# Toric IOLs for Astigmatic Correction

Selecting patients, obtaining positive results, and managing complications.

BY GEORG GERTEN, MD, AND OMID KERMANI, MD

In recent years, cataract and refractive surgery have grown closer. Cataract surgery techniques are now aimed at minimizing aberrations including corneal astigmatism and higher-order defects, and retreatments for preexisting image defects are commonplace. Very often, cataract procedures also aim to correct myopia or hyperopia by implanting a suitable IOL.

The next logical step is correcting preexisting corneal astigmatism using a suitable IOL. This IOL must be astigmatic—to balance out the existing corneal astigmatism that remains postoperatively—and achieve an overall spherical effect. This is done with IOLs containing at least one toric surface (Figure 1). Moreover, for purely refractive surgery, phakic toric IOLs (eg, Visian ICL [STAAR Surgical, Monrovia, California], Artisan Toric IOL [Ophthec BV, Groningen, Netherlands]) are also available (Figure 2). This article will highlight toric PCIOLs, although much information is the same for phakic implants.

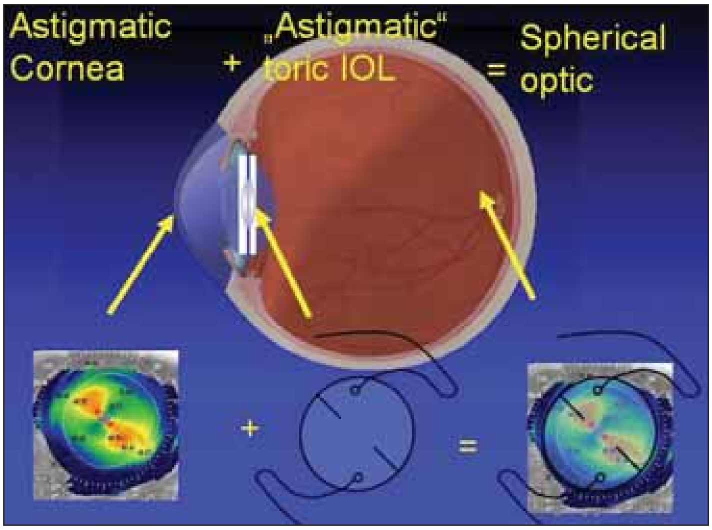


**Figure 1. Effect of a toric IOL in the eye. The corneal astigmatism of -6.00 D/47° (topography, bottom left) is balanced out by a toric IOL of the same optical effect (bottom center). When the axes are positioned correctly, a spherical image is formed on the retina (bottom right).**

## CHOOSING THE PATIENT

At the Eyeclinic Neumarkt, in Cologne, Germany, we have been developing toric IOLs since 1994. The range of indications for implanting toric IOLs after phacoemulsification has grown considerably. In the mid-1990s, toric IOLs were rigid and made from PMMA. The astigmatism induced by the required scleral tunnel was estimated preoperatively and then factored into the calculation for the toric IOL. The haptics were still modified C-loops, and approximately one-quarter of these older models rotated significantly postoperatively.[1-3] It is now possible to reduce or resolve both problems (Figure 3).[4]

Toric IOLs can only balance out regular and orthogonal corneal astigmatism and may be used if a significant proportion of the corneal astigmatism is orthogonal and regular. The astigmatism does not have to be completely regular and orthogonal however, as is the case after keratoplasty.[5-6] We have achieved excellent results implanting toric IOLs after keratoplasty,[4] and this is confirmed by others.[2,7-10] The subsequent modification of astigmatism must be excluded; all sutures must be removed and a stable status achieved.

To ensure perfect IOL position, the capsular sac must demonstrate long-term stability. Those that are likely to cause irregular wrinkling (eg, traumatic cataracts) are not ideal for toric implant. Accompanying corneal changes or posterior eye diseases (eg, macular degeneration), will also affect the indication.

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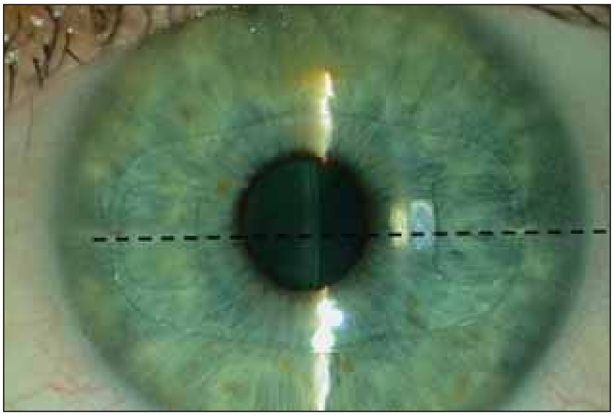

**Figure 2. Toric Artisan IOL. The minus cylinder axis is determined by the position of the iris claws, and in this case is positioned at 2° (black dashed line).**

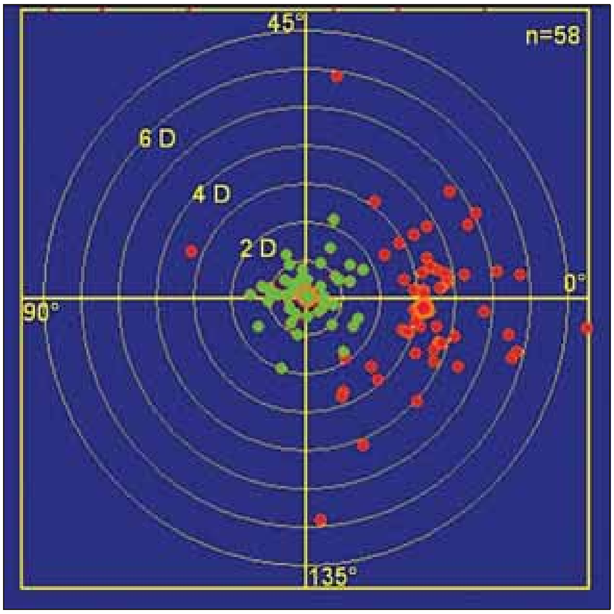


**Figure 3. Double-angle diagram of 58 toric IOL implants. The red dots represent the corneal astigmatism of each eye preoperatively (centroid: red, bordered in orange). The green points show the overall astigmatism (subjective refraction) postoperatively (centroid: green, bordered in orange).**

## INDICATIONS AND RESULTS

The present indications for toric IOL implantation include (1) an operable cataract and (2) a stable and largely regular corneal astigmatism (ie, 2.00 D). Between 1994 and 2005, we treated approximately 200 eyes with a toric IOL. Fifty-eight eyes received the Schmidt MS 6116 TU model (Humanoptics, Mannheim, Germany), a 6-mm silicon lens with a toric rear surface. By varying the silicone refraction index to modify the IOL strength, the anterior radius and central thickness of this IOL remains constant over a wide range of diopters. Therefore, the IOL is not too thick and remains easily foldable. The PMMA haptics undulate and have a Z-shape, both retaining rotational stability.

The average preoperative corneal astigmatism in our patients (ie, 3.75 D) ranged from 2.00 D to 11.00 D (Figure 3). A toric IOL implantation reduced the overall average astigmatism to 0.84 D ±0.53 D. Astigmatism induced by the incision was less than or equal to 0.50 D in all cases. Patients were observed for an average of 1 year, and 85% of all IOLs remained stable within 10° of the target axis. In 15% of eyes (n=8 of 58), an IOL rotation of 10º or more occurred. In two of these eight eyes, we did not rotate the IOL because the patient was happy, despite residual astigmatism (Figure 3). Another two eyes received LASIK, and in the remaining four eyes with residual astigmatism, further rotation was carried out 3 to 6 weeks postoperatively. This secondary rotation was a success if the IOL position was stabilized in the capsular sac in all four cases. We summarize that toric IOLs may reduce the overall astigmatism to less than 1.00 D.

## INCORRECT ROTATION, CYLINDER CORRECTION

If the toric IOL rotates in the eye, the physical and optical properties cause rotation of the axes of two overlapping spherical cylinder lenses (ie, cornea and the IOL)

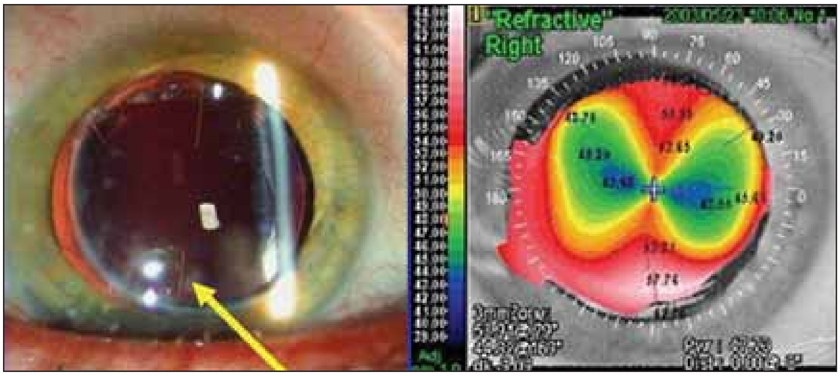

Figure 4. Toric IOL in situ after keratoplasty (top left). The yellow arrow points to the toric IOL's plus cylinder axial markings. The topography (top right) shows a not-quite regular astigmatism of 9.00 D. Nevertheless, the patient achieved a postoperative vision of 20/20 with a toric IOL and a refraction of -0.25 cyl -0.75/152.

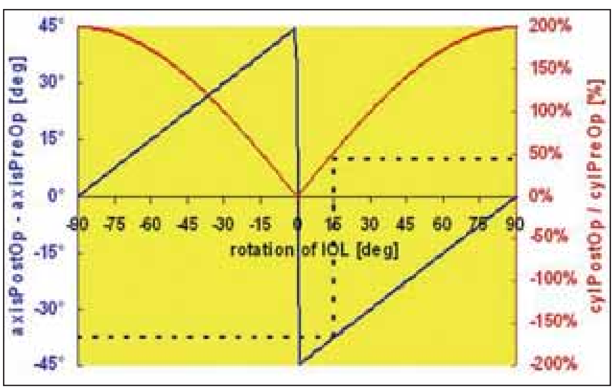


Figure 5. Modification of the overall cylinder strength (red curve and writing on the right) and axis (blue solid line and writing on the left) of the eye as a function of the rotation of a toric IOL. Written in is an example of an axial rotation of the toric IOL of 15° (blue dashed line). The result is an undesired axial rotation of around -37° and a loss of cylinder correction of just under 50%.

(Figure 1), giving rise to a new spherical cylinder lens. Ideally, in the absence of rotation, the cylindrical parts of the cornea and IOL (ie, the optical level of the cornea) balance each other out perfectly, and a pure sphere results. In the worst case, (ie, the IOL rotates 90°), the cylinder strengths are combined, and the IOL astigmatism is added to the corneal astigmatism that already exists. But, an approximate 15° malrotation of the IOL may reduce the desired cylinder correction by one-half and rotate the resulting cylinder axis (Figure 5). This is also why patients respond sensitively to minimal misalignment when prescribing spectacles: A 15º malrotation of the glass results in a 40° axial rotation of the image of the eye/glass system.

Clinically relevant incorrect rotation of a foldable toric IOL occurs in 10% to 15% of cases. Subsequent rotation via paracentesis—under droplet anesthesia—is an easy and quick procedure. These cases are also ideal for clarifying the fundamental physical and optical principles of toric IOL implantation.

## CLINICAL CASE

**The patient.** A 74-year-old cataract patient had reduced vision in the left eye, with a subjective refraction of 5.0 cyl -5.50/49°. Topography demonstrated a regular orthogonal corneal astigmatism of 6.00 D, with the minus-cylinder axis in 47° (Figure 1). The indication was for phacoemulsification plus toric IOL.

**Determining a suitable toric IOL.** After determining the eye length with the IOLMaster (Carl Zeiss Meditec AG, Jena, Germany), the flat radius (8.28/8.28) was entered into the software, and the derived IOL value for the flat meridian was printed out. An IOL was determined for the steep meridian (7.28/7.28).

To calculate the IOL, use a theoretical formula (eg, Haigis) instead of an empirical formula (eg, SRK II), because the latter only predicts the actual postoperative effect of the IOL. It only works on a limited range in a normal eye and for spherical implants.[11,12] Use the various IOL values for both meridians to derive the toric IOL. Here, we chose the 6116 TU IOL (19.00 sph 8.00 cyl), and IOL strength was based on its effect on the cornea or spectacle plane.[11-13]

**Planning the operation.** In the ideal position, the cylindrical parts of the cornea (6.00 D in 137°) and toric IOL (8.00 D, corresponding to 6.00 D in the corneal plane) balance each other out completely, resulting in a perfect sphere (Figure 1). The plus cylinder axis of the toric IOL, determined at 19 cyl 8.00 D, must sit at precisely 137°.

**Performing the operation.** A slight bulbous rotation more than 15° may occur when inducing peribulbar anesthesia or positioning the head. Therefore, the cornea is marked preoperatively, with the patient sitting upright. A Gerten Pendulum Marker using a plumb bob (Humanoptics) ensures the exact axis position of the marks on the cornea. The head of the Gerten Pendulum Marker may be rotated 360º, so that it can mark any given astigmatism axis. In this case, the plus cylinder axis at 137º was marked (Figure 1). In Figure 6, a marking of the horizontal meridian (0º/180º) is arbitrarily shown.

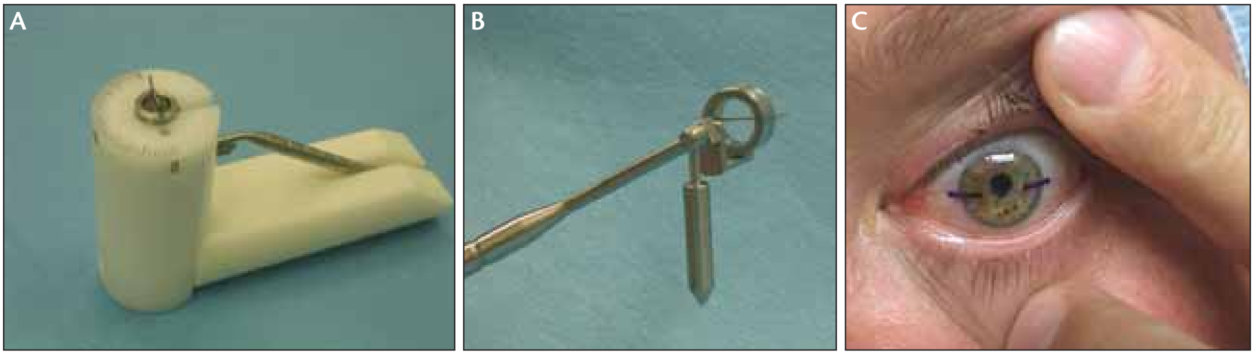


**Figure 6. (A) The head of the Gerten Pendulum Marker can be rotated 360º, so that it can mary any given astigmatism axis. (B) An exact position is always guaranteed by the applied plumb bomb when the patient is sitting upright. (C) Here, a marking of the horizontal meridien (0º/180º) is arbitrarily shown.**

A temporal astigmatism-neutral posterior limbal incision is placed on the eye. The rhexis is measured as large as possible (ie, 5.5 mm), ensuring the easy implantation of the toric IOL's long Z-haptics. Prior to implantation, the capsular sac is positioned deep with a hyaloronic acid, other than methycellulose. The toric IOL is folded out directly from the packaging, and the rear haptic clamps into position. The leading haptic enters into the capsular sac, and the subsequent haptic is rotated. The IOL then turns until the two lines on the IOL lens line up with the markings on the cornea. In approximately 90% of cases, it is possible to reduce the astigmatism to less than or equal to 1.00 D.

The implantation axis of the toric IOL plays a major role in determining the refractive result. The preoperative axial markings can be optimized with a pendulum marker.

**Postoperative checks.** One week postoperatively, the patient achieved a vision of 20/30 with correction, and an UCVA of 20/100. There was a significant refraction error of + 1.25 cyl -3.5/8°, however.

In a situation such as this, the preoperative data should be checked. Has the data been gathered correctly, entered correctly, and the IOL calculated correctly? Then, examine the operating technique. Is it possible that unwanted astigmatism was induced during the operation? Does the postoperative keratometry data match the preoperative values? Next, analyze the postoperative findings. Is there hypotension? Is the anterior chamber deep and the incision sealed?

We strongly discourage estimating the IOL position. Instead, measure the IOL markings with lenses for determining the axes of toric contact lenses or slit lamps, as these facilitate axial determination when the slit is rotated (eg, Haag-Streit). In this case, the IOL is positioned at 157° instead of 137°.

So, how has the postoperative astigmatism of -3.5/18° arisen from this malrotation? Astigmatisms behave mathematically like vectors (Figure 7).[2,4,11] The length of the vector corresponds to the strength,

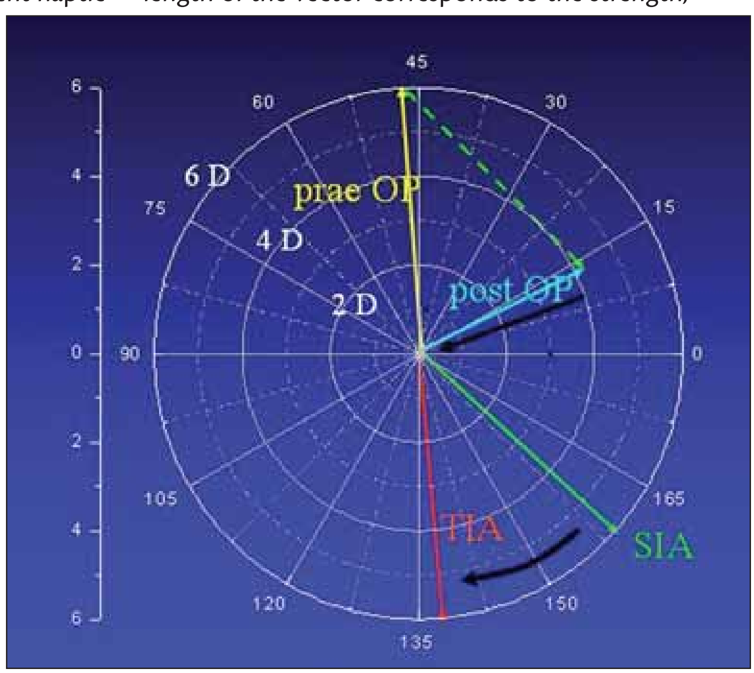


**Figure 7. Vector mapping of the IOL malrotation in the double-angle diagram. The yellow vector demonstrates preoperative astigmatism, and the red vector is the desired induced astigmatism by the IOL. The green vector is the amount of induced astigmatism actually achieved, and the blue vector is the postoperative residual astigmatism. If the green vector is rotated by 20° in clockwise direction (see black arrow), the blue vector and thus the postoperative astigmatism move toward zero.**

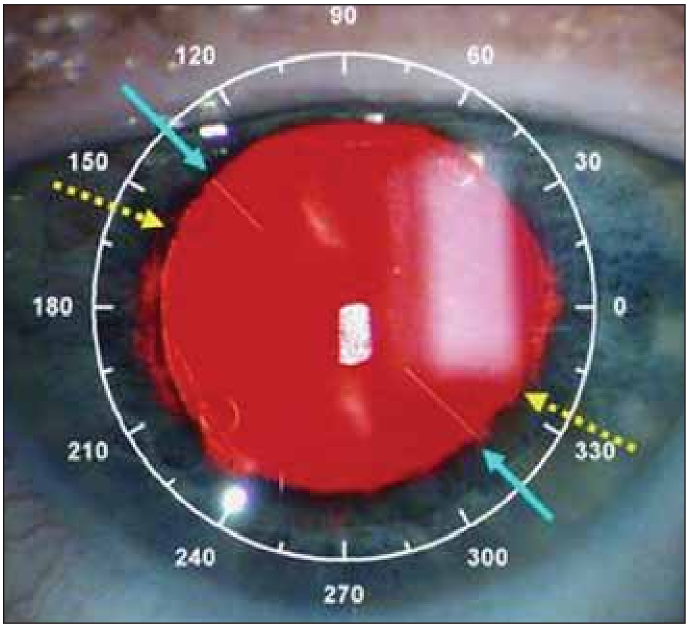


**Figure 8. Toric IOL after rotation. The markings of the toric IOL are ideally positioned at 137° (blue arrow). The yellow arrow shows misalignment before subsequent correction at 157°.**

while its direction corresponds to the axis of the astigmatism (ie, specified as 0° to 180°). The axis of a mathematical vector, however, is from 0° to 360°. For evaluation, a full circle is required so that trigonometric functions may be applied.

Cylinder axes values are doubled; graphically, the result is a double-angle diagram.[5,12] All cylinder strengths are relative to the corneal plane. The preoperative astigmatism was 6.00 D at 47° (Figure 7), and the ideal neutralization of this astigmatism would have been a vector of 6.00 D at 137º. An astigmatism of the same magnitude, but wrong axis at 157º, was induced by the toric IOL at 157° (Figure 7). The preoperative and induced astigmatism then provide the postoperative astigmatism, and the mathematical result is approximately 4.00 D at 15°.

Rotating the induced astigmatism by -20°, the preoperative astigmatism is neutralized, and the result is a spherical refraction. The toric IOL must also be rotated by -20°. It is prudent not to rotate the IOL too soon or too late: The IOL should be rotated after the capsular sac is stable, but before the capsular membranes have bonded with the IOL (ie, approximately 3 to 6 weeks postop).

## RESULTS OF SUBSEQUENT ROTATION

The following day, IOL position is determined using the slit lamp in the correct position at 137° (Figure 8). In this patient's eye, the astigmatic cornea and the opposite astigmatic toric IOL complement each other, creating a spherical overall refraction (Figure 1). The UCVA rises to 20/25, while the BCVA result rises to 20/20. The subjective refraction, at -0.25 cyl -0.5/90°, demonstrates a minimal residual cylinder. Generally, the result is stable after one subsequent rotation. Only in plate haptic IOLs have we seen the need for rerotation; twice in 10 years.

## SUMMARY

A three-piece toric IOL with Z-haptics is a safe and precise method for correcting higher magnitudes of corneal astigmatism. We advise implanting a toric IOL in patients with largely regular corneal astigmatism of 2.00 D and above. The precise axis alignment between corneal astigmatism and toric IOL is crucial for the refractive result. Keep a watchful eye on IOL placement and rotation for 4 weeks postop. In virtually all patients (ie, more than 95%), the overall postoperative astigmatism was reduced to less than 2.00 D and is thus correctable with spectacles. ■

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