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Dispensing II: Complex lens dispensing

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With reference to the terminology used by the General Ophthalmic Services (GOS), the expression complex appliance is defined as an optical appliance with at least one lens which has a power in any one meridian of plus or minus 10.00 or more dioptres, or is a prism-controlled bifocal lens. This definition provides us with a point at which a GOS complex lens voucher may be issued. For some practitioners it also signals the threshold at which simple dispensing becomes complex dispensing. The previous article in this series discussed lenses up to ±5.00 D in power. Although the title of this article is "Complex Lens Dispensing", reference will be made to lenses of less than ±10.00 D in power.

Initial Considerations

Whenever we are presented with a complex prescription to dispense there are several important factors that demand initial consideration.

Vertex Distance

Vertex distance is defined as "the distance from the corneal apex to the visual point on the lens". BS 2738-3:2004 states that a vertex distance should accompany a spectacle prescription if the power of the lens in any meridian is ± 5.00 D and above, for example, -5.00/-1.00 x 130 at 12mm where "at 12mm" refers to the vertex distance of the trial frame or refractor head.

The vertex distance of a spectacle lens plays an important part in the spectacle correction of ametropia as the effective power of a spectacle lens used for distance vision depends on its position relative to the eye. These effects are often used by presbyopes and in particular aphakes to enhance near vision. So why is a vertex distance necessary for medium and high prescriptions? The effective power of a lens changes as it is moved away from or closer to the eye and all lenses become more positive if they are moved away from the eye. This means that a minus lens becomes weaker (and therefore a stronger lens needs to be ordered to compensate for the change due to effectivity) and a plus lens becomes stronger (a weaker lens is therefore required) when moved away from the eye. The opposite occurs when the lens is moved towards the eye. If a practitioner is presented with a prescription of ± 5.00 D and above, he has three options. These are:

1. Ensure that the chosen frame sits at the prescribed vertex distance;
2. Chose a frame that sits at a different vertex distance, but alter the power of the lenses accordingly;
3. Choose another frame, which fits at the required vertex distance.

Point two above can be achieved by the use of:

a. Knowledge of focal length and focal power;
b. Appropriate conversion tables and charts;
c. Appropriate formulae;
d. Step-along.

Figure 1
The measurement of vertex distance using a vertex distance measuring gauge

The vertex distance can be measured using a vertex distance measuring gauge or by simply using a millimetre ruler (Figures 1 and 2). Tunnacliffe has provided a detailed account regarding the correct measurement of vertex distance[1]. Most trial frames employ a millimetre scale positioned along each side which can be used to measure the vertex distance assigned to a given spectacle refraction (Figure 3).

Differences between the vertex distance of the trial frame or refractor head and the final vertex distance

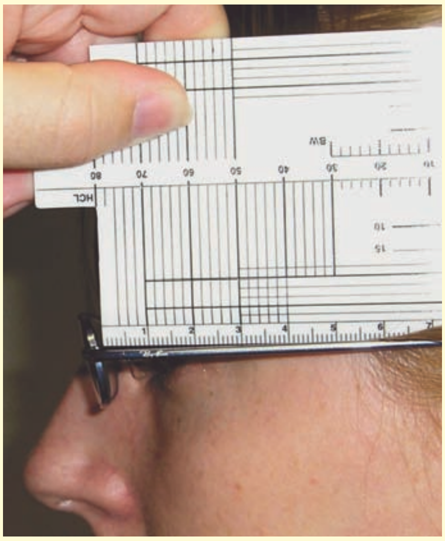

Figure 2

The vertex distance measured using a millimetre ruler

should always be taken into account for lens powers over ±5.00 D. Any significant difference between these two distances will change the effective power of the lens, with greater changes occurring with higher power lenses. When dispensing complex prescriptions it is vital that the two vertex distances are measured and compared, along with appropriate modification of the final prescription to be ordered. In practice, the easiest way to compensate for a change in vertex distance is to consult one of the available tables[2] or to use a computer spreadsheet that compensates for changes in vertex distance.

For those who are mathematically minded, the necessary equations to compensate for a change in vertex distance are given below.

If the vertex distance is decreased:

$$F_{new} = \frac{F_{old}}{1 - (dF_{old})}$$

If the vertex distance is increased:

$$F_{new} = \frac{F_{old}}{1 + (dF_{old})}$$

In both expressions, d (in metres) represents the change in vertex distance and not the vertex distance itself. Regardless of the method used to compensate for a change in vertex distance, when dealing with an astigmatic prescription, each principal power must be compensated in turn. The final result can then be re-written in the usual sph-cyl form.

A change in vertex distance will also affect the spectacle magnification produced by a correcting lens. An increase in vertex distance will be accompanied by an increase in spectacle magnification. This means that both the minifying effect of minus lenses and the magnifying effect of positive lenses will be increased if the vertex distance is increased. It is worth remembering that the corresponding reduction in retinal image size may result in a drop in visual acuity for the high myope if the vertex distance is increased by a significant amount. It is therefore helpful if the prescription contains the corrected visual acuities.

Frame Selection, Centration and Decentration

The reasons for the correct centration of spectacles lenses are well known and include:[3]

- The positioning of the zone of the lens where the paraxial prescription is most effective;
- Reducing unwanted differential prismatic effects;
- Reducing the possibility of the formation of ghost images.

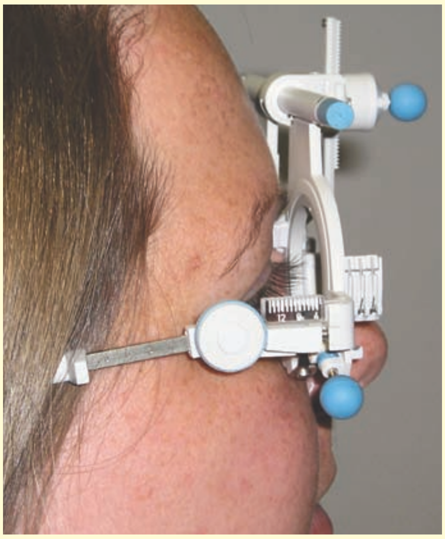

Figure 3

The vertex distance measuring scale on a trial frame

The term decentration is used to describe any displacement, horizontal and/or vertical of the centration point from the standard optical centre position. The centration point is the point at which the optical centre is to be located in the absence of prescribed prism or after any prescribed prism has been neutralised. The standard optical centre position is a reference point specific to each individual lens shape and is situated on the vertical line that passes through the boxed centre. However, if the manufacturer has not published information to the contrary, the standard optical centre is assumed to coincide with the boxed centre. Correct centration is of course important for both complex and simple dispensings. However the mechanical consequences of decentration become more of an issue when high-powered lenses are involved as the amount of decentration required to achieve

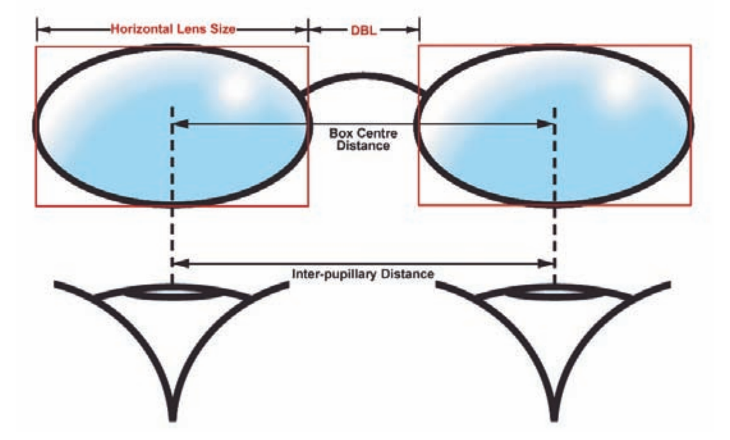

Figure 4

The boxed centre distance and inter-pupillary distance

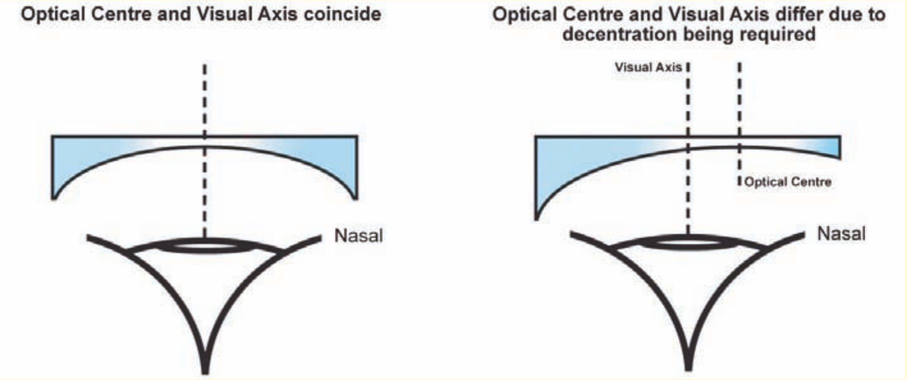

Figure 5.
A centred and decentred minus lens

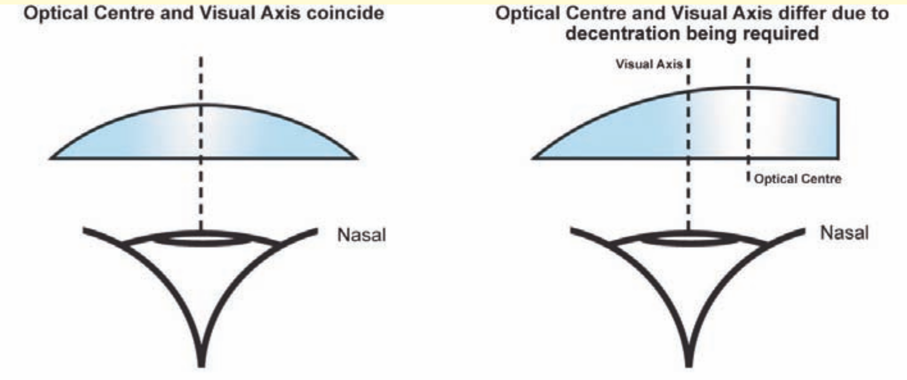

Figure 6.
A centred and decentred plus lens

correct centration can dramatically influence lens thickness and weight, resulting in less than optimum cosmesis. In addition, the published tolerances for centration are a cause for concern as the prescription becomes more complex.

Decentration is necessary when the box centre distance of the frame and the subject's inter-pupillary distance (or near centration distance in the case of near vision) are not the same (Figure 4). The exception to this is when decentration is used to produce a given amount of prescribed prism. The effects of inward decentration on high-powered lenses are well-known, with increased temporal edge thickness in minus lenses and increased nasal edge thickness in plus lenses (Figures 5 and 6).

To ensure that decentration is kept to a minimum it is important to select a frame with a boxed centre distance that is close to the required distance (or near) centration distance. Once the patient's inter-pupillary distance has been measured, appropriate frames can be used to establish a suitable bridge size (distance between lenses or DBL). Alternatively, this can be measured using a facial ruler. Once this is known, a theoretical eye size (horizontal boxed lens size) can be determined by subtracting the DBL from the inter-pupillary distance. For example, if the patient's inter-pupillary distance is 68mm and a 16mm DBL is required the "ideal" horizontal lens size of frame to avoid decentration will be 68 – 16 = 52mm. If the DBL is increased to 18mm we would need to reduce the horizontal eye size to 50mm. Additional reduction in lens substance can be achieved by further reducing the horizontal and vertical boxed lens size. This of course needs to be offset with a wider DBL so as to maintain a suitable box centre distance and thus avoid decentration. It should be pointed out that the lens powers do not need to be particularly high for this to become an issue and poor frame selection can instantly remove the benefits of using a lens with a higher refractive index to reduce lens substance!

However, practitioners must always think carefully about the patient sitting in front of them as the above guide may not work for a patient with a head width of 165mm and an inter-pupillary distance of 58mm! In this example a frame could be judged unsuitable because its dimensions are too small. Further considerations have to be made when dispensing multifocal lenses to ensure that there is sufficient depth for positioning the segment or progression.

It is often helpful to consider frame selection in complex dispensings as the patient choosing the frame we want them to have. Explain the reason for suggesting certain frames and point out the benefits of reduced decentration. Dispensing aids such as computer programmes that display the profile of the finished lens are very useful in this context.

Frame and Lens Harmony

Complex dispensing is often a balancing act resulting in a compromise somewhere along the line. On one hand we have the prescription and inter-pupillary distance. On the other we have lens material, lens form, frame style, material, fitting and centration requirements. In many instances we will have to play one off against the other, sacrificing frame size and zero decentration for higher refractive index materials or special lens forms. Whichever methods we employ it is vital to try and imagine the finished result. Will it be optically and cosmetically desirable? Once again, this is an area in which computer aided dispensing comes into its own.

High Myopia

Lens material and form

When faced with the challenge of dispensing lenses for the highly myopic patient three aspects immediately come to mind. These are:

- Selection of lens material;
- Special lenses for high myopia;
- Selection of a suitable frame.

As far as lens form is concerned, the available products can be broadly divided in the full aperture lenses and reduced aperture lenses.

The primary consideration when dispensing minus lenses is often the edge thickness of the finished lens. If the lens incorporates inward horizontal decentration it will be the temporal edge that displays the greatest substance. When dispensing full aperture lenses for medium to high myopia the use of higher refractive index materials combined with aspherical surfaces and a reflection free coating often provides the lens of choice. Such lenses give the practitioner a reasonable degree of control over the edge substance while providing good off-axis performance in oblique gaze[4]. Most of the major lens manufacturers produce resin materials with refractive indices of around 1.7. However, such products are invariably accompanied by low V-values[5]. Mineral (glass) lenses are available in refractive indices up to 1.9. Once again, such products often display low V-values resulting in transverse chromatic aberration when the patient views through points away from the optical centre.

In order to keep effects of TCA to a minimum, the following points should be considered by practitioners:

- Use materials with a high V-value;
- Apply correct horizontal and vertical centration and pantoscopic tilt. Placing the optical centres of high-powered, low V-value lenses at the zero pupil position with a zero pantoscopic tilt will reduce the effects of TCA and hence avoid the possibility of reduced visual acuity in primary gaze;
- Use best form designs;
- Be sensible with frame selection - consider shape and size carefully;
- Fit the spectacle frame with as small a vertex distance as possible. The larger the vertex distance, the greater the distance from the optical centre to the visual point for a particular ocular rotation. So, fitting the lenses as close as possible to the eyes keeps the visual points as close to the optical centres as possible and minimises the effects of TCA.

There are other advantages to be gained by keeping the vertex distance as small as possible. As previously mentioned, the spectacle magnification is less with smaller vertex distances. The field of view is larger with a smaller vertex distance. Both TCA and distortion increase with the distance of the chief ray from the optical axis. So, with a smaller vertex distance, both distortion and TCA are marginally less because the chief ray meets the lens closer to the optical axis for a given eye rotation. These effects are small but not insignificant and can be demonstrated by the application of accurate trigonometrical ray tracing. It should also remembered that myopes do not need to use as much ocular rotation as emmetropes or hypermetropes to observe at oblique angles in the object space because of the increased field of view with high minus lenses. Hence, less ocular rotation is needed which may mitigate the effects of TCA.

When considering mineral lenses, as the refractive index of the lens increases so does the density (mass/volume). It is therefore true to say that high refractive index glass materials are heavier if we compare like with like for example, a one-centimetre cube of one material with another of a higher density. However, this does not always translate to the finished spectacle lens. It is therefore incorrect to say that high refractive index glass lenses are heavier than normal refractive index glass lenses. This is because as a high refractive index glass lens is thinner than a normal refractive glass lens its volume will be reduced. There is less of it! This means that even though the lens is made from a denser material its finished weight may be less than the same lens made using a normal refractive index glass material. In lower powers however, it is probably true to say that high refractive index glass lenses will be heavier. If weight is the patient's priority then a resin lens has to be the material of choice. A reflection free coating should always be applied to a higher refractive index material as

Supplier/product	Index	Density	V-value	Range	Form
Seiko SPG AZ	1.74 Resin	1.47	33	To -15.00	Bi-aspheric
Essilor Lineis	1.74 Resin	1.46	33	To -18.00	Aspheric
Nikon Lite V AS	1.74 Resin	1.35	32	To -20.00	Aspheric
Norville Highlite	1.70 Glass	2.90	31	To -18.00	Spherical
Zeiss Lantal	1.80 Glass	3.62	35.4	To -20.00	Spherical
Nikon Pointal	1.80 Glass	3.65	24.4	To -20.00	Spherical
Zeiss Lantal	1.90 Glass	4.02	30.4	To -20.00	Spherical

Table 1
Very high refractive index minus single vision lens availability

ghost images 1, 3, 4 and 5 can be problematic to wearers of high powered minus lenses[6].

The ideal lens material does not unfortunately exist. Perhaps it never will if we keep moving the goal posts! However, with the aid of the polymer chemist, fantastic advances in ophthalmic lens technology have been made during the last ten years. Lens materials chosen are generally a compromise between vision and thickness or weight. It is also apparent that mid-index materials will soon become the "standard" material. It is of course important to ensure that the material best suited to the patient's requirements is always dispensed. In some cases, this material may be glass and while the use of glass as an ophthalmic lens material is in decline, there are some areas where glass can outperform plastics. The demise of glass spectacle lenses over recent years has left many entrants into the optical profession with little knowledge or understanding of the attributes of glass as an ophthalmic lens material. This has probably contributed the current lack of recommendation for glass lenses. As with any product, there are always advantages and disadvantages. A selection of products suitable for single vision high minus dispensing are listed in Table 1.

For very high myopic prescriptions, a reduced aperture lens can be considered. This type of lens employs various techniques to reduce the edge thickness using smaller effective lens apertures while still maintaining a viable overall lens size for glazing (Figure 7).

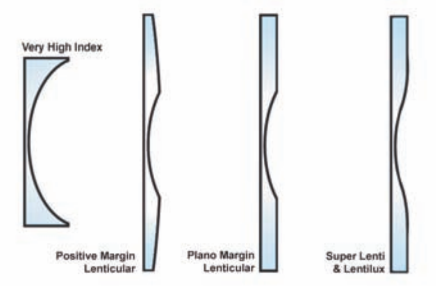

Figure 7.
Full and reduced aperture minus lens forms

Reduced aperture lenses

Super Lenti (Norville)

This is a custom manufactured, asphericsed lens for high myopic prescriptions, which attempts to eliminate the obvious disadvantages of high minus lenses (thick edges and the unsightly "bottle bottom" ring appearance). This lens is recommended for powers of -11.00 and above. The lens is available in a resin material with a refractive index of 1.55 and in glass materials with refractive indices of 1.7 and 1.8 with 1.9 being available in early 2008. A photochromic tint (photobrown in 1.6 index), cosmetic tints and multi-coatings are also available. The lens is decentred so that the optical centre is 4mm above the geometrical centre of the uncut, which is an advantage when it comes to frame selection. The lens should be fitted as a progressive so monocular distance centration distances and vertical centration data must be specified. It should be noted that as the power and refractive index increases the diameter of the central aperture decreases. If the lens were glazed centred on the pupil, in the primary position, a zero pantoscopic tilt would be required. With higher power, and therefore smaller apertures, it is best to fit with zero pantoscopic tilt. In addition, the lens should be fitted as close to the eye as possible.

Benefits to the patient include:

- Good visual acuity;
- Good field of vision;
- Controlled peripheral aberrations;
- Good edge thickness and weight;
- Allows for a wide range of frame selection;
- Reasonable cosmesis;
- Removal of the minification of the face which is seen with full aperture lenses.

Lentilux (Rodenstock)

The Lentilux is an aspherical, single vision lens for the correction of high myopia (up to -24.00 D). The stated advantages of this lens are:

- Good visual acuity;
- Thin and light lenses. The edge thickness will not exceed 4.50mm even at -24.00 D. The mean edge thickness for all powers is 3.5mm;
- Almost complete removal of power rings (ghost image no. 1) due to the flat "rim area" of the aspherical surface;
- Removal of the minification of the face and distortion of the facial features, which is seen with full-aperture high minus lenses.

The back surface of the Lentilux is a rotationally symmetrical aspherical curve, both in the central and peripheral zones, which has been calculated by the lens designers to provide the optimum conditions for the wearer to achieve good visual acuity. The diameter of the central optical zone reduces by stages as the power increases. For every 2.00 D increase in power the diameter of the optically effective zone reduces by 2mm. The diameter of the optical zone of a -6.25 D lens is 40mm whereas for a -18.50 D lens, the diameter is only 30mm. Rodenstock states that the field of view provided by the Lentilux is almost the same for all back vertex powers. The outer circumference of the optical zone connects at all points to a "rim area" in which the strong concave curvature of the power area continually decreases. It is this reduction in surface curvature that contributes to the considerable reduction in edge substance. The aspherical surface of the Lentilux has been optimised in the area surrounding the optical centre so that the patient is provided with the best possible off-axis acuity for a range of eye movements. The designers of Lentilux have given the "rim area" of the lens an aspherical form whereas high minus lenses are traditionally made using flat or spherical, concave surfaces.

A further thickness reduction is achieved by the fact that the lens is made using a high-refractive index glass material (Perfalux 1.7) ne = 1.707, Ve = 39.2 and density = 3.21 g/cm^3. The use of a high-refractive index material means that a multi-layer anti-reflection coating should always be applied.

As with all aspheric lenses correct centration is important and the usual

Product	Index	Density	V-value	Range up to
Norville Lenticular	1.498 Resin	1.30	58	up to -23.00
Zeiss Profile Lenticular	1.501 Resin	2.55	58.3	up to -25.00
Norville Lenticular	1.523 Glass	2.50	58	up to -23.00
Zeiss Profile Lenticular	1.706 Glass	3.19	39.3	up to -30.00
Norville Lenticular	1.701 Glass	2.90	31	up to -33.50
Norville Super Lenti	various	various	various	up to -45.00
Rodenstock Lentilux	1.707 Glass	3.21	39.2	up to -24.00

Table 2
Reduced aperture high minus lenses

rules apply. These are:

- Centre horizontally according to the subject's monocular (distance or near) centration distance.
- Centre vertically so that the position of the optical centre corresponds to the required pantoscopic tilt for the fitting. For every two degrees of pantoscopic tilt, position the optical centre so that it lies 2mm below the pupil centre. For a fitting with a pantoscopic tilt of 10°, the optical centre should be positioned 5mm below the centre of the subject's pupil.

Exact centration is important for all lenses of moderate to high power in order to avoid non-tolerances due to induced vertical differential prismatic effects.

Lenticular lenses

A good cosmetic appearance with very high minus lenses can be achieved by the use of lenticular lenses along with careful dispensing and rational frame selection. When compared to modern aspheric forms manufactured using very high index resin materials, lenticular lenses are often considered by some to be "old fashioned" but they still have a place in modern optometric practice.

In high minus forms, lenticular lenses are lenses in which the edge thickness has been reduced or "flattened", resulting in an aperture and a margin. A step usually exists between the flattened margin and the aperture. The aperture shape can be round, oval or profile with the margins being convex or plano. The major benefit of lenticular lenses is the reduction in volume and consequently a reduction in weight of the finished lens. The real field of view offered by minus lenticular lenses is also very good. Most manufacturers offer high minus lenses in lenticular forms. Zeiss, for example, offers high minus plano-margin profile lenticular lenses in a choice of 1.5 and 1.7 glass materials or Clarlet 1.5. With care, attention to detail and sensible frame selection, even extremely high powers can result in very neat and lightweight lenses, particularly if the profile design is chosen. A selection of reduced aperture lenses for high minus dispensing is given in Table 2.

The strategies for obtaining a cosmetically acceptable edge thickness in high minus powers are therefore:

- Little or no decentration
- Small horizontal and vertical eye sizes
- Very high index lenses
- The use of aspherical surfaces
- Specialist lenticular lens forms

Frame Selection and Field of View

Thick edge substances can occur even when using very high index lenses and the frame must be able to mechanically support these lenses. Plastics rimmed frames and thicker rimmed metal frames provide such support and help to obscure some of the edge thickness. Care should always be taken when selecting frames with adjustable pad bridges as excessive nasal edge thickness can obstruct the correct placement of the pad arms and pads. Smaller eye sized frames with wider bridges and swept out lugs are ideal, as these help to reduce the required decentration and overall edge thickness while retaining a reasonable adult sized head width in the frame. Lenticular lenses with their reduced edge substances and larger blank size availability can make frame selection far easier.

It is well known that the real field of view obtained with a minus lens is

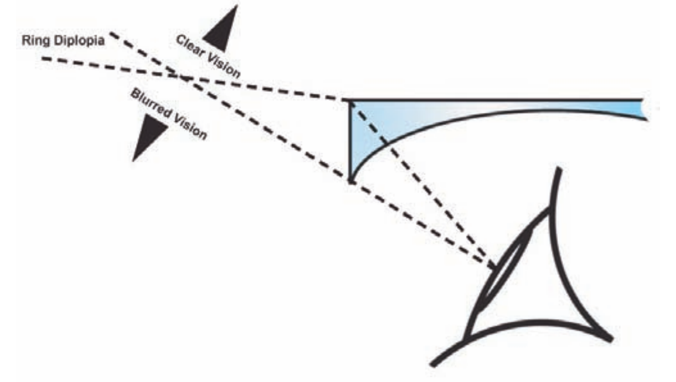

Figure 8
Ring diplopia in high minus lenses

greater than the apparent field of view. Even when reduced aperture lenses are used for the correction of high myopia the real field of view is still wider than the apparent field of view. It is interesting to note that -15.00 D lens dispensed with a 28mm aperture gives the same real field of view as a +5.00 D lens with a 45mm aperture[7]. Another and somewhat theoretical point to consider regarding the field of view in minus lenses is that of ring diplopia[8]. Minus lenses produce an overlap of fields at and around the lens margin (Figure 8). Although this has the potential to cause diplopia, it is rarely if ever noticed by patients as the rim is so far away from the primary line of sight that the wearer would need to maintain a rotation of some 45 to 50 degrees which would be very uncomfortable to sustain. Ring diplopia is also rarely noticed in lenticular lenses as the power difference between the optic and marginal zones is so great.

Centration and Fitting

Correct vertical and horizontal positioning of the lenses is of course vital when dispensing high prescriptions. Once the frame and lens selection has been completed accurate binocular and monocular inter-pupillary distances must be obtained. Spectacle wearers generally tend to spend most of their time looking through the lenses with their heads slightly depressed when compared to the primary position of gaze. When dispensing single vision high-powered distance lenses, it is recommended that the optical centres are fitted about 3mm below the pupil centre with 6° of pantoscopic tilt in the frame. This provides a reasonable compromise for distance and near vision use. It is also very important to examine the fit of any current spectacles, looking at aspects such as vertex distance, centration, pantoscopic tilt and the overall fit of the frame. When using a "specialist" lens design, it is also important to follow any specific recommendations provided by the lens manufacturer.

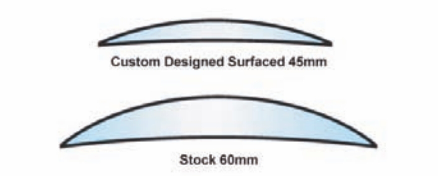

Figure 9.
Plus uncut lenses

Presbyopia

For the highly myopic presbyope we encounter a new problem, one of lens availability. Although the basic frame selection and decentration criteria remain the same, the only lens options available are very high index full aperture lenses. Examples of such lenses are given in Table 3.

It is interesting to note that some early presbyopes with high minus distance prescriptions are able to delay the need for a reading addition. This phenomenon occurs in spherical lenses because the mean oblique image vergence of the lens reduces with rotation away from the optical centre. Therefore if a -15.00 D distance lens is used for near vision, with the eye rotating to view a near object placed 30° from the principal axis, the oblique power obtained will be 0.67D less than the distance prescription. The lens effectively acts like a weak progressive power lens. This phenomenon, however, is not as noticeable with aspheric lens forms and can lead to complaints about poor near vision through distance aspheric lenses. In addition, myopes can create a reading addition by increasing the vertex distance.

Product	Index	Density	V-value	Range
Norville Solid 30mm bifocal	1.701 Glass	2.90	31	To -12.00
Zeiss Tital Gradal 3	1.706 Glass	3.19	39.5	To -20.00
Essilor Panamic Lineis	1.740 Resin	1.46	33	To -20.00
Nikon Presio GI	1.740 Resin	1.46	33	To -20.00
Zeiss Lantal Gradal Top E	1.800 Glass	3.62	35.4	To -20.00
Essilor Comfort	1.810 Glass	3.65	34	To -20.00
Essilor Panamic	1.810 Glass	3.65	34	To -18.00

Table 3
Very high refractive index bifocal/progressive lens availability for high myopia

High Hypermetropia

Lens material and form

High powered plus lenses present the practitioner with a different set of problems to overcome. Nasal edge thickness, centre thickness and overall weight are areas of most concern to both the practitioner and the patient.

The problems associated with high plus powered lenses are:

- Weight and thickness of the finished lenses;
- Oblique performance when viewing off axis;
- Magnification;
- Lack of accommodation if aphakic;
- Restricted field of view;
- Centration and prescribed prism.

Unlike high minus lenses, the finished blank size of a high powered plus lens plays a vital role in dictating the final thickness of the lens when glazed. The avoidance of unwanted decentration is essential and by combining minimum substance surfacing techniques along with higher refractive index materials and aspherical surfaces, surprisingly good results can be obtained (Figure 9).

The use of aspheric lens forms in very high plus powered lenses, for example, in the spectacle correction of aphakia, can dramatically improve the optical performance and cosmetic

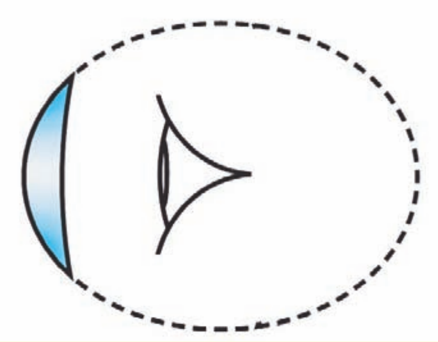

Figure 10.
A convex prolate ellipsoïdal surface

appearance of a high plus spectacle lens. As an example, consider a +12.00 DS lens made using spherical surfaces with a back surface power of -3.00 D, centre thickness 10mm and a centre of rotation distance of 25mm. If an eye rotates 30° away from the optical axis the oblique power will be +12.00DS/+1.50DC. In other words, the refracted pencil will include +1.50 D of unwanted cylinder. If the same lens were made using a convex prolate ellipsoidal surface (Figure 10) the off-axis performance would be +11.33 D at 30°. The lens is now free from aberrational astigmatism. However, it is not an ideal design as the mean oblique error (MOE) at 30º will be -0.68D. Another improvement in the performance obtained by the use of a prolate ellipsoidal surface is a reduction in distortion as the distortion produced by the aspheric lens will be around 30% less than in the spherical design[9].

Higher order aspherical surfaces can be obtained by deforming a conicoid to obtain a surface which flexes back on itself at larger diameters (Figure 11). Such surfaces are known as polynomial surfaces and were first employed for aspheric post-cataract lenses in 1978 (AO Fulvue Aspheric lens)[10]. The main advantage of this type of lens is the absence of ring scotoma and Jack-in-the-box effect which normally occurs at the edge of a strong plus lens. These two effects are shown in Figure 12 and are due to the abrupt change in power at the edge of the lens. With polynomial designs the surface power reduces from the centre of the lens to the edge, where the periphery is afocal. These lenses usually perform well out to about 30º from the optical axis.

Lenses such as the Essilor Omega, Zeiss Clarlet Aphal and Rodenstock Perfastar use a continuous polynomial aspheric front surface to give the effect of a blended lenticular. The chief advantage of these polynomial designs is the absence of any ring scotoma or Jack-in-the-box effect (Figure 13). The lens therefore offers awareness of objects in the peripheral field. However the field of clear vision is quite small and wearers often turn their head to obtain a wide field of vision. Polynomial lens designs combine the advantages of both lenticular and full-aperture lenses. To summarise, the advantages of the polynomial designs are:

- No visible dividing line
- Good mean oblique power when viewing off-axis;
- Reduced distortion;
- Very slightly thinner;
- Little sensitivity to fitting distance change;
- Increased field of view;
- Reduction in the "Jack-in-the-box effect";
- Flatter;
- Less magnification;
- Less TCA.

Although still available, traditional lenticular lenses for the correction of high hypermetropia have become far less popular since the introduction of polynomial designs. Table 4 lists a range of products that can be used for high plus dispensing.

It is also worth noting that although we rarely see aphakic patients today, when dispensing for aphakia an ultraviolet absorbing filter should be ordered as the natural crystalline lens is very good at absorbing UVA radiation. UV protection to 400 nm is advisable and there are many filters/coatings on the market that provide this level of protection.

When dispensing high plus lenses, particularly for the spectacle correction of aphakia, there must be cooperation and communication between the prescriber and the dispensing optician to ensure that the trial lens prescription is reproduced as accurately as possible. Points that must be considered include:

- The form of the trial lenses used;
- The pantoscopic angle of the trial frame;
- The vertex distance of the trial frame.

A diligent optometric practitioner

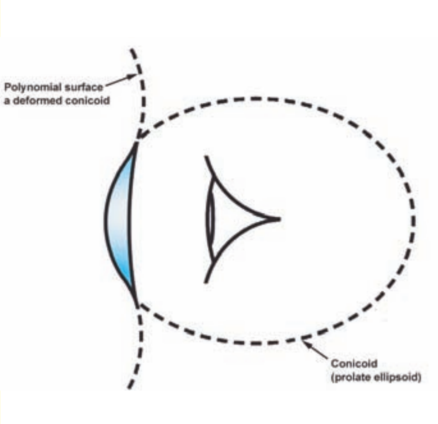

Figure 11.
A Polynomial surface

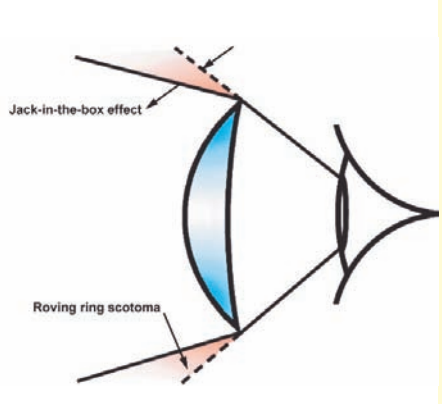

Figure 12.
Ring scotoma and the Jack-in-the-box effect

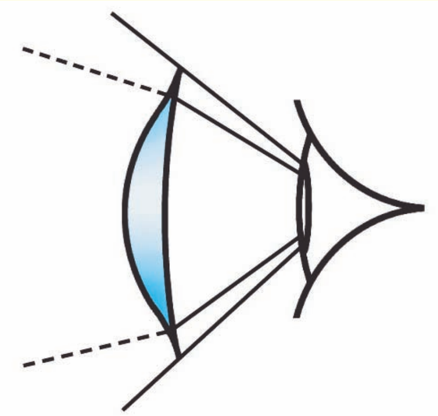

Figure 13.
The absence of ring scotoma and the Jack-in-the-box effect

may adjust and fit the chosen frame before the refraction takes place. He can then adjust the trial frame to match the characteristics of the final frame as opposed to the other way round!

Near vision effectivity error

Near vision effectivity error arises because lenses of the same power but manufactured in different forms are not interchangeable for near vision. Potential NVEE problems will only occur when dealing with medium to high hypermetropic patients. As an example, consider a +10.00 D lens made in plano-convex form and used for near vision (convex surface facing the eye) with an object placed at a distance of 33cm from the lens. The vergence incident at the lens will be -3.00 D and paraxial ray tracing will show that the vergence leaving the lens is +7.02 D. This value is known as the actual exit vergence. The anticipated exit vergence is found from -3.00 + (+10.00) and is +7.00 D. Near vision effectivity error (NVEE) is defined as the actual vergence leaving a lens minus the anticipated exit vergence. In this case the NVEE is +0.02 D and a value this small is of little consequence to the patient's visual comfort. If we now compare three more lenses (Table 5) all of back vertex power +10.00 D but in different forms, we can see the how lens form effects NVEE.

The bottom line here is that we have four lenses, all of the same back vertex power when measured on a focimeter, but providing four different effects for the wearer. These NVEE values illustrate how lenses of the same power but manufactured in different forms are not interchangeable for near vision. It also illustrates the problem of labelling the lenses in terms of their back vertex power! NVEE is of significance with medium/strong plus spectacle lenses only, never minus lenses and should always be considered for compensation as appropriate.

As mentioned in the section on high minus lenses, a loss in mean oblique image vergence occurs when of axis zones of the lens. This occurs when an aspheric lens is used for near vision and exacerbates the loss in power resulting from NVEE.

Frame Selection and Field of View

As with high minus lenses, high plus lenses need to be mechanically supported by the frame. The position of the centre of gravity of a plus lens can often lead to the frame being "front heavy" and therefore prone to slipping. Regular, fixed pad bridge and saddle bridge metal frames offer the best support and although adjustable pad bridges provide for useful refinement, excessive nasal edge thickness in the lens can obstruct correct placement of the pad arms and pads resulting in poor fitting. Smaller eye sized frames with wider bridges and swept out lugs are ideal, as these help to reduce the required decentration and overall thickness while retaining a reasonable adult sized head width in the frame.

When dispensing high plus powers, frames selected should:

- Be lightweight to avoid heavy/thick rims adding to a ring scotoma;
- Possess adjustable pads to allow some vertical movement of the optical centres;

Supplier/ product	Index	**V-value**	**Range**	**Form**
Norlite Aspheric	1.498	58	To +15.50	Aspheric
Norville Hi Drop	1.498	58	To +15.00	Aspheric
Essilor Orma Omega	1.500	58	To +20.00	Aspheric
Zeiss Clarlet	1.501	58	To +23.00	Spherical
Zeiss Aphal	1.501	58	To +23.00	Aspheric
Rodenstock Perfastar	1.502	58.2	To +22.00	Aspheric
Seiko SSV	1.67	32	To +16.00	Aspheric
Rodenstock Supersin	1.67	31.4	To +12.00	Aspheric
Rodenstock Cosmolit	1.67	31.4	To +12.00	Aspheric
Norville Highlite	1.701	31	To +12.00	Spherical
Zeiss Tital	1.706	39.3	To +25.00	Spherical
Norlite Lenticular	1.498	58	To +48.00	Spheric
Norlite Lenticular	1.498	58	To +22.00	Aspheric
Norville Lentic	1.701	31	To +28.00	Button
Norville Bi-Lentic	1.701	31	To +20.00	Spheric

Table 4
High plus single vision lens availability

- Have a box centre distance as close as possible to the patient's inter-pupillary distance in order to reduce or remove any decentration of the lens.

Centration and Fitting

When dispensing high plus powers the vertex distance should be kept as small as possible in order to:

- Maximise the field of view;
- Reduce convergence demand;
- Reduce the retinal image size;
- Reduce spectacle magnification;
- Reduce distortion and chromatic aberration;
- For single vision distance lenses the centration points should correspond to the monocular PDs;
- Near vision lenses should be centred according to the monocular NCDs;
- Vertical centration and pantoscopic tilt must correspond.

High Plus Presbyopes

For the high plus presbyope we again encounter the problem of lens availability with a greater range of bifocal than progressive lenses being available. Suitable products for this category are given in Table 6.

Astigmatism

Maximum and minimum edge thicknesses

The presence of a high cylinder within a prescription means that practitioners need to be able to estimate how the cylinder will affect the edge thickness of the finished lens. To do this we must of course compare the principal meridians and principal powers with the shape and dimensions of the chosen frame. As an example, consider the prescription -6.00/-2.00 x 85. The principal powers of this lens are -6.00 D along 85 and -8.00 D along 175. The maximum edge substance will therefore be found along the 175 meridian of the lens. The shape and size of the frame used to provide this prescription must be given careful consideration. A round shape would of course give unequal edge thicknesses with the horizontal meridian producing the thickest edge substance. If a modern shallow oval shape was employed, the smaller vertical frame dimension will produce the thin edge and the vertical the thick edge. The difference in the thick and thin edge substances will be more pronounced with a shallow oval shape that a round shape. If the power meridians were reversed i.e. -8.00 D along 85 and -6.00 D along 175, a shallow oval would be a better idea as there will be less difference between the thick and thin edge substances. Returning to the original case, it would be sensible to use a frame that has a reduced horizontal eye size for example, a "rounded" quadra.

When dealing with oblique

Lens Form	NVEE
Plano-convex	+0.02
Curved form	+0.42
Equi-convex	+0.13
Convex-plano	+0.31

Table 5
NVEE values for four +10.00D lenses

Supplier/product	Type	Seg	Index	Range to	Add to
Norlite 22mm	Bifocal	Round	1.498	To +16.00	To 20.00
Omega Aspheric 22mm	Bifocal	Oval	1.498	To +18.00	To 3.50
Orma Asph-lenti 25mm	Bifocal	Oval	1.50	To +17.00	To 2.75
Norlite Hyper Aspheric	Bifocal	Flat Top	1.498	To +15.00	To 5.00
Norlite 22mm Lenticular	Bifocal	Round	1.498	To +24.00	To 25.00
Norlite 22mm Asph-lenti	Bifocal	Round	1.498	To +20.00	To 6.00
Norlite 22mm Apsh-lenti	Bifocal	Flat Top	1.498	To +20.00	To 6.00
Perfastar Bifo 24mm	Bifocal	Round	1.502	To +16.00	To 4.00
Clarlet Duopal 25mm	Bifocal	Curve	1.501	To +20.00	To 3.50
Clarlet Alphal 22mm	Bifocal	Round	1.501	To +20.00	To 3.50
Rodenstock Grandasin	Bifocal	Curve	1.525	To +13.00	To 4.00
Norville Solid 30mm	Bifocal	Round	1.701	To +12.00	To 4.00
Varilux Omega Orma	PPL	-	1.50	To +15.00	To 4.00
Rodenstock Hyperop	PPL	-	1.67	To +13.00	To 3.00
Varilux Ipseo Lineis	PPL	-	1.74	To +13.00	To 3.50
Varilux Physio Lineis	PPL	-	1.74	To +13.00	To 4.00

Table 6
Bifocal and progressive lens availability in high plus powers

cylinders, the finished lens can become more difficult to visualise and it is vital to match and compare the principal powers of the lens with the frame dimensions. If the prescription

RT +0.50/+5.50 x 45
LT +0.50/+5.50 x 135

was matched with a frame that had a quadra or contour shape, the nasal edges of the lens would be very thick long the 135 meridian of the right lens and the 45 meridian of the left lens. The thin edge would of course be at ninety degrees to the thick edge. If the principal powers were reversed i.e. axis 135 in the right eye and axis 45 in the left eye, the differences between the thick and thin edges would be less extreme. When dealing with prescriptions of this nature it is necessary to employ minimum substance surfacing techniques resulting in an elliptical shaped uncut lens. It is also helpful to talk to your surfacing laboratory for advice on what may and may not work!

Bitoric lenses

For very high cylindrical powers we occasionally encounter a manufacturing problem when it becomes physically impossible to work the full cylindrical correction onto a single surface. To overcome this, a prescription laboratory may consider using a bitoric lens. In this form a toroidal surface is worked onto both sides of the lens, effectively splitting the prescribed cylinder across both surfaces.

Atoroidal Surfaces

Conicoidal and polynomial surfaces are rotationally symmetrical surfaces of revolution (they have the same degree of asphericity along all meridians) and can be used successfully for spherical prescriptions. For example a +2.00 D lens made with a +5.00 D front curve would be point-focal in form if the convex surface is a hyperboloid with a p-value of -0.1. The p-value of the aspherical surface would be the same (-0.1) along all meridians. When the prescription contains a cylinder the p-value of a symmetrical hyperboloidal surface would only be correct for one principal meridian of the lens. In the other meridian, the asphericity of the surface must be increased so that it is appropriate for this meridian of the lens. We have now described an aspherical surface that has two p-values at right angles to each other. Carl Zeiss employed a surface of this type for their original Hypal design (1986). This more complicated aspherical surface is not a rotationally symmetrical surface of revolution, but like a toroidal surface has a different shape along its two principal meridians. The geometry evolves from a minimum p-value along one meridian to a maximum p-value along the other. The surface employed on the original Zeiss Hypal lens was not strictly "atoroidal" as the surface did not incorporate the cylindrical correction which was worked, as usual, on the concave surface of the lens. When the toroidal surface itself is aspherised, it will have both different powers and different asphericity along each principal meridian. This type of surface is particularly useful when dispensing astigmatic lenses with a high cylindrical power[11].

Summary

Complex dispensing presents us with additional challenges to those in simple dispensing. These include:

- Care when selecting an appropriate frame in order to avoid decentration.
- The prudent consideration of lens material and form.

The above points are vital if we are to achieve a visually and cosmetically acceptable solution for our patients. It is the practitioner's professional duty to advise the patient having considered all the physical, mechanical and optical problems presented with a particular prescription. In the last twenty years or so, the optical profession has seen a transformation in spectacle lens dispensing and in the variety of lenses that are commercially available. Today, the practitioner has a wide selection of lens designs and materials to choose from. It is therefore vital that the practitioner is clear about the optical and mechanical properties of products. As professionals we have a duty to advise our patients of the advantages and disadvantages of products available. It is therefore important that practitioners keep up to date in terms of their product knowledge regarding lens design and availability. Question the patient carefully, listen to the responses and make a considered decision.

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About the authors

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References

1. Tunnacliffe A H (1995) *Essentials of Dispensing*. ABDO, London, **29-30**
2. Tunnacliffe A H (1995) *Essentials of Dispensing*. ABDO, London, **28**
3. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford **39**
4. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford, **102-103**
5. Keirl A (2007) The properties of ophthalmic lens materials. *Optometry in Practice* 8, **127-138**
6. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford, **111-112**
7. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford, **107-108**
8. Tunnacliffe A H (1995) *Essentials of Dispensing*. ABDO, London, **14-15**
9. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford, **174-175**
10. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford, **176-178**
11. Jalie M (2003) *Ophthalmic Lenses & Dispensing* 2nd Edition. Butterworth-Heinemann, Oxford, **214-215**

Module questions

Course code: c-8180

Please note, there is only one correct answer. Enter online or by form provided

An answer return form is included in this issue. It should be completed and returned to CET initiatives (c-8180) *OT*, Ten Alps plc, 9 Savoy Street, London WC2E 7HR by March 21 2008.

1. A prescription reads +8.00/+2.00 x 90 at 14mm. The final lens is to be dispensed at a vertex distance of 10mm. The most appropriate final lens to order is:

a. +8.25/+2.00 x 90
b. +8.25/+2.25 x 90
c. +8.00/+2.25 x 90
d. +8.00/+2.00 x 90

2. When dispensing high plus powers which of the following is not a reason for keeping the vertex distance as small as possible?

a. To maximise the field of view
b. To reduce convergence demand
c. To reduce the retinal image size
d. To reduce the centre thickness of the lens

3.Which of the following is not a reason for correctly centring a spectacle lens?

a. To position the lens where the paraxial prescription is most effective.
b. To reduce unwanted differential prismatic effects.
c. To reducing the possibility of the formation of ghost images.
d. To control spectacle magnification.

4. A pair of plus, distance aspheric lenses is to be dispensed to a subject with an inter-pupillary distance of 62mm. The frame chosen has a 48mm x 42mm oval shape. When the head is in the primary poison the subject's pupil centres lie 5mm above the horizontal centre line. The frame has a boxed centre distance of 66mm and the standard optical centre position coincides with the boxed centre. The pantoscopic angle of the frame is 10°. With regard to lens centration, which of the following would be ordered?

a. Decentre 2mm in.
b. Decentre 2mm in and 5mm up.
c. Optical centres to coincide with the pupil centres.
d. Optical centres to coincide with the boxed centres.

5. Which of the following will not assist in keeping the effects of TCA to a minimum?

a. Use materials with a high V-value.
b. Apply correct horizontal and vertical centration and pantoscopic tilt.
c. Fitting the spectacle frame with as large a vertex distance as possible.
d. Use best form designs.

6. Which of the following statements is most correct?

a. For all mineral and resin spectacle lens materials, as the refractive index increases, so does the density.
b. The term density simply relates to the weight of a finished spectacle lens.
c. The density of a material is given by mass/volume.
d. A lens manufactured using a low refractive index material will always weigh less than the same lens manufactured using a very high refractive index material.

7. When dispensing for high myopia, which of the following products is likely to produce a lens with the thinnest edge substance?

a. Essilor Lineis
b. Seiko SPG
c. Zeiss Lantal
d. Zeiss Tital

8. Which of the following statements is most correct?

a. Ring diplopia is a common complaint from high myopic patients.
b. A 44 year old medium to high myope might enjoy more comfortable near vision in spherical as opposed to aspheric lenses.
c. The Rodenstock Lentilux lens is manufactured using a resin material.
d. When dispensing medium to high plus lens, the uncut size used is of no consequence.

9. Which of the following statements is most correct?

a. If a high powered plus lens with a spherical back vertex power is manufactured with a convex prolate ellipsoidal surface, aberrational oblique astigmatism will be reduced.
b. If a high powered plus lens with a spherical back vertex power is manufactured with a convex prolate ellipsoidal surface, both aberrational oblique astigmatism and distortion will be reduced.
c. Ring scotoma and the Jack-in-the-box effect are not eliminated with polynomial aspheric designs.
d. The lens of choice for a high powered plus lens of spherical back vertex power is one that incorporates an atoroidal surface.

10. Which of the following statements regarding near vision effectivity error (NVEE) is most correct?

a. Lenses of the same power but manufactured in different forms are interchangeable for near vision.
b. NVEE is of significance with medium/strong plus spectacle lenses and is more significant when an aspheric lens is used.
c. NVEE is of significance with high powered minus lenses.
d. NVEE is a dispensing and not an optometric problem.

11. An atoric lens would be the lens of choice for which of the following prescriptions:

a. +2.00DS
b. +6.00/+3.00 x 180
c. -4.00DS
d. +8.00 DS

12. Which of the following lens shapes is most suitable for the prescription 5.00/-1.50 x 180?

a. Round
b. Oval with the long axis horizontal
c. Oval with the long axis vertical
d. Aviator

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