-up.

9.2.1 The lymph nodes in the head and neck

The lymph nodes are situated along the course of the lymphatic vessels. They are bean-shaped organs containing large numbers of leukocytes and phagocytes which filter out infectious and toxic material and destroy it. When infection occurs the nodes become enlarged and often painful and inflamed because of the production of anti-inflammatory lymphocytes and plasma cells.⁷

The lymphatic system of the head and neck is important in infections of the eye ([Figure 9.1](#)), particularly the preauricular lymph nodes which receive lymph from the upper eyelid, the outer half of the lower eyelid and the lateral canthus. They are located 1 cm anterior and slightly inferior to the tragus of the external ear at the temporomandibular joint. The submandibular lymph nodes lie in close proximity to the

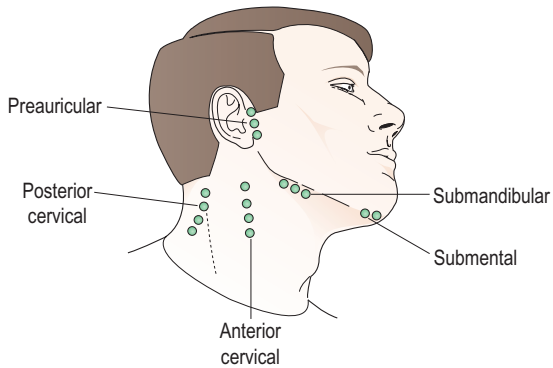


Fig. 9.1 The lymphatic system of the head and neck.

submandibular gland and drain lymph from the medial portion of the upper and lower eyelids, the medial canthus and the conjunctiva. They also drain lymph from the submental nodes that are located under the tip of the chin. The mental nodes also drain anterior aspects of teeth, tongue and lower lip so if an oral infection is present then they may be enlarged and this should not be mistaken for a sign of an ocular infection. The superior cervical nodes are located inferior to the ear and superficial to the sternocleidomastoid muscle. They receive lymph from the occipital nodes as well as the preauricular and post auricular nodes.⁷ The skin and orbicularis oculi muscles drain into the deep cervical nodes near the internal jugular vein (Figure 9.1).

9.2.2 Comparison of tests

Assessment of the lymphatic system by palpating the nodes is a quick and easy way of gaining information to aid in the differential diagnosis of a red eye. There are no alternative tests and there are no complications or contraindications to performing this technique other than being gentle with patients who have node tenderness.

9.2.3 Procedure for palpating the preauricular lymph nodes



See online video 9.1.

1. Wash your hands thoroughly.
2. Stand in front of the seated patient.
3. Place the index and middle fingers of each hand in front of the tragus of the patient's external ears.
4. Slowly move your fingers in a circular motion to slide the patient's skin over the underlying bony structures of the temporo-mandibular joint

and search for swollen lymph nodes. These will feel like a small pebble or bean under the patient's skin. A slight depression of the joint is the normal finding.

5. Compare the right and left sides to help determine whether a swollen node is present.
6. If lymphadenopathy is found, its laterality (right, left or bilateral), size (big or small), mobility, warmth and tenderness should be determined.

9.2.4 Procedure for palpating the cervical, submandibular and submental lymph nodes

See online video 9.2.



1. All these lymph nodes are in the neck area (Figure 9.1) and should be palpated using the tips of your index, middle and ring fingers of both hands (the submental can be palpated using just one hand). Slowly move your fingers in a circular motion to slide the patient's skin over the underlying bony structures and/or muscle and search for swollen lymph nodes, which will feel like a small pebble or bean under the patient's skin.
2. In each case, if lymphadenopathy is found, its laterality (right, left or bilateral if appropriate), size (big or small), mobility, warmth and tenderness should be determined.
3. To assess the cervical nodes, palpate at the angle of the jaw and slowly move your fingers down, continuing to palpate to the base of the neck.
4. To assess the submandibular nodes, palpate just under the edge of the jawbone.
5. To assess the submental lymph nodes, palpate under the tip of the chin.

9.2.5 Recording

Record if the nodes are palpable (positive, +ve) or not (negative, -ve). The preauricular node is commonly abbreviated as PAN. If swollen nodes (lymphadenopathy) are found, describe their laterality (right, left or bilateral), size (big or small) and mobility (mobile or non-mobile) and indicate whether warmth and tenderness are present.

Examples:

-ve PAN and neck lymph nodes.

+ve bilateral PAN small, mobile, non-tender, without overlying warmth.

+ve right PAN, large, tender and warm.

9.2.6 Interpretation

In the absence of disease there should be no palpable lymph nodes. Palpable lymph nodes (lymphadenopathy) are seen in the following conditions:

1. Viral conjunctivitis: visible preauricular lymphadenopathy often greater on the side of the more involved eye and accompanied by ear, nose and throat symptoms.
2. Severe bacterial lid conditions such as preseptal cellulitis or infection in the medial canthal region: preauricular or submental lymphadenopathy.
3. Parinaud's oculoglandular conjunctivitis: often visible preauricular lymphadenopathy.
4. Chlamydial conjunctivitis or trachoma: preauricular lymphadenopathy.
5. Following the resolution of an ocular infection (several weeks).

The presence of preauricular lymphadenopathy will therefore help rule in one of the above conditions when it is present although if it is not present the condition cannot be reliably ruled out.^{8,9} An awareness of the areas that the nodes drain is also important to rule out other causes of enlargement of the nodes. For example, if the submental and the submandibular nodes are swollen the infection could be in the area drained by the submental nodes such as infections of the teeth, tongue and lower lip. This should be ruled out in the case history.

9.2.7 Most common error

Pushing too hard with patients who have lymphadenopathy as they may experience tenderness.

9.3 BLOOD PRESSURE MEASUREMENT

Hypertension is the most common cause of mortality in the developed world as a major contributing factor in stroke, heart attack, coronary artery disease and peripheral arterial disease.¹⁰ Hypertension affects about 25% of adults and over 50% of people aged 65+ in Canada and the UK and over 60 million Americans, with varying prevalence throughout the world.^{11–14} Systemic hypertension can be classified as primary (which has no known cause, 90–95%) or secondary (where the causative factor could be renal or endocrine disease or coarctation of the aorta, 5–10%).¹⁰ Early hypertension is often asymptomatic but in acute cases, the patient may complain of suboccipital pulsating headaches that occur early in the morning and subside

during the day or any other type of headache.¹ Somnolence, confusion, visual disturbances, and nausea and vomiting are only present in hypertensive emergencies (BP >180/120).¹⁵

Systemic hypertension is associated with hypertensive retinopathy and also choroidopathy, optic neuropathy, arterial and venous occlusive disease, embolic events and arteriolar macroaneurysm formation.¹⁶ Wong and Mitchell proposed a simplified classification of hypertensive retinopathy that combined the Keith–Wegener–Barker classification of stage I and II into a 'mild' category (Table 9.1).¹⁷

If blood pressure is measured in patients who show moderate to malignant fundus signs of hypertensive retinopathy the blood pressure reading will allow the practitioner to determine if it is an emergency needing to be sent to the emergency department of a hospital or an urgency that would be best seen by the patients' primary care physician (section 9.3.4).¹³ A history of uncontrolled hypertension (e.g., the person stopped taking their medication without follow-up) or a family history is also an indication for measuring blood pressure.

However, approximately 40% of people with hypertension are not on treatment and two thirds of patients on treatment are not being controlled to less than 140/90.¹⁵ Also, not all patients with hypertension develop retinopathy.¹⁸ Even after 10 years, 70% of patients show either no retinopathy or only slight constriction and arteriolosclerosis.¹⁰ In addition, the inter-rater reliability of detection and classification of hypertensive retinopathy with ophthalmoscopy has been shown to be poor.^{18,19} Barnard showed that referral made on fundus signs alone resulted in a 78% false positive rate after blood pressure was measured and considered in patients between 45 and 64 years.²⁰ A survey by Wolffsohn et al. found that the majority of primary care physicians would appreciate receiving a report of their patients' blood pressure if it was found to be over 140/90.¹⁸ Therefore, consideration can be given to screening for hypertension as part of a routine eye examination of older patients. What still needs to be researched is the impact of optometric referrals on the ultimate blood pressure management of the patient.

9.3.1 Comparison of sphygmomanometers

Most devices for measuring blood pressure occlude a blood vessel in an extremity (usually the arm, wrist or finger) with an inflatable cuff then measure the blood pressure either by detection of Korotkoff sounds or oscillometrically.²¹ In the auscultatory method a

stethoscope is used on the brachial pulse to detect Korotkoff Phase I sound (the systolic blood pressure) and the cessation of the Korotkoff Phase V sounds (the diastolic pressure) on the deflation of the cuff. In this method the sphygmomanometer used to measure the pressure can be mercury, aneroid or electronic with a digital display. Mercury sphygmomanometers have a limited future due to concerns about toxicity of mercury for users, personnel and the environment.²² Aneroid devices are inexpensive and portable but the bellow-and-lever system used to measure pressure is subject to jolts and bumps which can lead to false readings.²² Aneroid devices require regular calibration and should be checked against a mercury sphygmomanometer every 6 months. Hybrid devices use an electronic pressure gauge and display.

An alternative to the auscultatory method are automated (oscillometric) sphygmomanometers, which are very simple and easy to use. They detect the variation in pressure oscillations caused by arterial wall movement under the cuff to measure systolic, diastolic and mean arterial blood pressure.²³ Automated devices were designed for self-measurement and are increasingly used in clinical practice.²⁴

Two recent systematic reviews have shown that automated devices have individual variability but are generally less accurate than auscultatory devices even when passing specified protocols.^{23,25} These devices should not be used in patients who have arrhythmia, hypertension or have had trauma. Since the devices may have poor reliability, multiple readings should be used and averaged when making clinical decisions.²⁵ Thresholds for standard sphygmomanometry should not be applied to automated readings. The definition of hypertension when using these devices is the same as for ambulatory methods at normal being <135/85.^{24,26}

9.3.2 Procedure for sphygmomanometry by the auscultatory method

 See online video 9.3.

1. Have the patient remain seated quietly with feet on the floor for at least 5 minutes before blood pressure readings are measured. Caffeine, smoking and exercise should have been avoided for 30 minutes prior to the blood pressure reading.¹⁵
2. Describe the procedure to the patient: 'I am now going to measure your blood pressure. This involves wrapping a cuff around your arm and inflating it. You will feel the pressure on your arm increase, but you shouldn't experience any pain.'
3. Ask the patient to remove any clothing covering the arm and ensure that any rolled up sleeve does not excessively constrict the arm.
4. Ask the patient to slightly bend their arm with the palm turned upwards and rest it on the chair armrest or nearby table. The arm should be at heart level.
5. Select a blood pressure cuff that encircles at least 80% of the arm to ensure accuracy.¹⁵ Typically two cuff sizes are required: large and regular adult.
6. Locate the brachial artery along the inner upper arm by palpation. Wrap the cuff smoothly and snugly around the arm, centering the bladder over the brachial artery (the artery arrow on the cuff should be pointing at the artery). The lower margin should be 2.5 cm above the antecubital crease (bend of the elbow).
7. Check that the cuff fits snugly, but is not too tight or too loose. If it is difficult to insert a finger under the cuff edge it is too tight, if you can insert more than one finger it is too loose.
8. Before measuring the blood pressure, you should palpate the systolic pressure to avoid an artificially low reading caused by auscultatory gap (see [section 9.3.5](#)). Palpate the radial pulse at the wrist and inflate the cuff by pumping the bulb until the pulse disappears then continue to inflate the cuff until the reading is approximately 30 mmHg over the point where the pulse first disappears. Deflate the cuff smoothly at a rate of 2–3 mmHg per second until the pulse is felt again and note this reading. Then deflate the cuff rapidly and completely.
9. Insert the earpieces of the stethoscope into your ears so that they angle forward and are comfortable. Position the stethoscope head over the brachial artery between the lower cuff edge and the antecubital crease. Turn the chestpiece of the stethoscope so that the diaphragm side is transmitting and place it over the artery with light pressure, ensuring skin contact at all points. Heavy pressure may distort sounds.
10. Rapidly and steadily inflate the cuff to 20–30 mmHg above the palpated systolic pressure value determined in Step 8. Release the air in the cuff by turning the manometer release valve to slowly and smoothly release air from the bladder at a rate of 2 to 3 mmHg per second.
11. Listen for the Korotkoff sounds (online audio 9.4). Note the systolic pressure at the onset of



the first audible Korotkoff Phase I sound (soft tapping sounds). Determine the diastolic pressure at the cessation of the Korotkoff sounds (Phase V). Listen for 10 to 20 mmHg below the last sound heard to confirm disappearance, and then deflate the cuff rapidly and completely. Between Phases I and V are Phase II, which is a swishing, murmur, Phase III which is crisper sounds with increasing intensity and IV which is an abrupt muffling of sounds.

12. If a repeat reading is required wait 1–2 minutes to permit the release of blood trapped in the forearm venous system.

9.3.3 Recording

Record the patient's position, the time and the arm used for the measurement. Record the cuff size if it was not the regular adult cuff that was used. By convention record the systolic and diastolic reading to the nearest even number in mmHg.

Examples:

120/80 right arm seated at 2:30 pm.

132/84, left arm, seated @ 9.30 am, large adult cuff.

114/72, left arm, standing @ 4.00 pm.

100/70, right arm, seated @ 2.30 pm.

9.3.4 Interpretation

The classification of hypertension is based on two properly measured seated blood pressure readings on each of two or more separate office visits and is shown in Figure 9.2, although research suggests that ambulatory measurements better predict who should be placed on treatment.^{15,26} Individuals that are suspected

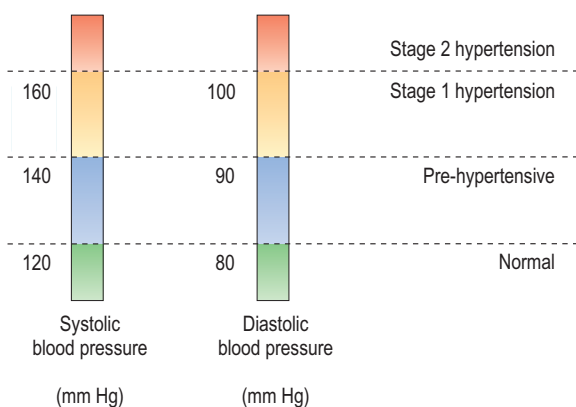


Fig. 9.2 Classification of hypertension in adults.¹⁵

to be in the pre-hypertensive classification should be referred to a general physician for health-promoting lifestyle modifications. These modifications include weight control, increase in physical activity, and reductions in salt intake and alcohol consumption and smoking cessation. Stage 1 and 2 hypertension should be referred to a general physician to be treated with pharmacological interventions with most patients needing two or more anti-hypertensive medications to achieve a blood pressure of less than 140/90.¹⁵

A hypertensive emergency occurs when the systolic blood pressure is greater than 210 mmHg and the diastolic greater than 130 mmHg. There is evidence of progressive or impending target-organ damage and the blood pressure must be lowered immediately but carefully to prevent end-organ damage from lowering the blood pressure too quickly. This treatment normally requires hospitalisation. A hypertensive urgency is an increase in diastolic blood pressure to greater than 120–130 mmHg without end-organ damage which can be treated in office or in the emergency room with oral medications over several hours to lower the blood pressure. This usually occurs in patients who discontinue their treatment after achieving normal blood pressure.^{15,27}

9.3.5 Most common errors

1. Using the wrong cuff size: If you use too small a cuff for the size of the patient's arm, it leads to excessive loss of pressure from the cuff through the thick and compressible soft arm tissue and a falsely high blood pressure reading can be gained. You need to select a blood pressure cuff that encircles at least 80% of the arm to ensure accuracy.¹⁵ Typically two cuff sizes are required in optometric practice: large adult and regular adult. Child size cuffs are also available, but unlikely to be used in optometric practice.
2. Ignoring the auscultatory gap: In some patients, particularly those with hypertension and when the cuff pressure is high, the sounds heard over the brachial artery disappear as the pressure is reduced and then reappear at some lower level. This early, temporary disappearance of sound is called the auscultatory gap and occurs during the latter part of Phase I and Phase II. Because this gap may extend over a range as great as 40 mmHg, you could seriously underestimate the systolic pressure or overestimate the diastolic pressure, if you fail to gain an initial estimate of the systolic pressure after palpating the radial pulse at the wrist.

3. Using an incorrect arm position: The pressure in the arm increases as the arm is lowered from the level of the heart (phlebostatic axis); conversely, raising the arm above this position lowers the pressure measurement. The effect is largely explained by hydrostatic pressure or by the effect of gravity on the column of blood. Therefore, when measuring indirect blood pressure, the patient's arm should be positioned so that the location of the stethoscope head is at the level of the heart. This location of the heart is arbitrarily taken to be at the junction of the fourth intercostal space and the lower left sternal border. When the patient is seated, placing the arm on a nearby tabletop a little above waist level will result in a satisfactory position. If a table is not available the arm can be supported at heart level by the examiner.

9.4 CAROTID ARTERY ASSESSMENT

Carotid artery (Figure 9.3) occlusive disease may result in stroke, neurological disability or loss of life.⁵ Ocular risk factors for haemodynamically significant carotid artery stenosis include transient loss of vision (amaurosis fugax), retinal emboli (Hollenhorst plaques), retinal vascular occlusions, peripheral retinal haemorrhages with dilated and tortuous veins (hypoperfusion retinopathy), microrubeosis iridis, ocular ischaemic syndrome, anterior ischaemic optic neuropathy, normal tension glaucoma and asymmetric diabetic retinopathy.^{5,6} Symptomatic patients are more likely than non-symptomatic patients to have carotid artery stenosis and the most common symptom is amaurosis fugax. Amaurosis fugax is a sudden onset, painless

loss of vision in one eye that is described as a curtain coming down over the vision. The vision loss generally lasts longer than one minute.² In addition, systemic risk factors are additive to the risk of carotid artery disease. These include hypertension, hyperlipidaemia, diabetes mellitus, coronary artery disease (including coronary artery bypass graft, peripheral vascular disease, a history of transient ischaemic attacks or cerebrovascular accidents,) carotid bruit and smoking.⁵

Since ocular risk factors alone can be poor or unreliable predictors of carotid artery occlusive disease (studies show a range of 0 to 100%), the additional information gained by the detection of a carotid bruit can be helpful in referring the patient with ocular signs to have carotid artery studies performed.^{2,6}

9.4.1 Comparison of tests

Auscultation for a systolic bruit is an easy rapid technique to gain information that aids the diagnosis of significant carotid stenosis (abnormal narrowing). A bruit is the sound of turbulence in blood flow when the normal laminar flow is disrupted by the stenosis. If a bruit is audible 77% of patients have been shown to have significant stenosis on angiography.⁶ However, only about 57% of patients with significant stenosis (over 50%) will have an audible bruit.⁶ Combining a history of amaurosis fugax and ocular signs such as venous stasis retinopathy or other signs of ocular ischaemia with the presence of a bruit increases diagnostic accuracy significantly. More sensitive testing for carotid stenosis includes duplex ultrasound scanning of the carotid arteries and carotid angiography, which are arranged through a referral to a family physician or internist.

Another technique infrequently used to determine carotid insufficiency is ophthalmodynamometry. In ophthalmodynamometry the relative ophthalmic artery pressure is measured by applying pressure to the sclera while watching for the pulsation (diastolic pressure) and collapse (systolic pressure) of the arterial tree at the optic nerve head. The technique requires only the ophthalmodynamometer, which is small and portable, and a direct ophthalmoscope or a binocular indirect ophthalmoscope. There is concern with this technique that the ophthalmic artery may become permanently occluded when measuring the systolic pressure. The technique is also prone to error with patient cooperation being crucial and may require an assistant to read the values. In addition, a clear ocular media is required for adequate visualisation of the retinal vasculature. The results are dependent on the intra-ocular

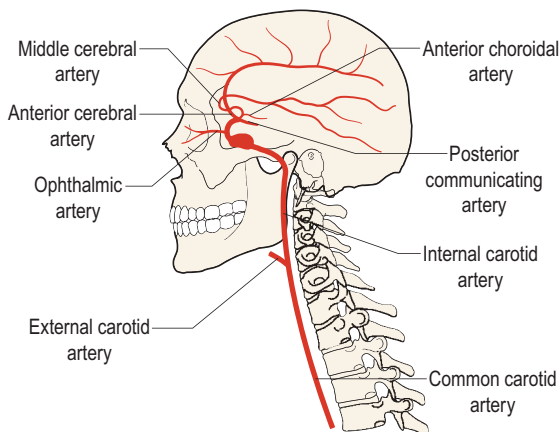


Fig. 9.3 The carotid artery.

pressure and are compared to the patient's brachial blood pressure to determine if the values are within normal limits (the diastolic should be within 45 to 60% of the diastolic blood pressure and the systolic should be within 57 to 70% of the brachial artery blood pressure).

Palpating the carotid arterial pulse is a straightforward technique requiring no equipment, that gives the examiner an indication of the strength of the blood flow through the arteries. However, if the examiner palpates the vessels too high on the neck the carotid sinus may be compressed. This may result in an increase in vagal tone, reflex bradycardia, a reduction in blood pressure and even syncope. Cardiac standstill is possible but very rare. Vigorous examination of the carotid arteries can also rarely cause embolisation of plaque and result in a cerebral stroke, especially in older patients. As a result, palpation of the arteries should be performed with care, always unilaterally and after substantial training. The technique is not described here.

9.4.2 Procedure for carotid auscultation

1. Explain the test to the patient: 'I am now going to use a stethoscope on your neck to check your blood circulation.'
2. For the right carotid assessment, stand to the right of the patient and ask the patient to look to their left. For the left carotid assessment, stand to the left of the patient and ask the patient to look to their right. Adjust the headrest on the examination chair so that the patient's head is resting backwards with the chin slightly elevated.
3. Adjust the stethoscope so that the bell side of the chestpiece is clicked into position to transmit sounds through the stethoscope.
4. Insert the earpieces of the stethoscope into your ears so that they angle forward towards your face (Figure 9.4).
5. Place the bell over the common carotid artery approximately 2.5 cm above the clavicle bone using gentle pressure.
6. Have the patient hold their breath in mid expiration to prevent the breath sounds from distracting from your evaluation and listen for bruits for a few seconds. A bruit is a 'whooshing' sound heard superimposed on the sound of the pulse. Have the patient resume breathing.
7. Reposition the stethoscope two or three times farther upwards on neck to the bifurcation of



Fig. 9.4 Using the stethoscope to listen for carotid bruits.

the common carotid artery and then the internal carotid artery. Listen for bruits.

8. Repeat the procedure on the contralateral side.

9.4.3 Recording

Bruits are recorded as present or absent. Additionally, if the artery is occluded by approximately 50% a soft, early systolic bruit may be heard and if it is occluded by approximately 75% a systolic and early diastolic bruit may be heard.

Examples:

Carotid pulse: R 3+	L3+
Carotid bruit: R absent	L absent
Carotid pulse: R 1+	L2+
Carotid bruit: R soft, systolic bruit	L absent

9.4.5 Interpretation

Picket et al. conducted a meta-analysis of the relationship between the presence of a carotid bruit and the subsequent occurrence of transient ischemic attacks (TIA), stroke and death from stroke.²⁸ The rate ratio for TIA in patients with a bruit was 4.0, for stroke was 2.49 and for death from stroke was 2.71. In another meta-analysis Picket et al. found that the odds ratio in patients with a bruit for having a myocardial infarction was 2.15 and for cardiovascular death was 2.27.²⁹ Therefore, referral should be made for an appropriate medical assessment in the presence of a carotid bruit. Note that the absence of a carotid bruit does not however rule out carotid stenosis as the artery could be nearly entirely occluded resulting in the absence of

turbulent flow sounds. An evaluation of symptoms, ocular and other systemic risk factors and current and previous medical care for carotid disease should be considered when deciding on referral for further assessment.

9.4.6 Most common errors

1. Inter-observer variability is high with this procedure so practice is required to obtain reliable results.
2. Interpreting as abnormal a bruit found in children or young adults. These are a result of the vessel elasticity in this age group and are benign.
3. Producing an iatrogenic bruit by placing too much pressure on the artery. Moving the bell over the skin, moving your fingers on the chestpiece or breathing on the tubing can also produce confusing sounds.

REFERENCES

1. Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders. 2nd ed. *Cephalalgia* 2004;24(Suppl 1):9–160.
2. McCullough H, Reinert C, Hynan L, et al. Ocular findings as predictors of carotid artery occlusive disease: Is carotid imaging justified? *J Vasc Surg* 2004;40:279–86.
3. Ehlers J, Shah C. *The Wills Eye Manual*. Chapter 5 Conjunctiva/Sclera/Iris/External Disease. 5th ed. New York: Lippincott, Williams and Wilkins; 2008. pp. 102–27.
4. Blaustein B. *Ocular Manifestations of Systemic Disease*: Chapter 3 Cardiovascular Disease. New York: Churchill Livingstone; 1994. p. 32.
5. Lyons-Watt V, Anderson S, Townsend J, DeLand P. Ocular and systemic findings and their correlation with hemodynamically significant carotid artery stenosis: a retrospective study. *Optom Vision Sci* 2002;79:353–62.
6. Lawrence PF, Oderich GS. Ophthalmic finding as predictors of carotid artery disease. *Vasc Endovascular Surg* 2002;36:415–24.
7. Gardner M. *Basic Anatomy of the Head and Neck*. Philadelphia: Lea and Febiger; 1992. pp. 183–6.
8. Uchio E, Takeuchi S, Itoh N, et al. Clinical and epidemiological features of acute follicular conjunctivitis with special reference to that caused by herpes simplex virus type 1. *Br J Ophthalmol* 2000;84:968–72.
9. Aoki K, Kaneko H, Kitaichi N, et al. Clinical features of adenoviral conjunctivitis at the early stage of infection. *Jpn J Ophthalmol* 2011;55:11–5.
10. Hurcomb P, Wolffsohn J, Napper G. Ocular signs of systemic hypertension: A review. *Ophthalmic Physiol Opt* 2001;21:430–40.
11. Daskalopoulou S, Khan NA, Quinn RR, et al. The 2012 Canadian Hypertension education program recommendations for the management of hypertension: blood pressure measurement, diagnosis, assessment of risk and therapy. *Can J Cardiol* 2012;28:270–87.
12. NICE clinical guideline CG 217. Hypertension: Clinical management of primary hypertension in adults. National Institute of Health and Clinical Excellence. www.guidance.nice.org.uk/CG217, 2011.
13. Meetz R, Harris T. The optometrist's role in the management of hypertensive crises. *Optometry* 2011;82:108–16.
14. Kearney PM, Whelton M, Reynolds K, et al. Worldwide prevalence of hypertension: a systematic review. *J Hypertens* 2004;22:11–9.
15. Chobanian AV, Bakris GL, Black HR, et al. Seventh report of the joint national committee on prevention, detection, evaluation and treatment of high blood pressure. *Hypertension* 2003;42:1206–52.
16. DellaCroce J, Vitale A. Hypertension and the eye. *Curr Opin Ophthalmol* 2008;19:493–8.
17. Wong T, Mitchell P. Hypertensive retinopathy. *N Engl J Med* 2004;351:2310–7.
18. Wolffsohn JS, Napper GA, Ho SM, et al. Improving the description of the retinal vasculature and patient history taking for monitoring systemic hypertension. *Ophthalmic Physiol Opt* 2001;21:441–9.
19. Neto J, Palacio G, Santos A, et al. Direct ophthalmoscopy versus detection of hypertensive retinopathy: a comparative study. *Arq Bras Cardiol* 2009;95:215–22.
20. Barnard N, Allen R, Field A. Referrals for vascular hypertension in a group of 45–64-year-old patients. *Ophthalmic Physiol Opt* 1991;11:201–5.
21. Beevers G, Lip G, O'Brien E. ABC of hypertension: Blood pressure measurement. Part I-Sphygmomanometry: factors common to all techniques. *Br Med J* 2001;322:981–5.
22. World Health Organization. *Affordable Technology: Blood pressure measuring devices for low resource settings*. WHO library; 2005.
23. Skirton H, Chamberlain W, Lawson C, et al. A systematic review of variability and reliability of

- manual and automated blood pressure readings. *J Clin Nurs* 2011;20:602–14.
24. Myers M, Godwin M. Automated office blood pressure. *Can J Cardiol* 2012;28:341–6.
 25. Wan Y, Heneghan C, McManus R, et al. Determining which automatic digital blood pressure device performs adequately: a systematic review. *J Hum Hypertens* 2010;24:431–8.
 26. Hodgkinson J, Mant J, Martin U, et al. Relative effectiveness of clinic and home blood pressure monitoring compared with ambulatory blood pressure monitoring in diagnosis of hypertension: systematic review. *Br Med J* 2011;342:d3621.
 27. Lou BP, Brown GC. Update on the ocular manifestations of systemic arterial hypertension. *Curr Opin Ophthalmol* 2004;15:203–10.
 28. Picket C, Jackson J, Hemann B, Atwood J. Carotid bruits and cerebrovascular disease risk: a meta-analysis. *Stroke* 2010;41:2295–302.
 29. Picket C, Jackson J, Hemann B, Atwood J. Carotid bruits as a prognostic indicator of cardiovascular death and myocardial infarction: a meta-analysis. *Lancet* 2008;371:1587–94.