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Aspheric Lenses

DISPENSE WITH CONFIDENCE PART 2 C-19559 O/D

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An aspheric lens is classified as one where either one, or both, surfaces are non-spherical, which means it could be toroidal or cylindrical. Such a surface is one which has been produced by rotating an ellipse about its major diameter, producing a conic section (oblate ellipse, circle, prolate ellipse, parabola or hyperbola). Aspheric lenses utilise a non-spherical surface with surface astigmatism to neutralise oblique astigmatism produced by off-centre refraction. They provide both the visual advantages of best form lenses and the cosmetic advantages of thinner, flatter and lighter lenses. This article describes the various types of aspheric lenses and the main dispensing considerations.

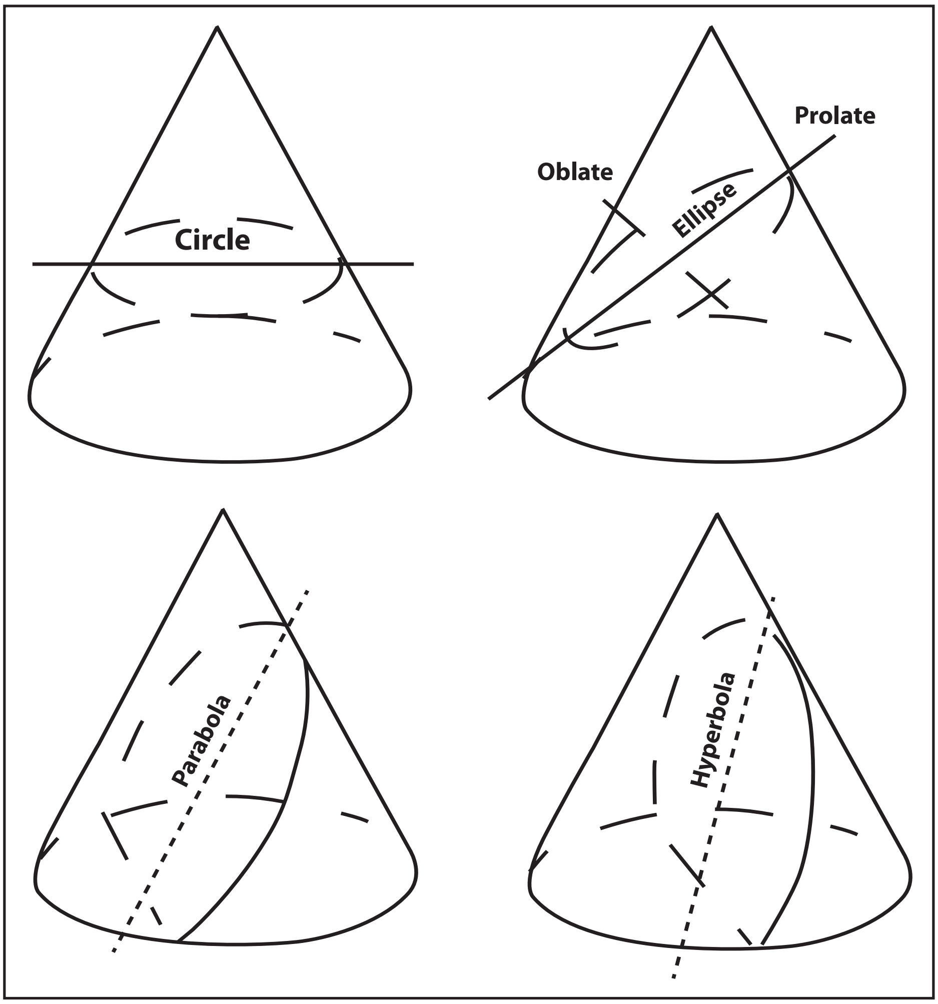

Figure 1

The origins of an aspheric lens surface are based on the rotation of an elliptical shape forming a conic shape. The various sections that can be produced are a circle, oblate ellipse, prolate ellipse, parabola and hyperbola. Reproduced with permission from Walsh[1]

What are aspheric lenses?

When a circle is rotated about its diameter, the solid form which results is a sphere and therefore, any lens produced from this will have a surface of a spherical nature. In contrast, any shape of variable diameter (eg an ellipse) which is rotated in a similar fashion will not produce a spherical solid – a lens produced from such a solid will have a surface that is classed as being aspherical. The latter encompasses both cylindrical and toroidal surfaces and these are collectively known as conic sections since they are curved forms which originate from sections of a cone (Figure 1). BS EN ISO 13666 (1999) states that aspheric lenses must be rotationally symmetrical. This excludes both asphérised astigmatic (atoral) and progressive addition lens surfaces.[1] When an ellipse is rotated about its x-axis, an ellipsoid is formed. If the major axis is horizontal then this is referred to as a prolate ellipsoid. However, if the minor axis is horizontal, it is referred to as an oblate ellipsoid. The parabola is in a plane parallel to the side of the cone. When a parabola is rotated about its x-axis, a paraboloid is formed. Should the plane at which the section is made be tilted beyond that of the parabola it is called a hyperbola. When a hyperbola is rotated about its x-axis, a hyperboloid is formed. Mathematically, aspheric surfaces are derived using the formula: $y^2=2r_0x - px^2$ where r0 is the radius of curvature of the surface at the vertex and p is the eccentricity of the curve (where the type of curve is determined by the value given).[2] Practically, an aspheric lens surface can be identified using a lens measure. If the sag of a spherical lens is read using a lens measure, the measurement obtained will be the same, no matter where the lens measure is placed on the surface. If this process is repeated for an aspheric lens, however, a change of curvature across the surface will be seen as the lens measure is moved. Therefore an aspheric surface is spherical at the very centre but becomes astigmatic away from the optical centre. The gradual change in curvature differs between positive and negative powered lenses such that the curvature of a positive powered lens gradually flattens from the centre to the periphery, whilst that of a negatively powered lens steepens from the centre to the periphery. Accordingly, this represents a change in tangential power,

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which means that, at each point on the surface (apart from the centre of the lens) there is surface astigmatism, which is utilised to counteract any oblique aberrational astigmatism. This in turn results in an improvement in optical quality of the retinal image formed. The other corresponding feature of aspheric lenses is that the sag of the lens is smaller than that of a spherical lens of the same diameter. As such, this allows thinner lenses to be manufactured, which also makes lenses correspondingly lighter.

Evolution of aspheric lenses

Aspheric lenses were first described in the early 1900s and Zeiss subsequently produced a famous range called the Katral lenses, which utilised concave ellipsoid surfaces to eliminate oblique astigmatism and reduce pincushion distortion.[2] These lenses were usually dispensed to patients post-cataract extraction, with resulting high hyperopic refractive errors that exceeded the +7.00DS limit of Tscherning's ellipse; lenses of such power cannot be made free of oblique astigmatism if made in the spherical form (Figure 2).[1] It was not until the 1960s, however, when changes occurred following the introduction of CR39 as a lens material. Then, the most widely used aspheric lenses employed convex ellipsoid surfaces to eradicate oblique astigmatism and diminish distortion and transverse chromatic aberration. This trend continued in the 1970s, whereby flatter ellipsoid curves were used to eliminate aberrations, but resultant uncut diameters of the lenses were very large and, in fact, using this flatter form resulted in overcorrection of oblique astigmatism at the lens periphery, inducing large amounts of mean oblique error and giving poor peripheral visual acuity. Lenses using such flatter curves were subsequently introduced to the market as blended lenticular lenses.[2] In 1976, Davis and Fernald were granted US patents for a series of aspheric lenses based on improved cosmetic appearance and minimum tangential error best form principles.[3] In 1981, Mo Jalie patented a design with the aspheric surface on the front surface of positive lenses (convex hyperboloid) and on the back surface of negative lenses (concave hyperboloid).[4] The reduction in thickness is possible through the use of hyperboloid surfaces, which means that the lens is flatter, which reduces the lens sag, which in turn reduces lens thickness (see the first article of this series, *OT* August 17, 2012). Flattening of the lens also reduces spectacle magnification whilst the aspheric surface serves to eliminate the high levels of oblique astigmatism. Such lenses are used in today's low power aspherics for hyperopic prescriptions, but not for myopic corrections due to the lack of toroidal surfacing tools. In the latter 1970s and early 1980s, the use of computer-aided design enabled more complex polynomial aspheric lens surfaces to be manufactured. These surfaces are generally of a higher order than the conic surfaces previously described, and their surfaces are denoted by a complex mathematical polynomial equation. They combine the advantages of lenticular and full aperture lens designs and so result in thinner and lighter lenses with no distinct dividing line, no annular scotoma and improved optical performance.[4]

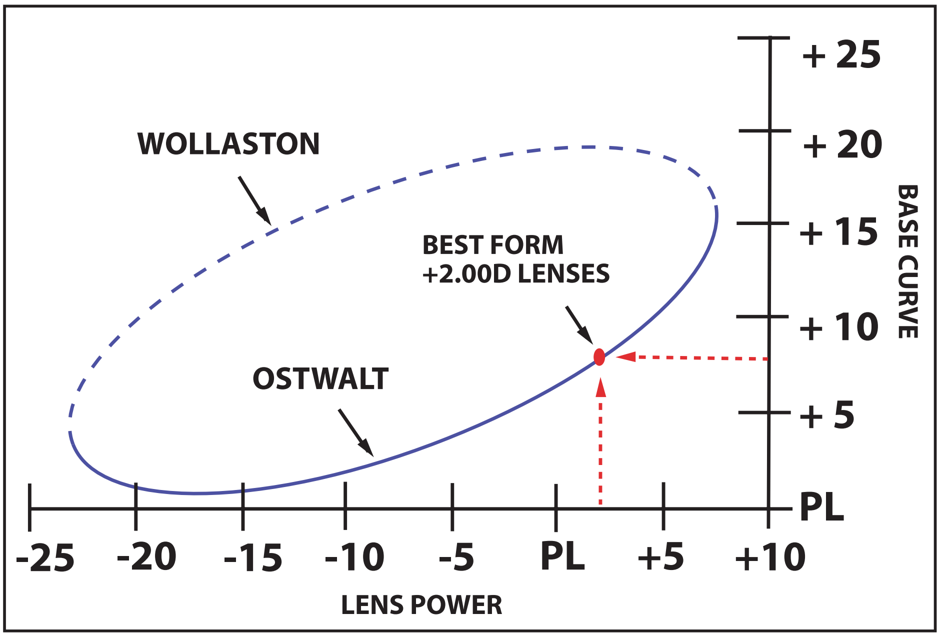

Figure 2

Tscherning's ellipse. The focal power of the ellipse is about +7.00DS and lenses above this power will experience aberrations such as oblique astigmatism that need aspheric lens designs to eliminate.

Current aspheric lens designs

Modern aspheric spectacle lens forms are now made according to far more complex criteria. They are produced by taking into account parameters such as refractive power, final lens thickness, face-form (dihedral) angle, pantoscopic angle and back vertex distance. Consequently aspheric surfaces comprising polynomial surfaces have been produced and this has been made possible with computer numerical control (CNC) technology. The ways in which polynomials differ from blended lenticulars are that they have excellent optical properties in their aspheric zones and the blending which occurs is concave. Like blended lenticulars, polynomials are thinner and lighter than full-aperture lenses of the same prescription and there is no dividing line between zones. The patient has a wide field of view and no ring scotoma. Aspheric designs for myopes utilise convex oblate ellipsoid or convex polynomial surfaces in order to produce thinner and flatter point focal lenses. Atoric lenses differ from standard aspheric surfaces in that the oblique astigmatic aberrations are controlled along both meridians and so the p-value (eccentricity of the curve) of the aspheric surface differs from a minimum along one meridian to a maximum along the other.[4]

Low powered aspheric lenses

It is in more recent years that aspheric designs have been used to correct prescriptions of low positive power. The use of such lenses again confers the benefits of making the lenses thinner and lighter. The reduction in thickness is as a result of initially making the lens flatter in form by utilising a shallower base curve, whilst also having a sag which is smaller than a spherical surface of the same vertex radius (and for any lens diameter) (Figure 3). This flatter aspheric lens form also neutralises oblique aberrational astigmatism. The same principles apply to negative lenses with regard to flattening them to make them thinner. Here one surface is made aspheric to restore the off-axis performance of the flatter lens form. It is generally accepted that convex oblate ellipsoid surfaces are used to reduce edge thickness of negatively powered lenses. This lens form enables positive surface astigmatism to neutralise the negative oblique astigmatism which results from the flat-form lens.[2]

Dispensing of aspheric lenses

When dispensing aspheric lenses, there are some rules by which to abide. These are listed below:

• Ensure correct horizontal centration of the lenses by taking monocular pupillary distances

• Ensure correct vertical centration of the lenses by taking heights of the optical centres. The vertical centration should then be compensated for the pantoscopic tilt of the spectacle frame to ensure that the optical axis of the lens passes through the eye's centre of rotation. The pantoscopic tilt angle should be measured and for every 2° of tilt, the vertical centres should be decentred 1mm down (by applying the dispenser's rule)

• The dihedral (face-form) angle of the frame front should be 5° for right and left sides. This ensures that there is no horizontal prismatic effect at the near centration points

• Keep the back vertex distance to a minimum as the back surface of the lens will be flatter than in a spherical lens, which enables the lenses to be fitted closer to the eye. However, owing to the flatter back surface, consider the patient's eyelashes as they should not touch the lens

• Unlike spherical lens forms, prism should not be provided by decentration in aspheric lenses. If an aspheric lens were to be decentred, the vertex of the aspheric surface no longer occupies the position assumed when originally designing the lens and, as such, the aspheric surface will no longer occupy a position in which symmetry occurs for ocular rotations away from the optical axis. Therefore prismatic correction must be incorporated during working of the lens[5]

• The flatter curves of aspheric lenses result in unwanted reflections, which are inevitably noticed by the patient. For this reason, aspheric lenses should always be dispensed with a multi anti-reflection (MAR) coating. This also improves the cosmetic appearance of the lenses

• Distortion may be greater in aspheric lenses compared to spherical lenses and so the patient may require some time to adapt[6]

	Spherical lens	Aspherical lens
Refractive Index	1.498	1.60
Centre thickness	6.1mm	5.1mm
Weight	12g	11g

Figure 3

Benefits of aspheric lenses. The spectacles shown have lenses of +6.00DS power. The lens on the left of the image is of spherical form whilst that on the right of the image is of aspherical form. The aspheric lens is clearly flatter and thinner. Other differences in properties are also shown.

Case scenario 1: myope

Prescription -7.00/-1.00x90 R+L

When dispensing aspheric lenses for such a myopic patient, the index of the material needs to be discussed with the patient. The patient is likely to be concerned by the edge thickness and weight of the finished lens and these can naturally be reduced with a higher index material. Combining this with an anti-reflection coating will provide the best lens of choice. Such lenses give a reasonable degree of control over the edge substance while providing good off-axis performance in oblique gaze, whilst serving to control the effects of distortion. In addition, there is less minification of the eyes too. For this prescription, 1.74 aspheric hard and MAR-coated lenses would be a good option. It is also important to be sensible with frame selection – consider shape and size carefully and fit the spectacle frame with as small a vertex distance as possible. If considering glass lenses, it is important to remember the refractive index of the lens increases with density (mass divided by volume). If weight is the patient's priority, then a plastic lens has to be the material of choice. It is, of course, important to ensure that the material best suited to the patient's requirements is always dispensed.

Case scenario 2: hyperope

Prescription +7.00/-1.00x90 R+L

When dispensing aspheric lenses for a hyperopic patient, nasal edge thickness, centre thickness, weight and overall cosmetic result will be the areas of most concern to the patient. Unlike minus lenses, the finished blank size of a positive lens plays an important role in dictating the thickness of the lens when glazed. The avoidance of unwanted decentration is vital and by combining minimum substance uncuts along with using aspherical surfaces, optimum results can be obtained. Only plastics should be considered for high hyperopes due to the volume of material involved; glass lenses would prove very heavy and unsafe. A hard and MAR coating should be dispensed on the lenses in order to prevent unwanted reflections. Lenticular lenses can be considered, not only standard lenticulars but also blended lenticulars, or even polynomial aspheric lenticular lenses too. Polynomial lenses give the main advantage of an absence of a ring scotoma and Jack-in-the-box effect which normally occurs at the edge of a strong positive lens. Frame selection is also important to ensure the shape and the size does not lead to overly great edge and/or centre thickness. For this prescription, 1.5 Omega hard and MAR coated polynomial lenses would be a good option.

In summary

Aspheric lenses do not necessarily provide better optical performance than best form lenses, but simply provide comparable performance without the restrictions imposed by best form base curve selection. However, the advantages of aspheric lenses over spherical lenses are:[7]

- Flatter than the best form spherical surface
- Elimination of large amounts of oblique astigmatism
- Decreased spectacle magnification/ minification as shape factor is reduced
- Increased field of view
- Reduced lens thickness
- Reduced edge substance in negative lenses
- More lightweight
- Good off-axis optical performance
- Controlled distortion
- Better cosmesis

Conclusion

Aspheric lenses are a highly useful group of lenses which provide visual and cosmetic benefits for patients. Unlike spherical lenses, aspheric lenses flatten progressively from the centre to the lens margin. This results in lenses of reduced thickness, which are consequently more lightweight and confer decreased peripheral visual distortion. Aspheric lenses can be ordered in high index materials for the ultimate in attractive thin lenses.

About the author

Eirian Hughes is the dispensing optician in charge of teaching dispensing to final year BSc optometry students at the School of Optometry and Vision Sciences, Cardiff University. She is a module tutor for paediatric optometry and eye care for people with learning disabilities for the MSc in clinical optometry. Her BSc and PhD are in medical biochemistry.

References

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1. Which of the following is NOT a conic section?
a) Oblate ellipse
b) Asymptote
c) Circle
d) Hyperbola

2. Which of the following is NOT an advantage of aspheric lenses?
a) Lighter in weight
b) Reduced spectacle magnification
c) More curved lens form
d) Cosmetically more appealing

3. Which of the following is the dispenser's rule for aspheric lenses?
a) For every 5° of pantoscopic tilt, vertical centres should be decentred 2mm down
b) For every 1° of pantoscopic tilt, vertical centres should be decentred 1mm down
c) For every 2° of pantoscopic tilt, vertical centres should be decentred 1mm down
d) For every 2° of pantoscopic tilt, vertical centres should be decentred 2mm down

4. Which of the following measurements is NOT required when dispensing aspheric lenses?
a) Horizontal centration
b) Vertical centration
c) Dihedral angle
d) Inset

5. Which British Standard defines aspheric lenses?
a) BS EN ISO 13666
b) BS EN 166
c) BS 2738
d) BS EN ISO 7998

6. Which of the following is MOST likely to improve the optical and cosmetic quality of aspheric lenses?
a) A photochromic lens
b) A hard coat
c) A mirrored coating
d) An anti-reflection coating