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New York State Continuing Education Mail-In Course

Astigmatism & the Prospective Contact Lens Patient

Robert J. Russo, MA, ABO, NCLE

No matter how sophisticated the contact lens practitioner becomes in designing a contact lens or using new lens materials, the type of astigmatism must be determined prior to selecting the proper lens modality for a given patient.

CAUSE OF ASTIGMATISM

As background, astigmatism may be defined as an “optical defective in which refractive power is not uniform in all meridians. Light rays entering the eye are bent unequally by different meridians, preventing formation of a sharp focus on the retina.”¹

Causes of astigmatism may arise from any or all of the following:

1. astigmatism due to the cornea;
2. astigmatism due to the crystalline lens;
3. the fovea of the eye's occupying an eccentric position in relation to the visual axis;
4. changes in vitreous gel, resulting in a change of index; or
5. irregularity in the surface of the retina.²

INCIDENCE OF ASTIGMATISM

Various studies have shown that about 83 percent of all patients wearing eyeglasses have correction for astigmatism. It is interesting to note that only about three percent of the population shows astigmatism in excess of 3.00 diopters. Almost 20 percent have less than .50 diopter. About 45 percent show astigmatism between .50 and 1.00 diopter and another 15 percent show astigmatism between 1.00 and 1.50 diopters. Therefore, 60 percent of the population show astigmatism between .50 and 1.50 diopters. Another 10 percent demonstrate astigmatism between 1.50 and 2.00 diopters, and finally another seven percent show astigmatism between 2.00 and 3.00 diopters.³

TYPES OF ASTIGMATISM

Total astigmatism of the eye consists of both corneal and lenticular astigmatism. To determine the type

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and amount of astigmatism, the following relationship may be utilized:

Total astigmatism = Corneal Astigmatism + Lenticular astigmatism (TA = CA + LA)⁴

Total astigmatism consists of corneal and lenticular astigmatism (internal).

Corneal Astigmatism - astigmatism found on the cornea and measured by keratometry. The difference between the two principal meridians is the amount of corneal astigmatism.

Lenticular Astigmatism - found within the eye and cannot be determined by keratometry.

Total astigmatism is given by patient refraction or spectacle correction; for example:

Rx -3.00 -50 x 180 total astigmatism = -.50 x 180.

Corneal astigmatism can be calculated by keratometer (K) readings, for example K = 42.50 @ 180/43.00 @ 90. The amount of corneal astigmatism is equal to a +.50 x 90 or -.50 x 180.

Lenticular astigmatism cannot be measured by keratometry, but can be calculated by using the following formula: Lenticular Astigmatism = Total Astigmatism - Corneal Astigmatism (LA = TA - CA)⁵
Example: Rx -2.50-1.50x180

“K” 44.00@180/45.00@90

LA = TA - CA

LA = -1.50 x 180 - 1.00 x 180

LA = -1.50 x 180 + 1.00 x 180

LA = -.50 x 180 or +.50 x 90

Most corneas, according to the law of nature, have at least .50 diopter difference in curvature between the horizontal and vertical meridians. This astigmatism may be classified as with-the-rule astigmatism (WTR), against-the-rule (ATR) or oblique astigmatism.

WTR astigmatism can be identified as the curvature of greatest power in the vertical meridian and the weakest power in the horizontal meridian. WTR astigmatism will have the flattest curve along the horizontal meridian. An example of a WTR astigmatic cornea is:

45.00@180/46.00@90. WTR astigmatism is corrected with a -x 180 or -x 90. In relation to keratometry readings, WTR astigmatism is more frequently found on the cornea than ATR astigmatism.

ATR astigmatism can be identified as the curvature of greatest power in the horizontal meridian and the weakest power in the vertical meridian. ATR astigmatism will have its flattest curve along the vertical meridian. An example of ATR astigmatism may be written as 46.00@ 180/45.00@ 90. ATR astigmatism is corrected with a - x 90 or + x 180. Lenticular astigmatism or internal astigmatism will usually manifest as ATR astigmatism and therefore neutralize WTR astigmatism. As mentioned earlier, this astigmatism cannot be measured by keratometry, but can be calculated by using the $LA = TA - CA$ formula.

Oblique astigmatism is a condition where the two major meridians are at some intermediate points other than the horizontal or vertical meridians. The greatest powers in oblique astigmatism lie between 30th and 60th meridian and 120th and 150th meridian. An example of oblique astigmatism may be written as 42.00@ 135/43.00@ 45.

With or Against or oblique astigmatism can be corrected with eyeglasses, rigid or soft contact lenses. Irregularities of the front surface of the cornea can be seen with the keratometer. This condition is called irregular astigmatism. Glasses will not accurately correct irregular corneal astigmatism, however rigid contact lenses are usually the modality of choice to enhance a patient's vision.

When a patient requests to be fitted with contact lenses, the contact lens practitioner should consider that an astigmatic error might manifest itself when a contact lens is placed on the patient's cornea.

The term "residual astigmatism", as used in the contact lens field, can be defined as the "astigmatic refractive error that is present when a contact lens is placed upon the cornea to correct the existing ametropia."⁶

Residual astigmatism may be subdivided into physiological residual astigmatism or induced residual

astigmatism. Physiological residual astigmatism may be caused by any or all of the following:

1. That portion of the anterior corneal surface that is not neutralized by the tear lens.
2. The difference in curvature of the principal meridians of the posterior corneal surface.
3. The difference in curvature of the principal meridians of the crystalline lens.
4. Tilt of the crystalline lens.
5. Variability of the refractive index of the cornea, crystalline lens or vitreous.
6. Oblique incidence of light upon the cornea.
7. An eccentric position of the fovea in relation to the visual axis.
8. Some irregularity in the shape of the retina.⁷

Induced residual astigmatism is the astigmatism that is introduced into the contact lens system by the contact lens itself. Possible causes of induced residual astigmatism may result from:

1. tilt or decentration of the contact lens;
2. lens warpage; or
3. lens flexure.⁸

Residual astigmatism caused by either physiological or induced astigmatism can reduce acuity; decrease visual performance and cause asthenopia. When the amount of residual astigmatism is great enough to cause any of these problems for a particular patient, then residual astigmatism must be corrected, or a different lens type must be chosen to reduce the residual error. When residual astigmatism is .50 diopter or less, it will seldom reduce the acuity to cause visual distress or asthenopia.⁹ If over .75 diopter of residual astigmatism is present, correction may become essential.

It has been established that a very large percentage of patients fitted with spherical contact lenses can manifest a certain amount of residual astigmatism. In one study, for example, comprising of 105 patients fitted with spherical contact lenses, 84 percent showed .50 diopter or more of residual astigmatism in one or both eyes. Of the 210 eyes in the given study, 56.4 percent had .50 diopter or more of residual astigmatism with 37 percent having .75 diopter or more.¹⁰ It would appear that the incidence of residual astigmatism is relatively high and the contact lens practitioner must be prepared to offer alternatives to the prospective patient.

Anticipation of residual astigmatism is the single largest factor in determining what type of contact lens is recommended to a patient.

Residual astigmatism may be calculated if the keratometer readings and spectacle refraction are known. Calculated residual astigmatism (CRA) is the difference between the keratometer readings

(KA) and the refractive astigmatism (TA): $CRA = TA - KA$. Calculating residual astigmatism can be used to predict whether or not a significant amount of residual astigmatism may be present with a certain type of contact lens. However, from a clinical standpoint, another method of verifying residual astigmatism is to perform a subjective spherocylinder over-refraction over a spherical diagnostic contact lens to determine the measured or actual residual astigmatism. The difference between calculated residual astigmatism and measured residual astigmatism is that calculated is predicted through a formula and actual residual is determined subjectively with a contact lens on the patient's eye. Specific studies have shown that there can be significant differences between calculated and measured residual astigmatism. Although residual astigmatism is common, clinically measured residual astigmatism is often less than calculated residual astigmatism.

A number of reasons can be given to account for the difference between the calculated and measured residual astigmatism;

1. Errors of measurement in refraction or "K" readings probably reduce a random difference.
2. Keratometer readings may not give a valid description of the corneal toricity for the segment of the cornea through which the line of sight passes;
3. The tilt or decentration of the contact lens system relative to the line of sight produces a small but significant amount of oblique astigmatism;
4. Flexure of thin corneal lenses will produce an induced residual astigmatism that may increase or decrease the total residual astigmatism.¹¹

When a spherical rigid lens is placed on a cornea, the tear lens corrects the astigmatism on the cornea but not the astigmatism due to the other components of the eye. When evaluating where the astigmatism on the eye is present, residual astigmatism may be calculated depending on the type of contact lens you may wish to fit. As mentioned earlier, calculating residual astigmatism is determined by subtracting keratometer astigmatism (KA) from the total astigmatism (TA):
 $CRA = TA - KA$.

The following examples will illustrate the method for anticipating residual astigmatism and the type of lens to recommend based on the amount of residual astigmatism calculated.

Example #1

Spectacle Rx: -3.50 -5.0 x 180
 K reading 43.50 @180/44.00@90

In this case, there is -.50 x 180 WTR astigmatism in the spectacle prescription. If a rigid lens is fit to this cornea, the tear lens will neutralize the .50 diopter

WTR astigmatism on the cornea. Therefore, there is no residual astigmatism in this case.

$$\begin{aligned} CRA &= TA - KA \\ &= -.50 \times 180 - .50 \times 180 \\ &= -.50 \times 180 + .50 \times 180 \\ &= 0 \end{aligned}$$

Lens recommendation: rigid or gas permeable lens.

If a soft lens were being considered, the contact lens practitioner must realize that soft lenses will not correct corneal astigmatism. Residual astigmatism for soft spherical lenses is the patient's refractive astigmatism.

$$\begin{aligned} CRA &= TA - KA \\ &= -.50 \times 180 - 0 \\ &= -.50 \times 180 \end{aligned}$$

The calculated residual astigmatism is -.50 x 180. Because the residual astigmatism is .50 diopter, the cylinder power can be ignored because most patients will tolerate up to .50 diopter of uncorrected astigmatism. In this case, the patient's vision will not be compromised if the patient is fit with a soft lens. However, there are occasions when the spherical equivalent of the spectacle prescription may be incorporated. Spherical equivalent = one half the spectacle cylinder + sphere, e.g., -3.50 -5.0 x 180, power in contact lens = -3.75.

Example #2

Spectacle Rx: -4.00
 K reading 42.25@180/42.25@90

Since there is no astigmatism correction present in the spectacle prescription or on the cornea, a rigid or soft spherical lens would correct this patient's ametropia.

Example #3

Spectacle Rx: -4.00
 K reading 42.00@180/44.00@90

In this case study, there is no astigmatism in the spectacle prescription. However, there is 1.00 diopter WTR astigmatism on the cornea. If a rigid lens were fitted on this patient, the tear lens would neutralize the 1.00 diopter WTR astigmatism on the cornea. This would then leave 1.00 ATR astigmatism uncorrected. If the contact lens practitioner were to fit this patient, an induced residual astigmatism of -1.00 x 90 would manifest itself and would diminish the person's visual acuity. In this particular case, it would be more advisable to fit the patient with a soft lens. This would not induce any residual astigmatism because the soft would not compromise the astigmatism on the cornea. A spherical soft would be recommended for this patient.

Example #4

Spectacle Rx: -3.75 - 1.50 x 90
K reading 43.50@180/43.00@90

In this case, there is -1.50 x 90 ATR astigmatism in the spectacle prescription. However, on the cornea, there is .50 diopter of ATR astigmatism. If a rigid lens is considered for this patient, the tear lens will neutralize only the .50 diopter ATR of the total 1.50 in the spectacle prescription. Because the total and corneal astigmatism are both ATR, the residual astigmatism with a spherical rigid lens would be -1.00 x 90

$$\begin{aligned} \text{CRA} &= \text{TA} - \text{KA} \\ &= -1.00 \times 90 - .50 \times 90 \\ &= -1.00 \times 90 + .50 \times 90 \\ &= -1.00 \times 90 \text{ residual} \end{aligned}$$

If a soft lens were recommended, the calculated residual astigmatism would be -1.50 x 90.

$$\begin{aligned} \text{CRA} &= \text{TA} - \text{KA} \\ &= -1.50 \times 90 - 0 \\ &= -1.50 \times 90 \end{aligned}$$

In both cases, there is a significant amount of residual astigmatism that the prospective contact lens wearer may not adapt to. In either case, the practitioner may wish to design a front rigid toric or use a soft toric lens to correct the ametropia.

Example #5

Spectacle Rx -2.75 - 1.00 x 90
K reading 42.50 x 180/43.50 x 90

In this case study, there is -1.00 x 90 ATR in the spectacle prescription and the cornea has 1.00 WTR astigmatism. In this example, if a rigid lens were fitted on this patient, the tear lens would neutralize 1.00 diopter of WTR astigmatism on the cornea. However, an additional -1.00 X 90 ATR astigmatism would manifest itself over the -1.00 x 90 already present in the spectacle prescription. By fitting a rigid spherical lens, an induced residual astigmatism of -2.00 x 90 would be present.

$$\begin{aligned} \text{CRA} &= \text{TA} - \text{KA} \\ &= -1.00 \times 90 - 1.00 \times 180 \\ &= -1.00 \times 90 + 1.00 \times 180 \\ &= -1.00 \times 90 - 1.00 \times 90^* \\ &= -2.00 \times 90 \end{aligned}$$

*To combine two cylinders of a different axis, transpose one to a - cylinder to get the same axis.

If a soft lens were recommended, the residual astigmatism would only be -1.00 x 90. By not neutralizing the cornea, the spectacle cylinder would only have to be considered.

$$\begin{aligned} \text{CRA} &= \text{TA} - \text{KA} \\ &= -1.00 \times 90 - 0 \\ &= -1.00 \times 90 \text{ residual} \end{aligned}$$

In a practical application where both cases manifest residual astigmatism, the soft lens option would induce less residual astigmatism, making it an easier option for both the fitter and the patient.

In summary, anticipation and calculation of residual astigmatism is possible, if the contact lens practitioner takes the time to evaluate the options and consequences of different lens modalities before fitting the prospective contact lens patient. In doing so, chair time can be reduced and the possibility of poor visual acuity and frustration by the patient can be avoided.

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About the Author

Professor Robert J. Russo is an associate professor and chairman in the Department of Vision Care Technology at New York City College of Technology. He has been a licensed optician and contact lens fitter in New York State for 30 years. He is certified by the American Board of Opticianry, the National Contact Lens Examiners and licensed in the states of New York and New Jersey. Professor Russo received his Associate Degree in Ophthalmic Dispensing at New York City Community College, a Bachelor of Science degree in Business Management from the City University of New York and a Master's degree in Education from New York University. He is a past Commissioner for the Commission on Opticianry Accreditation, a past board of director of the Contact Lens Society of New York State and past chapter president of the New York State Society of Opticians.

Professor Russo has served on the faculty for the Opticians Association of America, Vision Expo East and West and Eyequest. He is also an independent consultant and contact lens fitter.

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 - The Snellen Chart consists of alphabet letters designed to subtend 5-minute angles to the eye at a distance of 20 feet
 - Each letter is enclosed in a square of 5' of arc
 - Each letter's arms and interstices subtend 1' of arc
 - All of the above
- Which of the following is not a cause of astigmatism?
 - astigmatism due to the cornea
 - astigmatism due to the crystalline lens
 - irregularities in the surface of the retina
 - the portion of the anterior corneal surface that is not neutralized by the tear lens.
- What percentage of the patients have astigmatism of .50 to 1.00 diopters?
 - 20 percent
 - 35 percent
 - 45 percent
 - 3 percent
- Total astigmatism does not consist of which type of astigmatism?
 - corneal astigmatism
 - internal astigmatism
 - residual astigmatism
 - refractive astigmatism
- What is the total astigmatism in the following example? Rx -4.75 -0.75 x 180
 - 4.75 sphere
 - 0.75 x 180
 - 0.75 x 90
 - 0.75 x 145
- What is the amount of lenticular astigmatism in the following example? Rx +3.00 -1.75 x 180. "Ks" 44.00@180/44.75@90.
 - 0.75 x 180
 - 0.75 x 90
 - 1.00 x 180
 - 1.00 x 90
- Which of the following K readings corresponds to "with-the-rule" astigmatism?
 - 46.00@180/45.00@90
 - 44.00@180/44.00@90
 - 46.00 @180/45.75@90
 - 44.00@180/44.75@90
- In order to calculate residual astigmatism, the following is needed?
 - spectacle prescription
 - keratometer readings
 - corneal topography
 - a and b
- Astigmatism that manifests itself after a contact lens is placed on the cornea is referred to as:
 - corneal astigmatism
 - lenticular astigmatism
 - residual astigmatism
 - total astigmatism
- Which of the following is a cause of residual astigmatism?
 - tilted lenticular surface
 - anterior toric corneal surface
 - decentered position of the fovea relative to the visual axis
 - all of the above
- Which type of astigmatism is more common in relation to keratometry readings?
 - with-the-rule astigmatism
 - against-the-rule astigmatism
 - irregular astigmatism
 - oblique astigmatism
- The amount of astigmatism revealed by a spherocylinder refraction over a spherical contact lens is considered the amount of:
 - lenticular astigmatism
 - corneal astigmatism
 - residual astigmatism
 - irregular astigmatism
- If a patient has one diopter of WTR corneal astigmatism and wears spectacles that correct for one diopter of WTR astigmatism, which contact lens would provide the best visual acuity?
 - soft lens
 - rigid lens
 - rigid front toric
 - bitoric lens
- A patient has the following Rx -2.75 -1.00 x 90. What is the expected spherical equivalent for this Rx?
 - 2.75
 - 3.25
 - 3.75
 - 4.25
- A patient has a -5.25 spectacle Rx, "K" reading 42.00/43.00@90. With which contact lens should this patient be fit with?
 - rigid lens
 - soft toric lens
 - soft lens
 - rigid toric lens
- A patient has a spherical cornea, but wears a 1.75 cylinder in spectacles to fully correct their ametropia. What type of lens would be indicated for this patient?
 - spherical rigid lens
 - front cylinder lens
 - bitoric lens
 - toric back curve
- A patient has a "K" reading of 43.00@180/43.50@90. The spectacle Rx is -4.00 -0.75 x 90. What is the anticipated residual astigmatism if a rigid lens is fit on this patient?
 - 0.75 x 90
 - 0.50 x 90
 - 1.25 x 90
 - 1.25 x 90
- Using the information in the above example, what is the anticipated residual astigmatism with a soft lens?
 - 0.75 x 90
 - 0.50 x 90
 - 1.25 x 90
 - none
- Which of the following "K" readings will correspond with "against-the-rule" astigmatism?
 - 46.00@180/47.00@90
 - 41.00@180/40.00@90
 - 41.00@135/41.00@45
 - 40.00@180/41.00@90
- Eyeglasses will not accurately correct what type of astigmatism?
 - ATR astigmatism
 - WTR astigmatism
 - Oblique astigmatism
 - Irregular astigmatism
- Residual astigmatism with spherical soft lenses is usually equal to:
 - corneal astigmatism
 - lenticular astigmatism
 - refractive astigmatism
 - irregular astigmatism

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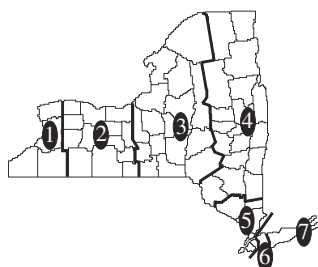
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