Refraction and prescribing

by Claire McDonnell FAOI

Competencies covered:	Refractive management for dispensing opticians, visual function for optometrists, binocular vision for optometrists
Target groups:	Dispensing opticians, optometrists

Refraction and prescribing are two different concepts and often a prescribed correction is not the same as the error found in the testing room. This article explores the reasons why the results of a refraction may not necessarily be identical to the correction the patient needs to wear.

Refraction can be divided into two types: subjective - where input is required from the patient and objective which requires patient cooperation but little or no input. Objective refraction is particularly useful where a patient may have communication difficulties, eg, young children, mental handicap, Alzheimers etc and indeed often in these cases the objective results are the only power that can be prescribed. One of the most commonly used forms of objective refraction is the autorefractor. Many studies have shown that autorefractor results are generally very similar to subjective results but it is widely accepted that the main use of an autorefractor is to give the optometrist a starting point for subjective[1].

Autorefractors are based on the Scheiner double pinhole principle. In the Scheiner experiment a double pinhole is placed in front of the eye and the patient is asked to look at a spotlight which they perceive as double. If the top pinhole is covered and the patient reports that the upper spotlight disappears (remember images on the retina are inverted) then the light must be focussing in front of the retina and therefore the patient is myopic and vice versa for hyperopia **(**see **Figure 1)**. By adjusting the position of the object eventually a single focus of light will be seen by the patient and the patient's far point and therefore refractive error can be determined. In the autorefractor two (usually infra-red) diodes illuminate the retina through a small aperture and their images are reflected onto a photodetector. By moving the aperture the image can be brought into focus and its position then gives a measurement of refractive error.

Autorefractor results themselves are not usually prescribed because they don't control/relax accommodation as well as can be achieved during a subjective refraction. Proximal
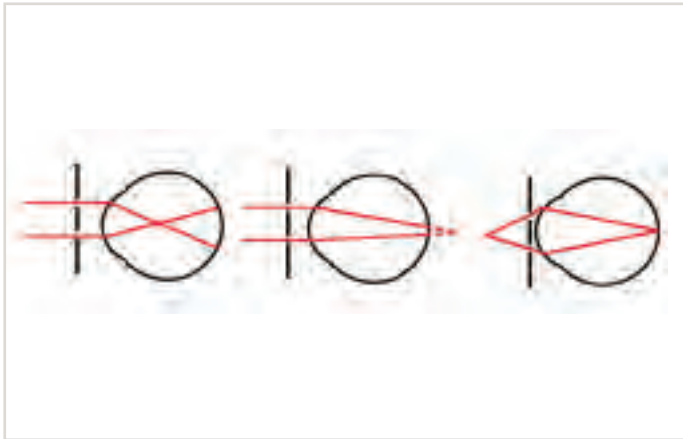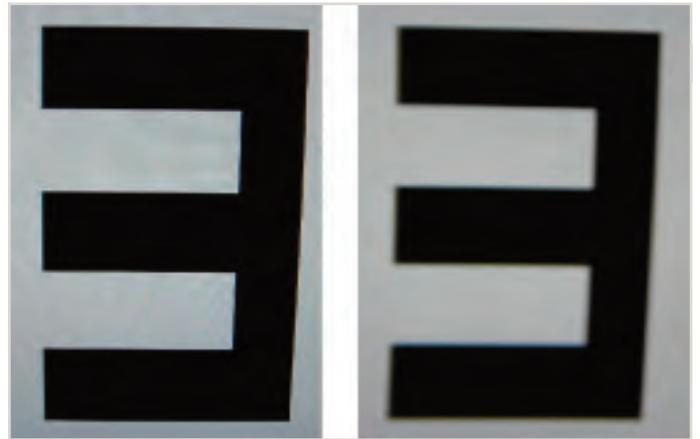
Figure 1: Scheiner's double pinhole

Figure 2: Shows a letter viewed with a correctly aligned cylinder on the right and a 2.50DC five degrees off-axis on the left

accommodation from an awareness of being in an enclosed environment (propinquity), may be evoked by some autorefractors[2]. Although a cycloplegic drop can be used to relax accommodation, this is still not ideal. Autorefractor results are affected by corneal refractive surgery and certain ocular pathologies, eg, asteroid hyalosis (a form of vitreous degeneration in which calcium soaps aggregate in the vitreous body). Autorefractor results can lack accuracy in high degrees of myopia due to off-axis aberrations[3].

The other common objective method of refraction is retinoscopy. Retinoscopy results are prescribed for children, as subjective refraction of the under fives is meaningless, from ages five to seven subjective responses can only be used as a rough guideline and it is only really from age eight and upwards that the subjective refraction can be used for prescribing. Retinoscopy can also suffer from problems of accommodation. The technique must be carried out with the practitioner's eye exactly aligned with the patient's eye, as being off-axis can result in over or under estimation of both the sphere and the cylinder components. Patients with a manifest strabismus may have to have their fixing eye occluded during retinoscopy (to straighten the eye that turns) which increases the likelihood of unwanted accommodation. Obtaining an accurate result with retinoscopy can be difficult with small pupils, media opacities and keratoconus. Even large pupils can cause problems as sometimes a split reflex can be seen, where one

movement is observed centrally and a different movement observed in the periphery. This can make it difficult to decide on an exact end point.

Even with subjective refraction there can be errors. In fact in one study comparing subjective refraction with autorefraction, VA was better with autorefraction than subjective refraction in 15% of cases[1]. Subjective refractions are usually carried out at a testing distance of six metres. (This distance usually being achieved by use of a mirror). The hypothesis is that at six metres the effects of accommodation will be negligible. (Although in fact the eye must accommodate by 0.167D to see an object at six metres). When test charts are used at four metres (as with many logMAR charts) or at three metres (as is the case with some computerised and projector test charts), the amount by which the patient is accommodating is 0.25D and 0.33D respectively. This can lead to the patient being under-plussed or over-minussed in the refraction and some optometrists will make an allowance for this in their final prescription.

Optometrists may wish to modify prescriptions to correct binocular vision problems. If a patient has a divergent deviation (a tendency for an eye to turn outwards) the optometrist may prescribe the lowest plus prescription compatible with comfortable VA. By leaving the patient under-plussed, the eyes are obliged to use accommodation. An increase in accommodation causes the eyes to converge and this can correct the divergent deviation. It is also possible

to over-minus the patient to achieve the same effect. This works well with young patients with lots of accommodation and may be considered in favour of prisms, which can have a tendency to be absorbed, thus requiring increasing amounts.

To help correct a convergent deviation with an accommodative element, the patient is usually given their full cycloplegic prescription. This relaxes accommodation and reduces convergence helping to straighten the eyes. Sometimes a patient cannot accept the full prescription as there is ciliary muscle spasm preventing complete relaxation of accommodation. In these situations the patient is often given 75% of the full prescription initially. In the case of children under the age of seven, 100% of the prescription must be given within six months or the convergent deviation may never be fully corrected.

Prescriptions may also have to be modified in cases of anisometropia. This can be divided into two types: early onset - which has been present since childhood and late onset or secondary anisometropia which may occur as a result of unilateral surgery or injury, eg, cataract operation or laser refractive surgery to one eye. Patients with early onset anisometropia normally have some suppression of the eye with the higher prescription but this suppression may be mild and usually only applies to central vision. The depth (or density) and extent of the suppression will depend on a number of factors such as whether or

not there is also a turn in the eye, whether the patient ever wore a patch, how much anisometropia is present etc. Some optometrists will not even bother to refract the worse eye if the corrected VA in this eye is poor (ie, the eye is amblyopic) and will simply write "balance" in the prescription. Others may refract the amblyopic eye but still just prescribe "balance", leaving it up to the dispensing optician or even the technician to decide what power lens should be placed in front of the amblyopic eye. Normally the balance lens is a lens approximately equal in power to the prescription in the fellow eye (usually equivalent to the mean spherical equivalent). This can be frustrating for a patient with good peripheral vision in their amblyopic eye. It is more appropriate to prescribe a specific power in the balance lens, but what should that power be?

Anisometropia causes two problems: differential prismatic effect and aniseikonia. A patient with a small amount of central suppression could probably tolerate up to one prism dioptre of vertical prismatic effect. Assuming that most people look 8mm below the optical centres of their spectacles to read, then an inter-eye difference of 1.25D could probably be tolerated by most amblyopes (using Prentice's rule: P =cF = 0.8x1.25 = 1 prism dioptre). Aniseikonia seems to become clinically significant at values of 3-5%[4,5,6,7,8]. (See **note 1** on how to calculate spectacle magnification as a percentage).

This translates as an inter-eye difference of 2.12D (assuming a vertex distance of 13.75mm). Therefore the prescription in the worse eye

should be reduced to a point where it is within 1.25 - 2.12D of the prescription in the good eye. (Usually an inter-eye difference of no more than 1.50D is the aim). That is straightforward enough if the prescription is spherical but what if the prescription has a cylindrical component?

If astigmatism cannot be fully corrected, then the best case scenario would be to have the circle of least confusion on the retina, the next best would be to have one focal line on the retina (preferably one that is close to vertical).

From personal experience a useful rule of thumb for modifying prescriptions with astigmatism is as follows:
1. Hyperopic anisometropia with negative cylinder:
   (a) Add the sphere and the cylinder (from the worse eye) together
   (b) Add 1.50D to the prescription in the good eye, this will be the proposed modified sphere for the worse eye
   • If (a) is greater than or equal to the proposed modified sphere (b), then the worse eye does not need any cylinder.
   • If (a) is less than the proposed modified sphere (b), then the worse eye will need some cylinder in most cases.
2. Myopic anisometropia with negative cylinder: convert the prescription to plus cylinder form
   (a) Add the sphere and the cylinder (from the worse eye) together
   (b) Subtract 1.50D from the prescription in the good eye, this will be the proposed modified sphere for the worse eye
   • If (a) is numerically greater than or equal to the proposed

modified sphere (b), then the worse eye dos not need any cylinder.
   • If (a) is numerically less than the proposed modified sphere (b), then the worse eye will need some cylinder in most cases.
The modified prescription for the worse eye never requires the full cylinder as established in refraction.

Example: Hyperopic anisometropia
A patient has the following prescription at the end of refraction:
   RE: +4.00/-1.00x90   LE: +0.50
(a) Add the sphere and the cylinder (from the worse eye) together:
   +4+(-1) = +3D
(b) Add 1.50 to the prescription in the good eye:
   +0.50+1.50 = +2.00D. This is the proposed modified sphere.
(a) is greater than the proposed modified sphere (b) and therefore the poorer eye does not need any cylinder correction.
The new modified prescription will be:
   RE: +2.00DS   LE: +0.50DS

This new prescription for the RE leaves both focal lines behind the retina but if any cylinder component was to be incorporated into the prescription one focal line would lie even further behind the retina.

Example: Myopic Anisometropia
A patient has the following prescription at the end of refraction:
   RE: -4.00/+3.00 x 90   LE: -0.50
(a) Add the sphere and the cylinder (from the worse eye) together:
   -4+3 = -1D
(b) Subtract 1.50 from the prescription in the good eye:
   -0.50-1.50 = -2.00D. This is the proposed modified sphere.
(a) is numerically less than the proposed modified sphere (b) and therefore the poorer eye will need cylinder correction.
The new modified prescription will be:
   RE: -2.00/+1.00 x 90   LE: -0.50

This new prescription for the RE leaves one of the focal lines on the retina.

It is also possible for the optometrist to modify the refraction results in the trial frame to come up with a modified

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Spectacle magnification as a percentage
RE: Plano LE:+2.12D
Vertex distance = 13.75mm
K (ocular refraction) = +2.18D
Spectacle magnification (SM) for the LE = K/Fsp = 2.18/2.12 = 1.03
Spectacle magnification as a percentage: 100(SM-1) = 100(0.03) = 3%
Note: in the case of a thick lens, the form of the lens will affect the spectacle magnification, in which case the thick lens formula should be used.

Note 1

Trial lens power for near	Correction value for the stated add		
	+2.00	**+2.50**	**+3.00**
+8.00			
+8.50			
+9.00			+0.25
+9.50			
+10.00		+0.25	
+10.50			
+11.00	+0.25		
+11.50			
+12.00			
+12.50			+0.50
+13.00			
+13.50			
+14.00		+0.50	
+14.50			
+15.00			
+15.50	+0.50		
+16.00			+0.75

Table 1

prescription that the patient is comfortable with and most dispensing opticians will look at the patient's previous balance lens and ask if the patient was happy with that lens. In cases where the poorer eye has a very reduced VA, the prescription in the balance lens is largely irrelevant. Where the anisometropia is late onset or secondary the optometrist may want to attempt to give the full prescription (particularly if it is the patient's dominant eye that has the higher prescription). In this case the dispensing optician can look at dispensing bicentric lenses or attempting to order different lens forms to minimise the inter-eye difference in retinal image size.

If the patient with late onset anisometropia cannot tolerate or afford specialist lenses or does not like their cosmetic appearance, the prescription should be modified by either changing the prescription in the eye with the worse VA to bring it to within 1.50D of the other eye or, if the VAs are equal, changing the prescription in the non-dominant eye. There are many different ways of testing for ocular dominance but for the purposes of prescription modification, the simplest way is to put the prescription in a trial frame with the RE modified and then with the LE modified and check which one causes the patient the least amount of noticeable blur.

Modification of a prescription may also be required to correct for near vision effectivity error (NVEE). The back vertex power (BVP) of a lens represents the vergence leaving the lens when the light originates from a distant object. For near vision the light originates from a point which is a finite distance from the front of the lens. In this case the vergence of light leaving the back surface depends on the BVP, the form and thickness of the lens and the patient's working distance. When patients are tested for a reading prescription, trial lenses made in flat form are used. However when the lenses are made up into spectacles, they are in a more curved form. In the case of lenses greater than +8D, this difference in form means that the patient gets less power from their spectacles (compared to the trial lenses) and so they have to make up the shortfall with accommodation. The difference between the vergence leaving a lens when the light originates from a near object and the vergence for a distant object (the sum of the incident vergence + BVP) is known as the NVEE. It is possible to calculate what the error will be using the formula: $NVEE = [(t/n)L_1(L_1+2F_1)]$ where t is the centre thickness of the spectacle lens, n is the refractive index, L_1 is the incident vergence (for a reading distance of a third of a metre, this would be -3D) and F_1 is the front surface power of the spectacle lens. In reality, most dispensing

opticians would not know the thickness and front surface power of the proposed spectacle lens and so it is simpler just to use a table (see **Table 1)**. It is not necessary to calculate NVEE for minus lenses as these tend to be quite flat and thin and are therefore similar in form to trial lenses.

Even for distance prescriptions the BVP of a combination of trial lenses in the trial frame is not necessarily its algebraic sum. It depends on the power, thickness, form and position of the lenses used. This is particularly so with high refractive errors. After refracting a patient with high ametropia in a trial frame, the BVP should be measured using a focimeter and the subsequent reading should be ordered for the patient's spectacles.

It is well known that a change in vertex distance between that read from the trial frame during refraction and that which the patient will eventually wear in their new spectacles can cause problems, but at what power does this become an issue? According to the relevant standards, the vertex distance is only required to be included on written prescriptions above ± 5.00D. Assuming that the closest a frame (trial frame or spectacle) might be worn is 8mm and the furthest it might be worn is 15mm (giving a change in vertex distance of 7mm) then the lowest prescription that could have a change of approximately 0.25D is ±5.50D. Realistically however the change in vertex distance between the testing room and the dispense is not normally that large. For example nearly all phoropters have a vertex distance of 13.75mm assuming they are used correctly. If we say that a change of 5mm is more likely then the lowest prescription with an approximately 0.25D change becomes ± 6.50D. The simplest way to avoid having to make adjustments for vertex distance is to help the patient to choose a frame prior to the test, measure the back vertex distance of the chosen frame and then set the trial frame up at this distance for the actual refraction itself.

Unequal reading additions are uncommon in prescriptions but there

may be reasons why they are sometimes required. The additions may be different where the accommodation is not equal in both eyes. There can be a number of reasons why this might occur. If a patient has unilateral pseudophakia the eye with the intraocular lens implant will have little or no accommodation while the other eye still has accommodation normal for the patient's age. Third nerve palsies can cause paralysis of accommodation. Horner's syndrome causes an increase in accommodation and Adie syndrome causes a reduction in accommodation but this is usually short-lived.

Some patients who are prescribed astigmatic spectacle prescriptions for the first time will not tolerate their full cylinder (or indeed any cylinder). A patient is increasingly likely to struggle to adapt to astigmatism, the older they are when they get their first spectacles, the higher the cylinder, the more oblique the axis and the less they wear their spectacles. Normally if an astigmatic prescription has to be modified the aim would be to put the circle of least confusion (CLC) on the retina. However if the spherical element of the patient's prescription is plano or mildly hyperopic then they will be accustomed to having one focal line on the retina so it should be checked to see if they prefer a modified prescription that puts the CLC or a focal line on the retina. Once the cylinder has been reduced to a level that the patient can adapt to, the CLC can be placed on the retina by adding half the modified cylinder to the sphere and this is the new sphere. If the aim is to keep one focal line on the retina, leave the sphere as found on refraction. If the patient cannot tolerate any cylinder simply add their sphere and half the cylinder together and prescribe this as a sphere. Again this will place the CLC on the retina.

Example 1
A patient has the following prescription at the end of refraction:
    RE: Plano/-3.50x35
    LE: +0.50/-3.25x155
The patient has a history of being

unable to take their full cylinder prescription. In this case their spheres should remain the same and their cylinders reduced.
The new modified prescription will depend on their VA requirements but it could be:
    RE: Plano/-2.00x35
    LE: +0.50/-1.75x155

Example 2
A patient has already had spectacles made up to their full refracted prescription which is:
    RE: -2.00/-1.00x70
    LE: -2.50/-1.50x65
but they are noticing distortion that they never had with their previous spectacles (no astigmatic correction). To place the CLCs on the retina, the prescription can be modified to:
    RE: -2.50
    LE: -3.25

Another rare problem that can occur with astigmatic prescriptions is cyclotorsion. This is where the eyes rotate as well as converging when looking at a near object. For most patients this is not a problem but a patient with high cylinders and incyclotorsion at near may find that they need two separate pairs of spectacles for distance and reading with different axes in each. Figure two shows the effect that five degrees of cyclotorsion can have on a 2.50D cylinder.

It can be seen then that there are quite a number of scenarios in which a prescription may differ from that found in the refraction. It is important to remember that if it is necessary to modify a prescription it should be noted on the patient's copy (as well as the practice's record card) that a modification has been made so that other optometrists will be aware of it and will not query what appear to be large changes in prescription. It is also necessary to ensure that patients still meet certain visual standards (e.g. the driving standard) when their prescription is modified.

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Multiple choice questions (MCQs): Refraction and prescribing

1. What principle is used as the basis of design for an auto refractor?
a. The Fundamental Paraxial equation
b. The Airy Disc
c. The Scheiner double pinhole
d. Snell's Law

2. How much would an eye have to accommodate as a result of the testing distance if a logMAR chart was used at a distance of 4 metres from the subject?
a. 0.167D
b. 0.25D
c. 0.33D
d. 0.50D

3. Given that a patient is able to tolerate 1 prism dioptre differential between their two eyes, what degree of anisometropia is likely to be the most that a patient could tolerate when looking downwards to read through a point 8mm below the distance optical centres?
a. 0.50D
b. 0.75D
c. 1.00D
d. 1.25D

4. Aniseikonia is a condition caused by the two lenses of a pair of spectacles giving different levels of spectacle magnification from one another. At what degree of difference between the image sizes does aniseikonia appear to become significant?
a. 2 - 4%
b. 3 - 5%
c. 4 - 6%
d. 5 - 7%

5. In the case of an anisometropic astigmatic prescription where the astigmatism cannot be fully corrected, which of the following options would be the best case scenario?
a. Place the circle of least confusion on the retina
b. Place the focal line closest to the horizontal on the retina
c. Place the focal line closest to the vertical on the retina
d. None of the above would make any significant difference

6. NVEE only has an impact when considering a certain prescription range. Which is this prescription range?
a. Over -8.00D
b. -8.00D to -0.25D
c. +0.25D to +8.00D
d. Over +8.00D

7. Which of the following parameters is not a required known factor when calculating NVEE for a prescription?
a. The lens thickness, t
b. The refractive index of the lens material, n
c. The back surface power of the lens, F_2
d. The front surface power of the lens, F_1

8. What kind of power modification is most likely to be selected for a patient with a divergent deviation, in order to assist their binocular vision?
a. A small increase in plus power
b. A small decrease in plus power
c. The lowest plus prescription that will allow a comfortable V/A
d. The highest plus prescription that will allow a comfortable V/A

9. A patient has the following prescription: RE +1.00DS LE +4.25/-0.75 x 90. In this case of this being a troublesome anisometropic prescription requiring alteration what is the most likely combination to be prescribed?
a. RE +1.00DS LE +2.50DS
b. RE +2.50DS LE +4.25/-0.75 X 90
c. RE +1.00DS LE +3.50DS
d. RE +2.50DS LE +3.50DS

10. What is/are likely to cause secondary anisometropia in an adult?
a. A congenital condition
b. Laser refractive surgery to one eye
c. An injury to one eye in infancy
d. All of the above

11. When dealing with a convergent deviation, what refractive result would usually be prescribed?
a. 75% of the full prescription
b. 100% of the prescription within six months
c. The full cycloplegic prescription
d. 50% of the full prescription

12. Spectacle lenses for near vision are being dispensed for a patient whose prescription is:
    RE +9.50/+0.50 x 90 LE +9.25/+0.75 x90
    Reading Addition +3.00 R & L
    Vertex Dist. 12mm.
If this prescription is dispensed at 12mm, what lens powers would be ordered?
a. RE +12.00/+0.50 x 90 LE +11.75/+0.75 x 90
b. RE +9.50/+0.50 x 90 LE +9.25/+0.75 x 90
c. RE +12.50/+0.50 x 90 LE +12.25/+0.75 x 90
d. RE +13.00/+0.50 x90 LE +12.75/+0.75 x 90