Contact Lenses for the Correction of Astigmatism

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Astigmatism: A Brief Review

Astigmatism is a common refractive error which is correctable through the use of eyeglasses, contact lenses or surgery.

If we think of the normal cornea as being essentially spherical in shape, when light enters the eye, it is refracted or "bent" evenly in all directions, resulting in a sharp point of focus on the retina. However, if astigmatism is present the cornea is shaped more like a football or the back of a spoon. So when light enters the eye it is refracted more in one direction than the other, resulting in blurred vision in at least one of the two principal meridians.

Astigmatism can be hereditary and is often present at birth. It can also result from pressure from the eyelids on the cornea, incorrect posture or an increased use of the eyes for close work. Untreated it can cause headaches, fatigue, eyestrain and blurred vision at all distances. Astigmatism can almost always be corrected with properly prescribed eyeglasses or contact lenses. In cases with only a small amount of astigmatism, corrective lenses may not be needed at all, as long as other conditions such as myopia or hyperopia are not present. If the astigmatism is moderate to high, however, corrective lenses are probably needed.

Correcting Astigmatism
Corrective spectacle or contact lenses containing cylinder are used for the correction of astigmatism. These lenses have greater refractive power in one direction than the other. Another method for correcting astigmatism is by changing the shape of the cornea through refractive or laser eye surgery. While there is more than one type of refractive surgery, specific treatments are recommended on an individual basis. Refractive surgeries require healthy eyes that are free from retinal problems, corneal scars and any eye disease.

Regular and Irregular Astigmatism
Astigmatism may be divided into two broad categories: regular and irregular. Irregular astigmatism is caused by a diseased or damaged cornea resulting in light scattering in the crystalline lens. Irregular astigmatism cannot be corrected by standard spectacle lenses.

However rigid gas permeable (RGP) contact lenses can help treat regular astigmatism due to the tear lens which fills in the irregularities and re-creates a smooth optical surface. There will be more on the tear lens later in this course.

Regular astigmatism, which can be caused by either the cornea or crystalline lens, can be corrected by a toric (cylindrical) lens. A toric surface resembles the surface of a football where there are two curves, one steeper than the other. This optical shape results in regular astigmatism.

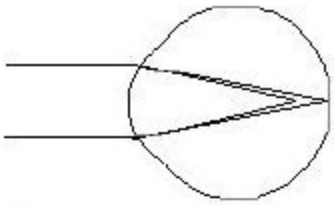
With-the-rule and against-the-rule astigmatism
In with-the-rule corneal astigmatism, the cornea is steeper in the vertical meridian and flatter in the horizontal. Imagine holding a football with the tips of the ball held horizontally. The flatter curve is in the horizontal and the steeper curve in the vertical. That would represent with the rule astigmatism. If the football were held vertically, with the steeper curve in the horizontal and the flatter curve in the vertical that would represent against the rule astigmatism.

Astigmatism with-the-rule

Astigmatism against-the-rule

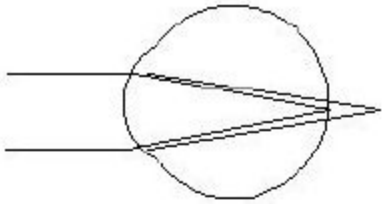
In with-the-rule astigmatism, the eye sees vertical lines sharper than horizontal lines. Against-the-rule astigmatism the horizontal meridians are sharper. Axis is always recorded as an angle in degrees between 0 and 180 degrees in a counter-clockwise direction. 0 and 180 lie on a horizontal line at the level of the centre of the pupil, and as seen by an observer 0 lies on the right of both eyes.

Types of Astigmatism



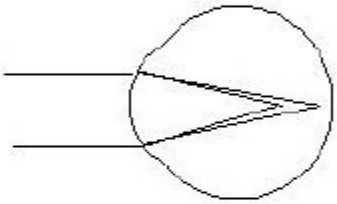
Simple Myopic Astigmatism

one point of light comes to focus on the retina and one point comes to focus in front of the retina



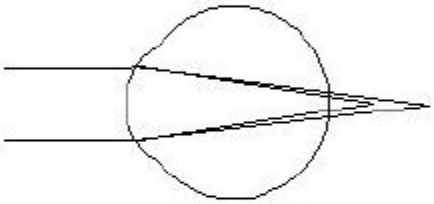
Simple Hyperopic Astigmatism

one point of light comes to focus on the retina and one point comes to focus behind the retina



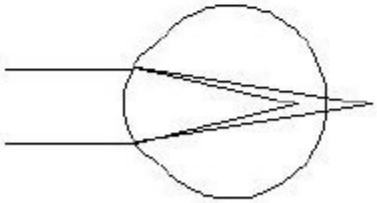
Compound Myopic Astigmatism

both points of light come to focus in front of the retina



Compound Hyperopic Astigmatism

both points of light come to focus behind the retina



Mixed Astigmatism

one point of light comes to focus in front of the retina while the other comes to focus behind the retina

Toric Contact Lenses

Soft toric contact lenses for the correction of astigmatism

Toric soft lenses have different curves in different meridians to correct astigmatism. Special weighting and/or thin zones in toric lenses keeps the proper lens meridian in front of the corresponding meridian of the eye and prevents the lens from rotating during wear.

Because they have a more sophisticated design, toric soft lenses are more expensive to manufacture and cost more than regular soft lenses.

Spherical soft contact lenses have the same curve in all meridians and cannot correct astigmatism.

Rigid gas permeable (RGP) contact Lenses

As their name implies, rigid gas permeable (RGP) lenses are hard lenses. They maintain their shape on the eye and don't conform to the unequal contours of an astigmatic eye like soft lenses do.

When an RGP contact lens is worn on an eye that has mild to moderate astigmatism, the space between the (spherical) back surface of the contact lens and the (astigmatic) front surface of the cornea is filled with tears. This layer of tears is shaped in such a way that it becomes, in effect, a lens that fully corrects the astigmatism of the eye.

This "tear lens" behind the RGP contact lens is unaffected by lens rotation. Therefore the only lens power required in the contact lens is the power needed to correct any myopia or hyperopia that exists along with the astigmatism.

In cases of moderate to severe astigmatism, a standard rigid gas permeable contact lens may be uncomfortable or unstable on the eye because the shape of the cornea is so irregular that the contact lens doesn't center properly on the eye and moves (or "rocks") too much during blinks. In these cases, a toric RGP contact lens may be used.

A toric RGP lens has a spoon-shaped back surface that more closely matches the front surface of an astigmatic eye for a more stable and comfortable fit. This closer fitting relationship also keeps the lens from rotating on the eye, allowing different powers (curves) to be ground on different meridians of a toric RGP lens. The variable powers on the lens surface correct the astigmatism without having to rely solely on the power of the "tear lens" between the cornea and the back surface of the lens. The front surface of a toric RGP lens may be spherical or toric, depending on the required prescription. (If both the front and back surfaces are toric, the lens is called a bitoric lens.)

Because toric rigid gas permeable lenses have a more sophisticated design, they are more expensive to manufacture and therefore cost more than regular RGP contact lenses.

When Toric Contact Lenses are indicated

Toric contact lenses may be indicated when residual astigmatism results in vision which is compromised. Residual astigmatism may result from a toric posterior corneal surface, a toric crystalline lens, or a partially dislocated crystalline lens.
Toric lenses may also be required when moderate to high corneal astigmatism results in either mechanical irritation or centration problems with spherical hard lenses.
Astigmatic contact lenses may be classified into the following categories and these are applicable to both hard and soft lenses.

A) Anterior toric, with spherical back surface

B) Posterior toric base curves

1. Posterior toric only
2. Bitoric

Anterior toric with spherical back surfaces: These are available in both hard and soft lenses. They are typically fit when there is a significant amount, generally more than 0.75 D, of uncorrected residual astigmatism. The correcting cylinder is put on the front surface of the lens while the diameter and posterior curves remain the same.

Posterior base curve toric lens: These are available in both hard and soft lens materials, although they are used predominately with hard lenses. They are indicated when a spherical lens does not provide a stable fit and when there is at least 1.50 diopters of corneal astigmatism. They can also be indicated when irritation is experienced due to inadequate clearance of a spherical lens on a corneal cylinder.

A bitoric lens design is needed when the back toric surface results in enough residual astigmatism so that a front surface correcting cylinder is needed. At least 1.50 diopters of corneal astigmatism should be present.

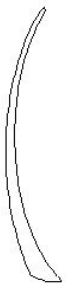
Stabilization Techniques for Toric Contact Lenses

Many of the techniques used for stabilizing toric contact lenses are also used for the stabilization of segment style multifocal lenses. In either case, for obvious reasons, lens rotation on the eye needs to be minimized.

Prism Ballast:

This is one of the most common stabilizing techniques. A prism of between 1.00 to 1.50 D is ground base down into the lens.

However, greater amounts of prism may be needed for patients with particularly tight lids, flat corneas, or oblique axis astigmatism. The lens will tend to rotate so that the base of the prism is oriented inferiorly. The added thickness of the lens along the prism base can reduce oxygen permeability through that portion of the lens resulting in possible hypoxic disturbances in the inferior zone of the cornea.



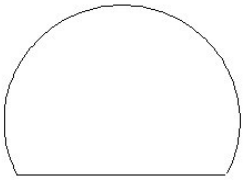
Prism Ballast

Truncation:

When a lens is truncated, a portion of it is sectioned off. It is usually 0.50 to 1.5 mm on the lower edge

of the lens. The amount sectioned off will depend on the size of the lens; larger lenses require greater amounts than smaller lenses. Occasionally the upper edge is sectioned off as well resulting in a double truncated lens.

The truncation will serve to stabilize a lens when the lower flat edge comes to lie adjacent to the lower eyelid margin. Truncation is often combined with prism ballast.

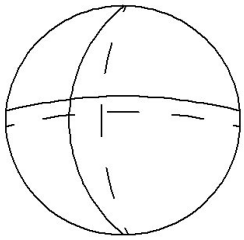


Truncated

When a lens is truncated its diameter is effectively reduced which results in a looser fit. To compensate for this the base curves of truncated lenses are generally made somewhat steeper.

Double Slab-off lenses:

This technique creates a lens which is thicker along its central body which lies along the palpebral fissure and thinner along the inferior and superior edges which come to lie under the upper and lower lids. This technique is comfortable since there is no lid impact along the inferior surface. However it does not offer as much lens stability as the truncated or posterior toric techniques. Double slab-off lenses are often combined with a prism ballast to help prevent rotation.



Double Slab Off

Posterior Toric Lenses:

A back toric surface can be used as a lens stabilizing technique. When the shape of the posterior contact lens surface closely parallels that of the cornea lens rotation can be minimized.

Aspheric Lens Surface:

An aspheric surface can aid in lens-axis stabilization by adding drag to the motion of the lens. It is generally used in combination with truncation or prism ballast since it is only minimally effective by itself.

Toric Reference Markings

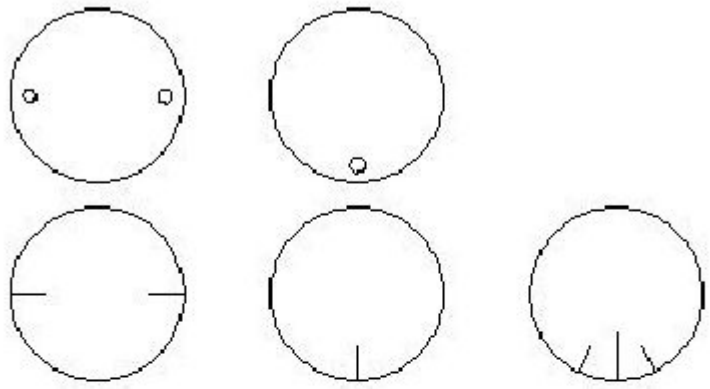
Because it is necessary to inhibit lens rotation, toric lenses will typically come with reference markings so the fitter can determine how the lens is oriented on the cornea. If one were to superimpose the face of a clock over the cornea, these markings, which may be circles or lines, are located at the six-o-clock or three and nine-o-clock meridians. Each hour on the clock represents 30º. So if a lens becomes oriented at five-o-clock that means it has rotated 30º to the right, while seven-o-clock is 30º to the left.

The expression LARS stands for left add, right subtract. If the lens is rotated to the fitter's left, the appropriate number of degrees is added to the prescribed axis. If it is rotated to the right the appropriate number of degrees is subtracted.

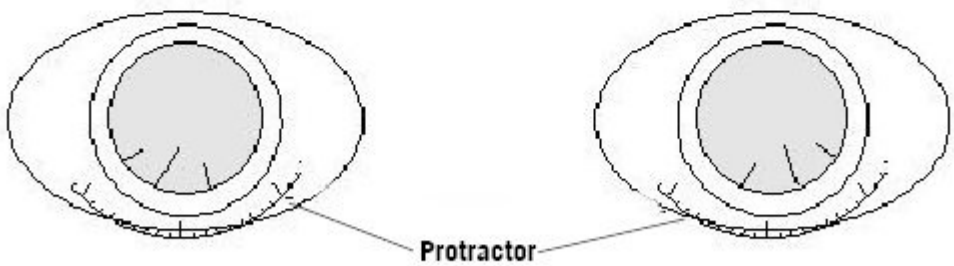
Lens rotation can be measured using a slit lamp equipped with a protractor.

The use of trial lenses is especially important when fitting toric contact lenses.

TORIC REFERENCE MARKINGS



Engraved Reference Markings
on Soft Toric Lenses



LARS: Left Add, Right Subtract

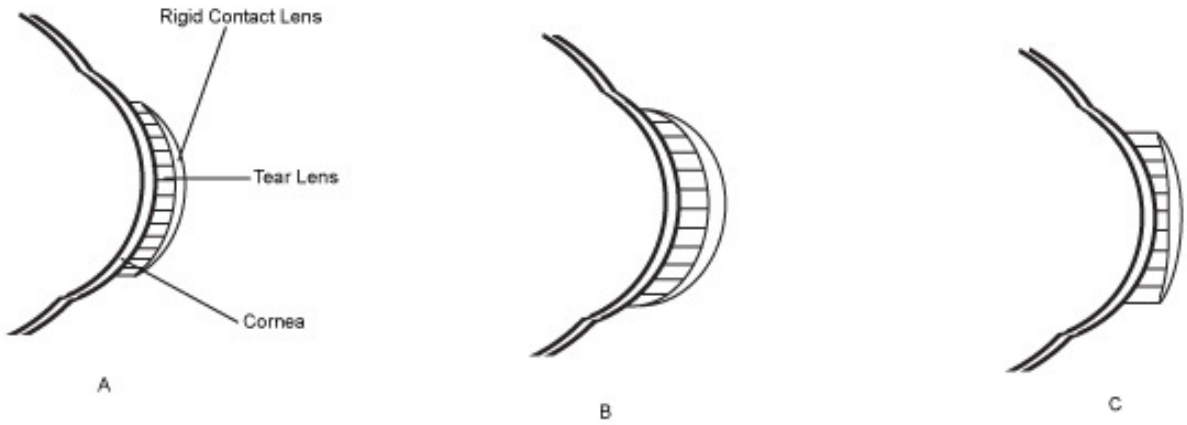
How the tear lens can correct for significant amounts of corneal astigmatism

Let's first consider a spherical lens on a spherical cornea.

A: Figure A below illustrates rigid contact lens fit "on K" where the base curve of the lens parallels the curvature of the cornea. In this case the power of the tear lens is plano. When there is corneal astigmatism, a lens fit "on K" parallels the flatter of the two corneal meridians.

B: Figure B shows a rigid contact lens which is fit steeper than K. Note that the shape of the resultant tear lens is thicker in the center and thinner on the edges which produces a lacrimal lens with plus power. The power of the lacrimal or liquid lens must be considered when determining the correct power the contact lens.

C: In figure C the rigid contact lens is fit flatter than K resulting in a tear lens which is thinner in the center and thicker on the edges. The lacrimal lens in this case will contain minus power.



How the tear lens can correct for significant amounts of corneal astigmatism

Example 1:

Spectacle Rx: -3.25

K: 43.50 Vertex distance = 12 mm

Using the data above, what would be the power of a rigid the contact lens which is fit on K?

When a lens is fit “on K” it indicates that its base curve is designed to parallel the flattest corneal meridian. In this case we are presented with a “spherical” cornea. Therefore a lens fit on K would contain a base curve of 43.50 which is equal to the curvature of the flattest (in this case only) corneal meridian. As indicated in figure A on the previous page when the back curve of the contact lens parallels the front curve of the cornea the power of the tear lens produced is plano or zero.

The Rx in this example tells us that a spectacle lens with a power of -3.25 D is needed to correct this person’s myopia. Since the power at the spectacle plane is less than -4.00, it is not necessary to compensate for vertex distance. The total power of the contact lens plus the power of the tear lens needs to equal -3.25. Since the tear lens is plano, the power of the contact lens would be -3.25.

Using the data above, what is the power of a rigid contact lens fit 0.50 D steeper than K?

In this example a lens fit 0.50 D steeper than K would contain a base curve of 44.00 diopters. Since it is steeper than K the shape of the tear lens would resemble the one in figure B on the opposite page, thicker in the center and thinner on the edges thereby creating a liquid lens of plus power. How much plus power? If it is 0.50 D steeper than K the power of the tear lens is approximately equal to +0.50 D. As previously stated, the total power needed at the corneal plane is -3.25 D which will be the combined power of the contact lens plus the tear lens. If the tear lens contains a power of +0.50, therefore, the contact lens must contain a power of -3.75. So, -3.75 (contact lens power) plus +0.50 (tear lens power) results is the desired -3.25 diopters of power at the corneal plane.

Using the data in example one above what is the power of a rigid contact lens which is fit 0.25 D flatter than K?

When the lens is fit flatter than K the shape of the tear lens will resemble figure C on page 6, thinner in the center and thicker on the edges thus creating a liquid lens containing minus power. How much minus power? When the contact lens is fit 0.25 diopter flatter than K the power of the tear lens is equal to approximately -0.25 diopter. Since the combined power of both the contact lens and tear lens needs to be -3.25 D, the contact lens would require a power of -3.00. So -3.00 (contact lens power) plus -0.25 (tear lens power) results in the needed -3.25 diopters at the corneal plane.

How the tear lens can correct for significant amounts of corneal astigmatism

Example 2:

Spectacle Rx: -6.75 - 1.00 x 180

K readings: 44.50\45.50

Vertex Distance: 12 mm

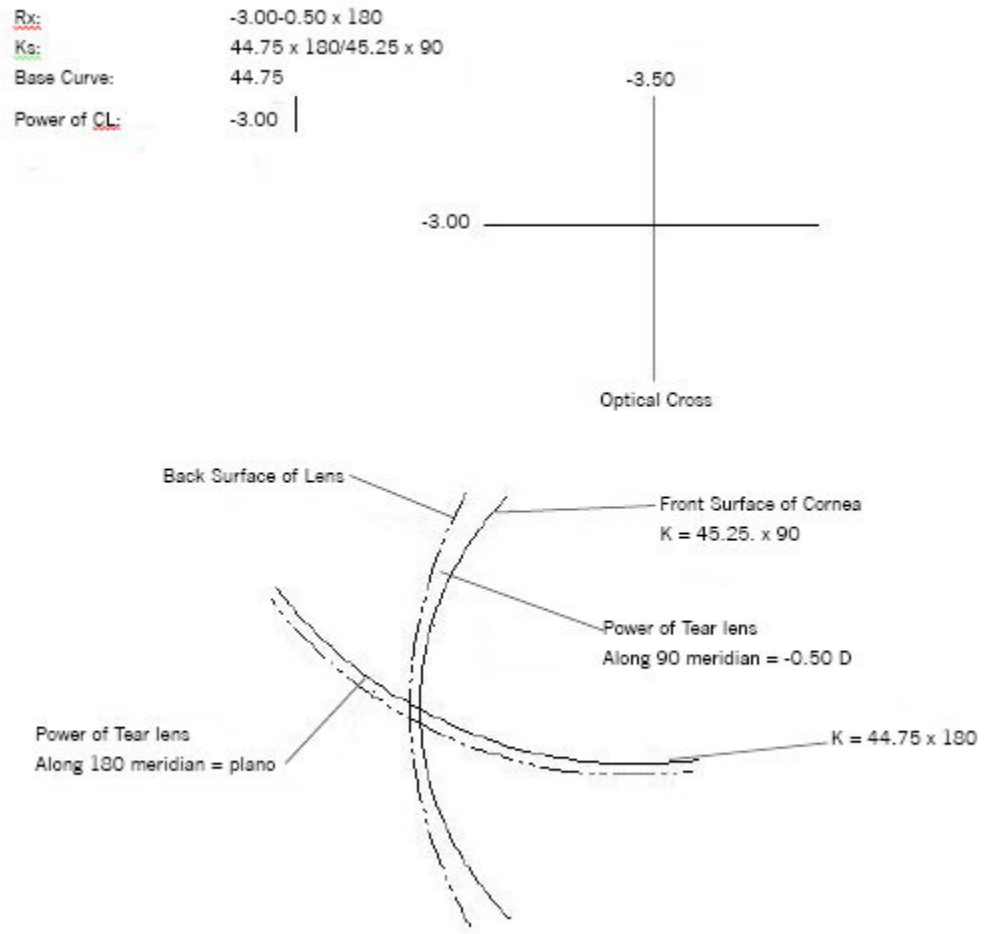
When presented with a spectacle prescription containing cylinder for the correction of astigmatism, it must first be determined how much of that astigmatism is the result of a toricity in the front surface of the cornea, corneal astigmatism, and how much of it may be residual astigmatism. Residual astigmatism may be caused by a toricity in the crystalline lens, a toricity in the posterior surface of the cornea, or by some other reason. For now we'll observe the toricity of the cornea as indicated by the K readings and compare it to the amount of cylinder included in the refraction. In example 2 above it can be observed that one diopter of cylinder is included in the spectacle prescription. By analyzing the K readings we can also see that there is one diopter of toricity in the front surface of the cornea. Therefore, all the astigmatism is found in the cornea and no residual astigmatism is present. When this situation occurs it is often possible to completely correct the corneal astigmatism using a spherical rigid contact lens.

To achieve this, it is first necessary to transpose the prescription to minus cylinder form and then drop the cylinder and axis. It is then possible to fit the lens as if it were a spherical prescription following the guidelines discussed. Looking at example 2 on the previous page we can observe that there is one diopter of cylinder in the spectacle prescription and one diopter of toricity on the front surface of the cornea. Therefore all the astigmatism is corneal. The Rx is already in minus cylinder form so by dropping the cylinder and axis we are left with -6.75 at the spectacle plane. Since this power is greater than ±4.00 diopters it is necessary to compensate for vertex distance. A -6.75 diopter spectacle lens at 12 mm, would need to be compensated to -6.24 at the corneal plane. Rounding off to the nearest quarter diopter gives us -6.25. What this means is that the total power of the contact lens plus the tear lens at the corneal plane needs to equal -6.25 dioptors.

We can now proceed as in example 1. If the lens is fit on K the tear lens is plano thus requiring a -6.25 diopter contact lens. If fit steeper than K the tear lens contains plus power which would then require more minus power in the contact lens. If the lens is fit flatter than K the tear lens would then contain minus power thereby requiring less minus (or more plus power) in the contact lens.

So if the lens in example 2 were fit on a 44.75 diopter base curve, what contact lens power would be required? Since 44.75 is 0.25 D steeper than K the tear lens contains a plus power of +0.25 diopter. Therefore the contact lens power must be -6.50 which, when combined with the tear lens power of +0.25 diopter, yields the desired -6.25 dioptors.

How a spherical rigid contact lens can correct for corneal astigmatism



The illustration above demonstrates how a spherical rigid contact lens can correct for corneal astigmatism. By analyzing this prescription utilizing an optical cross we can see that the power of the lens along the 180° meridian is -3.00 D and the power in the 90° meridian is -3.50 D. If a -3.00 D rigid contact lens is fit on K, the power of the resultant tear lens along the 180° meridian is plano, so the power of the contact lens in that meridian needs to be -3.00 dioptors. Since the corneal curvature is steeper along the 90° meridian, the tear layer forms a minus lens with a power of approximately -0.50 diopter. When combined with the -3.00 D contact lens, the total power of the two lenses in this meridian equals -3.50. Thus the combined power of the tear lens plus the contact lens in each principal meridian contains the power called for by the prescription—and this has been achieved through the use of a spherical rigid contact lens.

Conclusion

Achieving success in fitting toric contact lenses for the correction of astigmatism requires the expertise of a motivated fitter as well as a motivated patient. New toric soft lens products are continually reaching the market and promise more successful fits for the astigmatic patient who wishes to wear contact lenses.