UNRAVELLING TORIC RGP CONTACT LENSES

This lecture deals primarily with what happens on the front surface of a toric RGP lens when you do or do not provide correction for residual astigmatism. While it is not necessary for you to specify the different types of toric lens design (i.e. compensated bitoric, alignment bitoric, etc) when ordering a toric RGP lens, a better understanding of toric lens optics will make it easier for you to fit and prescribe toric RGP contact lenses.

Consider the toric RGP lens nomenclature we have previously encountered:

1. Spherical power equivalent bitoric lenses (compensated bitorics) - these are lenses which do not correct for any residual astigmatism. They are bitoric because the front surface contains a cylinder solely for the correction of the induced astigmatism.

2. Cylindrical power equivalent (CPE) toric lenses - all these lenses incorporate a correction for residual astigmatism. This category can be further subdivided as follows:

(i) Alignment bitoric - these have both a toroidal front and back surface. The front surface incorporates correction for residual astigmatism as well as for the induced astigmatism. In addition, the axes of the spectacle refraction over the lens correspond with the principal meridians of corneal curvature, so the correction for the residual astigmatism will be along one of the principal meridians of the lens (hence the name 'alignment bitoric').

(ii) Back surface torics - these have a toroidal back surface but a spherical front surface. The design principle is similar to that for alignment bitorics. As with alignment bitorics, the front surface incorporates correction for residual astigmatism as well as for the induced astigmatism and the correction for the residual astigmatism is along one of the principal meridians of the lens. The correction for the residual astigmatism, however, is equal and opposite to the correction for the induced astigmatism. Hence the two required cylindrical corrections cancel each other out, meaning that the front surface is left spherical.

(iii) Front surface torics - these have a toroidal front surface and a spherical back surface. They are generally used when there is significant residual astigmatism but minimal corneal astigmatism, so a toroidal BOZR is not an option due to reasons of rotation and stability.

(iv) Oblique bitorics - as with alignment bitorics, these have both a toroidal front and back surface. As with alignment bitorics, the front surface incorporates correction for residual astigmatism as well as for the induced astigmatism. With oblique bitorics, however, the principal meridians of the toroidal back and front surfaces are not parallel, due to a difference between the axes of the spectacle refraction and the principal meridians of corneal curvature.

We will not be concerned with either front surface torics or oblique bitorics in this lecture.

3. Contact lens toricity - the toricity of the contact lens with respect to the eye (tears).

4. Air cylinder - the toricity of the contact lens in air.

5. Residual astigmatism - that part of the ocular astigmatism which is not due to the cornea.

6. Induced astigmatism - the astigmatic effect created in the contact lens/tear lens system by the toroidal back optic zone bounding two surfaces of different refractive index, namely the lens (refractive index 1.43 to 1.49 depending on the material) and the tears (refractive index 1.336). Induced astigmatism is introduced into the system every time toroidal back optic zone surfaces are used.

When fitting toric RGP contact lenses, there are 3 possible scenarios:

1. The patient has no or insignificant residual astigmatism. The corneal astigmatism is equal or approximately equal to the ocular astigmatism. In this case we use a compensated bitoric design (spherical power equivalent lens).

2. The patient has significant residual astigmatism and the axis of the residual astigmatism corresponds to one of the principal meridians of curvature of the cornea (note that you may need to approximate to satisfy this requirement). In addition, the axis of the residual astigmatism is the same as that of the corneal astigmatism. In this case, we need to use a cylindrical power equivalent (CPE) toric lens, either an alignment bitoric or back surface toric design.

3. The patient has significant residual astigmatism and the axis of the residual astigmatism corresponds to one of the principal meridians of curvature of the cornea (again you may need to approximate to satisfy this requirement). This time, however, the axis of the residual astigmatism is at 90 degrees to the axis of the corneal astigmatism. Here we also need to use a CPE toric lens, although this time only an alignment bitoric design is possible (it is not possible to design a back surface toric in this situation).

Note again that in these scenarios we are assuming that corneal toricity is greater than 2.00D (so front surface torics are not applicable) and that the axis of the residual astigmatism is within about 25 degrees of one of the principal meridians of curvature of the cornea (hence we need not worry about oblique bitorics).

Following are four examples which demonstrate how both the contact lens toricity and the magnitude and type of residual astigmatism will determine the eventual toric RGP lens design.

Example 1: Compensated Bitoric

Ocular Rx +3.00/-6.00 x 180 K readings 8.00 (42.19) @ 180
7.00 (48.21) @ 90

BOZR: 8.00mm n = 1.47
7.00mm t = 0.30mm

Over-refraction over a 8.00mm BOZR trial lens with BVP of +1.00D gives +2.00DS.

Along 180,

$$F_2 = \frac{1 - 1.47}{8.0 \times 10^{-3}} = -58.75$$

$$F_v' = +1.00 + 2.00 + \left(\frac{336}{8.00} - \frac{336}{8.00}\right) = +3.00\ D$$

$\therefore \quad F_1 = +60.98$

Along 90,

$$F_2 = \frac{1 - 1.47}{7.0 \times 10^{-3}} = -67.14$$

$$F_v' = +1.00 + 2.00 + \left(\frac{336}{8.00} - \frac{336}{7.00}\right) = -3.00D$$

$\therefore \quad F_1 = +63.31$

The total power of the front surface is +60.98DS with +2.33DC x 180. This front surface cylinder represents the correction for the induced astigmatism.

The correction for the induced astigmatism is always a plus cylinder with *same axis as the flatter principal meridian of the cornea*. (in other words, the same axis as the corneal cylinder). The magnitude of the induced astigmatism is directly proportional to the degree of contact lens toricity and the refractive index of the lens material.

Example 2: Compensated Bitoric

Ocular Rx +3.00/-6.00 x 180 K readings 8.00 (42.19) @ 180
7.00 (48.21) @ 90

BOZR: 8.00mm (Note the decreased contact lens toricity) n = 1.47
7.15mm t = 0.30mm

Over-refraction over a 8.00mm BOZR trial lens with BVP of +1.00D gives +2.00DS.

Along 180,

$$F_2 = -58.75$$

$$F_v' = +3.00$$

$\therefore \quad F_1 = +60.98$

Along 90,

$$F_2 = \frac{1 - 1.47}{7.15 \times 10^{-3}} = -65.73$$

$$F_v' = +1.00 + 2.00 + \left(\frac{336}{8.00} - \frac{336}{7.15}\right) = -2.00D$$ (actually -1.99 but rounded off to -2.00)

$\therefore \quad F_1 = +62.92$

Note the reduced front surface toricity compared with that in Example 1 (1.94D compared to 2.33D).

A quick way to calculate the induced astigmatism is to use the appropriate radii considered with the change in travelling from the RGP lens to tears.

Induced astigmatism can be calculated by the following formula:

$$\frac{1000(1.336 - n_{cl})}{BOZR_{fl}} - \frac{1000(1.336 - n_{cl})}{BOZR_{st}}$$

where n_{cl} = the refractive index of the contact lens material (usually somewhere between 1.45 and 1.48; 1.47 is a good approximation) and $BOZR_{fl}$ and $BOZR_{st}$ are the BOZR along the flat and steep meridians of the contact lens respectively.

For example 2, using this method the value for the induced astigmatism is = 1.99D. Allowing for rounding errors, this value shows agreement with that obtained through calculating the resultant front surface powers (1.94D)

Example 3: Back Surface Toric

It is often thought that the induced astigmatism created by using a toroidal back optic zone surface on an eye with corneal astigmatism and residual astigmatism will fortuitously cancel out the residual astigmatism. In practice, however, this will only occur in a small percentage of cases. Indeed, the induced astigmatism usually exaggerates the effect of the residual astigmatism.

Very occasionally, however, a case of induced and residual astigmatism cancelling out one another is encountered in practice, as in this example.

Ocular Rx +3.00/-4.00 x 180 K readings 8.04mm (42.00D) along 180
7.50mm (45.00D) along 90

BOZR: 8.00 n = 1.47
7.55 t = 0.25mm

A spherical RGP trial lens with BOZR 7.95mm and BVP +1.00D is placed on the cornea. Refraction over this trial lens gives +1.50/-1.00 x 180 and 6/6 acuity. Hence we have residual astigmatism equal to -1.00DC x 180.

The induced astigmatism can be determined using the formula previously described:

$$\frac{1000(1.336 - n_{cl})}{BOZR_{fl}} - \frac{1000(1.336 - n_{cl})}{BOZR_{st}}$$

Induced astigmatism = $\frac{-134}{8.00} - \frac{-134}{7.55} = 1.00D$

The correction for the induced astigmatism is always a plus cylinder with same axis as the flatter principal meridian of the cornea. (in other words, the same axis as the corneal cylinder). Hence, in this example, the induced astigmatism will be corrected by +1.00DC x 180.

The correction for the residual astigmatism is -1.00DC x 180, so the residual astigmatism and the induced astigmatism should cancel each other out. This can be confirmed by calculation of the back vertex powers and the front and back surface powers of the lens (assuming a lens centre thickness of 0.25mm).

Along 180,

$$F_v' = +1.00 + 1.50 + \left(\frac{336}{7.95} - \frac{336}{8.00}\right) = +2.75D$$

$$F_2 = \frac{1000(1 - 1.47)}{+8.00} = -58.75D$$

$\therefore \quad F_1 = +60.86D$

Along 90,

$$F_v' = +1.00 + 0.50 + \left(\frac{336}{7.95} - \frac{336}{7.55}\right) = -0.75D$$

$$F_2 = \frac{1000(1 - 1.47)}{+7.55} = -62.25D$$

$\therefore \quad F_1 = +60.86$

The front surface is spherical (same power along both principal meridians) so the residual and induced astigmatism have indeed cancelled each other out. (When calculating surface powers, for clinical purposes a difference in power of ≤0.12D between the principal meridians constitutes a spherical surface.)

A back surface toric design is only possible if the correction for the residual astigmatism is *equal* and *opposite* to the correction for the induced astigmatism. The residual astigmatism will be *opposite* to the induced astigmatism when the axis of the residual astigmatism is the same as the flatter principal meridian of the cornea. In the above example, both the axis of the residual astigmatism and the flatter principal meridian of the cornea were along 180.

Many practitioners believe that most toric RGP lenses can be made up in a back surface toric design and yet the preceding discussion clearly demonstrates the absurdity of this position. The likelihood of the residual astigmatism being both equal and opposite to the induced astigmatism is low, so only in a small percentage of cases will a back surface toric design be appropriate. As was stated earlier on, the induced astigmatism will generally exaggerate the effect of the residual astigmatism.

Example 4: Alignment Bitoric

Ocular Rx +3.00/- 4.00 x 180 K readings 8.00 (42.19) @ 180
7.00 (48.21) @ 90

BOZR: 8.00 n = 1.47
7.15 t = 0.30mm

Over-refraction over a 8.00mm BOZR trial lens with BVP of +1.00D gives +4.00/-2.00 x 90 (we now have a residual cylinder equal to -2.00DC x 90).

Along 180,

$F_2 = -58.75$

$F_v' = +1.00 + 2.00 + \left(\frac{336}{8.00} - \frac{336}{8.00}\right) = +3.00D$

$\therefore \quad F_1 = +60.98$

Along 90,

$F_2 = -65.73$

$F_v' = +1.00 + 4.00 + \left(\frac{336}{8.00} - \frac{336}{7.15}\right) = 0.00D$

$\therefore \quad F_1 = +64.86$

This alignment bitoric corrects for residual astigmatism and it has both a toric front and toric back surface.

In this example, the axis of the residual astigmatism is the same as the steeper principal meridian of the cornea (in other words, at 90 degrees to the flatter principal corneal meridian) and so a back surface toric design is not possible. The front surface toricity in this case (64.86 - 60.98 = 3.88) is a combination of the correction for the induced astigmatism (1.93) and the residual astigmatism (2.00).

Remember, a back surface toric design is only possible if the residual astigmatism is *equal* and *opposite* to the correction for the induced astigmatism. The correction for the induced astigmatism is always a plus cylinder with *same axis as the flatter principal meridian of the cornea*. (in other words, the same axis as the corneal cylinder). Hence, the residual astigmatism will be *opposite* to the induced astigmatism when the axis of the residual astigmatism is the same as the flatter principal meridian of the cornea.

Hence, a back surface toric design is only possible when the axis of the residual astigmatism is the same as the axis of the corneal astigmatism **AND** the magnitude of the residual cylinder is approximately equal to the magnitude of the induced astigmatism. The amount of induced astigmatism can be manipulated slightly by altering the contact lens toricity (i.e. the BOZR), however the primary consideration when specifying BOZR must always be the alignment of the lens to the cornea.