CHAPTER 11

ASTIGMATISM

Astigmatism is that condition of refraction, wherein a point of light cannot be formed upon the retina [120]. Astigmatism can either be an error of curvature, centring, refractive index, retinal irregularities or combinations of these factors. Astigmatism due to curvature errors, usually arise from the anterior or posterior surface of the cornea, as well as the surfaces of the crystalline lens. When the crystalline lens is slightly out of line with the other components of the optical system, centring astigmatism results. Finally, small differences in the refractive index of the different optical components (cornea, crystalline lens and vitreous) can also cause astigmatism [138].

Regular astigmatism is defined as astigmatism where the two principle meridians are at right angles to one another. The majority of regular astigmatism is either with-the-rule (steepest meridian is along the vertical or 90° meridian) or against-the-rule (steepest meridian is along the horizontal or 180° meridian), but oblique astigmatism is not uncommon (axis of principle meridians oblique but still at right angles to one another). Irregular astigmatism is defined as astigmatism where the principle meridians are not at right angles so that no geometrical figure is adhered to. Irregular astigmatism is commonly caused by pathological conditions of the cornea (keratoconus) or the crystalline lens (lenticonus) and cannot be effectively corrected by spectacles [138].

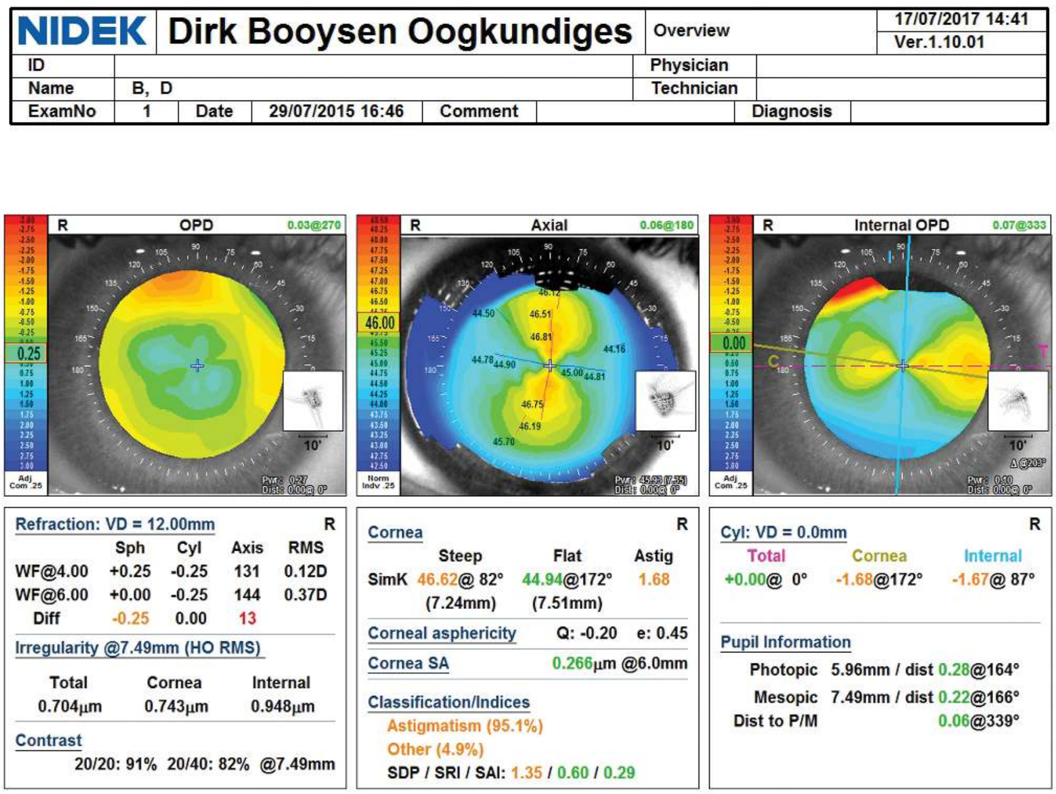

Figure 39: With the rule corneal astigmatism and against the rule lenticular astigmatism measured using the Nidek OPD3® corneal analysis system

Other than the vision problems caused by astigmatism, the contact lens practitioner also have to consider the curvature of the cornea especially when fitting RGP lenses. Soft lenses drape over the cornea and different methods can be used to stabilise the rotation of these lenses when correcting astigmatism. RGP lenses correct regular (and irregular) corneal astigmatism by creating a new spherical surface for the eye. The tear layer between the lens and the cornea then corrects the astigmatism. Therefore, these lenses do not have to be rotationally stable. Different RGP designs are used to correct corneal astigmatism while ensuring a good alignment fit (Table 29) [1, 88, 128].

Table 29: Choice of lens design according to corneal astigmatism

Amount of corneal astigmatism	RGP design
Mild 0.5–2.00DC	C3, C4, Multiflo[2], Aspherics
Moderate 2.00–3.00DC	Asticon or Toric peripheral curve and Cylcon or toric base curve lenses
High >3.00DC	Cylcon or toric base curve lenses
Against-the-rule - Steep meridian horizontal	Normally large diameter lenses, asticon or cylcon lenses
Irregular	Specialised lenses such as Rose K, Clek K3, Keratocon

RESIDUAL ASTIGMATISM (RA)

Residual astigmatism can be defined as the "astigmatic refractive error that remains when a soft or RGP contact lens is placed on the cornea to correct the existing ametropia" [1, 139, 140]. Residual astigmatism can be further classified as;

Physiological RA [1, 139, 140]

- Astigmatism from the anterior corneal surface not neutralised by the tear lens
- Astigmatism from the posterior surface of the cornea
- Astigmatism from the crystalline lens surfaces or tilt of the crystalline lens
- Eccentric position of the fovea or irregularities in the macular area
- Misalignment of various elements of the eyes optical system

Induced RA [1, 139, 140]

Astigmatism can be induced by the contact lens itself either due to toricity, warping or flexure of the lens. Astigmatism can be also induced when a toric back surface lens is placed on a toric cornea and due to the difference in refractive indexes between the lens and the tears. This induced astigmatism is normally against-the-rule if the spectacle astigmatism is with-the-rule. Induced astigmatism is more prevalent with PMMA lenses due to the higher refractive index of theses lenses and less prevalent with modern gas permeable materials.

Residual astigmatism can be calculated using geometric optics equations, but it is more commonly measured when the contact lens is on the eye by over refraction [1]. The correlation between measured RA and calculated RA have been reported to be between 0.51 [141] and 0.78 [142], with calculated RA typically being higher than measured RA [143]. It is also possible to predict measured RA to within 0.50D from calculated RA [144].

Incidence of RA

Measured RA with spherical contact lenses and a reduction of visual acuity is the rule rather than the exception. However the magnitude is frequently lower than -0.50D (mean -0.23 ± 0.30D) [128, 144] and almost always against-the-rule [145]. Although the RA can vary in magnitude from one refraction to the next, it does not disappear as the patient wears the lenses [1].

Correction of RA

The simplest way to correct residual astigmatism in contact lens wear is to prescribe over spectacles to correct the residual refractive error. However, contact lens wearers use contact lenses to get rid of the need for spectacles and are usually not easily convinced to use this option. With RGP lenses, toric base curve, bitoric and/or stabilised toric front surface lenses are often used to correct residual astigmatism. Front or back surface toric prism ballasted or zone stabilised soft contact lenses are also useful to correct residual astigmatism. Ultrathin (<0.12 mm CT) spherical RGP lenses tend to flex on the astigmatic cornea and can be used to correct residual astigmatism. However, spherical RGP lenses that flex on a with-the-rule cornea will reduce against-the-rule residual astigmatism and if both corneal and residual astigmatism are against-the-rule (or with-the-rule) the lens flexure will increase the against-the-rule (or with-the-rule) residual astigmatism [1, 88, 89, 128].

TORIC RGP LENSES [1, 88, 89, 128]

Toric RGP lenses are normally used to improve the physical fit of the lens when a spherical lens is unstable, decentres, bears in certain meridians, is not comfortable, flexes and produces moulding of the cornea. Toric RGP lenses can also be used to improve visual acuity in cases of residual and induced astigmatism. RGP lenses can have front surface toric designs to correct residual astigmatism, toric peripheral curves with spherical front surfaces to improve stability and fit, back surface toric with spherical front surfaces to improve the fit and stabilise the lens on the cornea, and bitoric lenses which have both front and back toric designs to improve the fit on a toric cornea and correct any residual or induced astigmatism.

Front Surface Toric Lenses With Spherical Back Surfaces [1, 88] [146, 147]

Front surface toric lenses with spherical back surfaces can be stabilised by using prism ballast (1.5–3.0 dioptres). These designs work due to the weight and thickness differential between the top and bottom of the lens which then orientates the lens with the prism base downwards. These lenses tend to rotate slightly nasally (5–10°) when blinking due to lid tension and position. Always consider the effect of the base down prism on binocular vision if only one eye needs correction of residual astigmatism. Another method of stabilising these lenses involves truncation, either with or without prism ballast. 0.5–1.0 mm is removed from the inferior lens edge to allow the truncation to effectively sit on the lower lid. It is not effective with small diameter lenses or when the lower lid position is below the lower limbus.

When fitting front surface toric lenses, a spherical diagnostic lens should be used to insure an optimal cornea lens relationship. The best corrected spherical lens is then ordered with at least 1.5 dioptres of prism with the base clearly marked. An over refraction can then be done to establish the residual astigmatism. Any rotation of the lens is taken into consideration using the LARS or CAAS rules (see later explanation). The lens is then returned to the laboratory to add the cylinder power on the front surface.

Toric Peripheral Curve Lenses with Spherical Base Curves– Asticon or Toric Second Curve Lenses [1, 88, 146, 147]

Asticon lenses are used on moderately toric corneas (-2.00–3.00DC) to improve the fit and stability of the lens. The second curve toricity is normally at least 0.60 mm, the peripheral curve and the base curve is normally slightly steeper (0.1–0.2 mm) than flattest K. The BC is spherical, but the shape is oval with the smallest diameter along the flattest meridian. Fitting can be accomplished by using spherical lenses or an Asticon fitting set. Corneal astigmatism is neutralised by the tear lens.

Back Surface Toric With Spherical Front Surface [1, 88, 146, 147]

Back surface toric lenses are used to improve the fit and stabilise the lens on corneas with more than 3.00D of astigmatism. A spherical fitting set can be used to establish the flatter meridian and the cylinder determined by calculation. As a general rule, the one meridian is fitted on or slightly steeper (0.1 mm) than flattest K, and the second meridian 1/3 of the difference between the K-readings, steeper than flattest K.

Bitoric Lenses [1, 88, 146, 147]

Bitoric lenses are used when toric base curve lenses have induced sufficient astigmatism (usually more than 0.75DC) to warrant correction with a front surface cylinder, or if significant residual astigmatism is present after fitting a toric base curve lens on a toric cornea. In this case, the toric base curve lens provides the rotational stability for a front surface toric design. These lenses are fitted the same way as toric base curve lenses. The toric base curve lens is then placed on the eye and an over refraction is done to determine the cylinder which can be added to the lens by the laboratory. Remember to check rotational stability and use the LARS and CAAS rules when ordering the final adjustments.

TORIC SOFT CONTACT LENSES [1, 88, 89, 128, 148]

In contrast to RGP lenses, toric soft contact lenses are not normally prescribed to correct the physical fit, but rather to correct astigmatism and provide good vision where spherical lenses fail to do so. As a general rule, astigmatism of >0.75DC should be corrected using a toric lens. The main influence on the rotational stability of the lens on the eye is the position of the lower lid, lid angles, size of the palpebral aperture, lid tension, force of blink and direction of lid movement with the blink. Other factors that having an effect on the rotational stability of the lens include; gravity, water content, lens modulus of elasticity, lens thickness and hydrostatic pressure. In the case of with-the-rule astigmatism, the thickest portions of the lens lie at the top and bottom. Therefore, the normal actions of the lids would be to rotate the lens 90° off-axis.

Methods of Stabilisation [1, 88, 89, 128, 148]

Various methods of stabilisation can be used, and it includes: toric back surfaces designs, prism ballast, truncation and dynamic stabilisation.

Toric Back Surface Soft Lenses

This design has a natural stabilising effect on a toric cornea, due to the elastic distortion that occurs when the lens is properly aligned. The most commonly used soft toric designs, employ both toric base curve and prism ballast to ensure rotational stability.

Prism Ballast

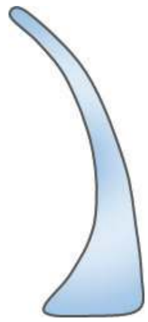

Figure 40: Side view of toric prism ballasted contact lens

As with RGP lenses 1.5–3.0 dioptres of prism ballast can be used to ensure rotational stability. Modern lenses include prism free optic zones with prism only in the periphery of the lens and slab-off prisms to ensure equal thickness at both the base and the other meridians of the lens. As mentioned previously, binocular status should be considered when prescribing a prism ballasted lens for one eye only. Furthermore, the "thicker" part of the lens can lead to staining and hypoxia in the underlying cornea.

Truncation

This design is hardly used with the modern lens designs, as it does not lend itself to mass production moulding methods used to manufacture disposable lenses. As with RGP lenses a 1.0–1.5 mm section of the inferior part of the lens is removed, in order for the lens to rest on the lower lid and give rotational stability. These lenses tend to be very stable but can be uncomfortable and cosmetically more noticeable.

Dynamic Stabilisation

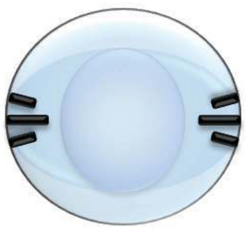

Figure 41: Orientation markers on dynamically stabilised soft toric contact lens

The top and bottom parts of the lens are chamfered to reduce the thickness where the stabilisation zones fit beneath the lids. The lids and blink keep the lenses oriented and comfort, as well as cosmetic appearance is good. Dynamically stabilised lenses also tend to keep their orientation, if the patient is lying on his/her side which is not the case with prism ballasted lenses.

Lens Markings

Various markings are employed by the lens manufacturers and additional information regarding the cylinder power is also included by some manufactures. The following figure illustrates the most commonly used markings (Figure 42). These markings are used to determine the rotational stability of the lens on the eye and if necessary compensate for any rotation when ordering the final lens.

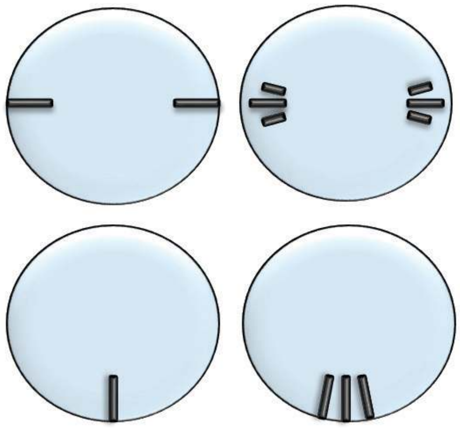

Figure 42: Commonly used lens orientation markers on soft toric contact lenses

The slit lamp is used to evaluate the position of the lens markings. This can be accomplished by using an optic section aligned with the markings and reading the deviation on the instruments protractor scale. Many manufacturers use three markings on their lenses and these markings are either 10 or 15° apart making it easy to estimate the amount of deviation. Toric soft lenses are unlikely to be successful if deviation is >20° and if the lens does not return to rotational stability within a few blinks after manually rotating it off-axis.

The LARS rule is useful for markings at 6 o'clock. Rotation to the left = add, and rotation right = subtract the deviation from the axis needed. The CAAS rule is useful for markings at 3 and 9 o'clock position. Rotation clockwise = add and rotation anti-clockwise = subtract from the axis. For example: If a lens rotates 10° to the left of the right eye and the required cylinder axis is 70°, the LARS rule is applied and a contact lens with axis 70 + 10° = 80° is ordered to compensate for the rotation of the lens on the eye [1, 88, 89, 128, 148].

Often some residual astigmatism may still be present after fitting a toric soft contact lens. Various methods can be used to correct this, but all of them require a good sphero-cylindrical over refraction. This resultant prescription can then be used to calculate the new lens which corrects the residual astigmatism. Various formulae and tables are available to do this, but a simple effective way entails using a trial frame with the contact lens prescription and the over refraction placed in the lens holder. A vertometer can then be used to measure the resultant lens prescription or new contact lens prescription. This technique is fully discussed in chapter 13. A simple table can also be used to estimate the amount of residual astigmatism caused by a cross-cylinder effect (Table 30).

Table 30: Residual astigmatism due to axis misalignment [148]

Effects of Different Amounts of Lens Cylinder Power on Residual Astigmatism*	
Lens Cylinder Power	10° of Axis Misalignment gives residual astigmatism of….
–0.75 DC	–0.25 DC
–1.25 DC	–0.42 DC
–1.75 DC	–0.58 DC
–2.25 DC	–0.75 DC
–2.75 DC	–0.92 DC
** The amount of residual astigmatism induced by axis misalignment varies with the cylinder power of the lens.*	