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Surgical Management of Cataract and Astigmatism

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Learning Objectives: *After reading this lesson, the participant should be able to:*

1. *Describe preoperative assessment of patients with cataract and co-existing astigmatism and management options in such patients who desire a reduced dependence on spectacles.*
2. *Explain preoperative planning and surgical techniques for toric intraocular lens (IOL) placement and limbal-relaxing incisions.*
3. *Explain relative and absolute exclusion criteria for placement of toric IOLs, as well as management of related complications.*

The concept of cataract surgery as refractive surgery that reliably decreases spectacle dependence is receiving increasing attention from ophthalmic surgeons, and has spawned a new subspecialty known as *refractive cataract surgery*. Refractive cataract surgery can be defined as cataract surgery with the dual goals of improved visual acuity and reduction of spectacle dependence at distance, near, or both. In fact, many patients now undergoing refractive cataract surgery do not even have cataracts, and are undergoing clear lensectomy (often termed *refractive lens exchange*) with the sole purpose of reducing spectacle dependence. Consequently, the management of astigmatism in patients undergoing refractive cataract surgery or lens exchange is of great importance. The multifactorial causes of this paradigm shift in care include:

- The ability to perform cataract surgery routinely through small incisions;
- Advances in diagnostic technologies for measuring corneal power and axial length;
- New intraocular lens (IOL) technology that can treat presbyopia and astigmatism;
- An evolving regulatory climate in the United States that permits an elective, self-pay component for cataract surgery using specific types of IOLs, making innovation in this area more profitable for both industry and surgeons; and
- Increased acceptance of and demand for elective, quality-of-life–enhancing medical procedures by the aging baby boom generation.

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Patient Expectations

As technology and surgical results have improved, the desire for independence from spectacles among individuals undergoing cataract surgery has increased dramatically. Patients undergoing cataract surgery with presbyopic and toric lenses (i.e., refractive IOLs) have higher expectations for visual outcomes and are less tolerant of even modest residual postoperative refractive errors. The precise control of astigmatism in the patient with cataract has therefore assumed great importance. This article focuses on the correction of coexistent astigmatism and cataract.

It is estimated that 15% to 29% of patients presenting for cataract surgery have more than 1.50 D of corneal astigmatism.[1–3] As little as 0.50 to 0.75 D of uncorrected cylinder after cataract surgery can leave a patient with visual disturbances including blur, halos, and ghosting. Furthermore, in patients with multi-focal IOLs, even small amounts of residual astigmatism may reduce visual acuity noticeably, especially at near. For these reasons, the need to manage corneal astigmatism to achieve adequate uncorrected postoperative visual acuity has become an important aspect of preoperative planning for modern small-incision cataract surgery, despite the fact that the small incision sizes used for such procedures induce minimal corneal astigmatism. Aside from glasses or contact lenses, treatment options for patients with cataracts who have preexisting corneal astigmatism include excimer laser refractive procedures; astigmatic keratotomy (AK) with limbal or more anteriorly located, nonpenetrating, corneal-relaxing incisions; and toric IOLs. Corneal-relaxing incisions can be used in combination with monofocal, toric, or presbyopia-correcting IOLs at the time of cataract surgery. Cataract surgery, with or without corneal-relaxing incisions, also can be done before or after laser vision correction. In most cases, it is more desirable to perform cataract surgery before planned excimer laser refractive procedures, allowing for more precise IOL power calculations and latitude to adjust both residual astigmatism and spherical refractive error after IOL implantation.

Incisions

Once small, minimally astigmatic incisions became possible for the vast majority of cataract surgeries, the potential benefits of intraoperative limbal-relaxing incisions (LRIs), AK, or other types of corneal incisions to alter astigmatism increased dramatically. While reducing astigmatism at the time of cataract surgery dates back to the mid-1980s with the use of AK,[4–7] only during the 1990s did surgeons recognize the advantages of moving corneal-relaxing incisions to the limbus, away from the central optical zone (Figure 1).[4,8–10]

Kaufmann et al.[11] showed that patients with 1.5 D or more of keratometric astigmatism realized greater benefit from the LRI technique than from a 3.5-mm on-axis incision alone. An on-axis incision resulted in a 0.41-D flattening affect, whereas the LRI group showed 1.21 D of flattening affect using the modified Gills nomogram.[12] Now that even smaller clear corneal incisions (2.2 to 2.5 mm) and foldable IOLs are used routinely, the degree of flattening associated with on-axis incisions has decreased even further, and the average clear corneal wound of this size generally results in induction of 0.3 D or less of cylinder.

The benefits of LRIs versus AK include reducing the likelihood of induction of irregular astigmatism and the attendant undesirable symptoms of glare or starburst effect.[5] Several different nomograms are available; we most commonly use the nomograms by Donnenfeld or Gills and Gayton for their simplicity (Tables 1 and 2).[11–14] A detailed discussion of LRI technique is provided later in this article.

Toric Intraocular Lenses

In addition to managing corneal astigmatism in the corneal plane with AK or LRI, astigmatism can be managed in the lenticular plane. The use of toric IOLs to treat corneal astigmatism has become increasingly popular. The first toric IOL was used by Shimizu et al.[15] in 1994. Subsequently, the first widely available toric posterior chamber IOL was produced by Staar Surgical (Monrovia, CA), and was first implanted in 1999.[16] This IOL was introduced in North America by Gimbel and Ziemba.[17] Structurally, the Staar toric IOL is a one-piece, plate haptic silicone lens available in a full range of spherical powers, but available only in two cylinder power options at the IOL plane (corneal plane): 2.00 D (1.4 D) and 3.50 D (2.3 D). In United States, clinical studies of more than 300 patients with cataract who had preexisting astigmatism, 47% achieved postoperative uncorrected visual acuity (UCVA) of 20/30 or better with the Staar IOL, as compared with 21% in the spherical IOL control group.[18–20] The main problem with this IOL has been poor rotational stability. In one study by Till et al.,[18] in which Staar toric IOLs were implanted in 100 eyes, 27 eyes were off axis by between 6 and

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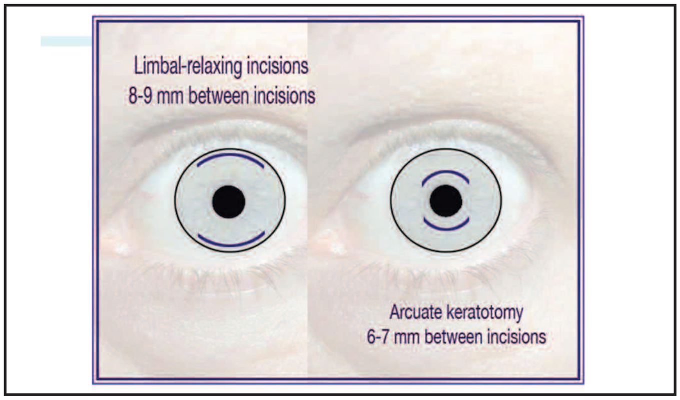

Figure 1. Incisions for astigmatic keratotomy and limbal-relaxing incision.

Table 1. Donnenfeld Limbal-Relaxing Incision Nomogram[12]

Astigmatism (D)	Number and Position of Limbal Relaxing Incisions*
0.50	One incision, 1.5 clock hours (45 degrees)
0.75	Two incisions, 1 clock hour (30 degrees each)
1.50	Two incisions, 2 clock hours (60 degrees each)
3.00	Two incisions, 3 clock hours (90 degrees each)

* Incisions are placed 0.5 mm from the limbus. Use 5 degrees more for against-the-rule astigmatism and for patients less than 45 years old. Use 5 degrees less for patients over 65 years old. The blade depth is between 600 and 650 microns based on peripheral pachymetry readings. A 600-micron setting is used for peripheral pachymetry readings under 625 microns, and a 650-micron setting is used for a peripheral pachymetry reading greater than 650 microns.

15 degrees, and 14 eyes were rotated more than 15 degrees off axis. The remainder of the eyes achieved IOL position within 5 degrees of the intended axis, and no additional rotation was noted after 1 week. Euler's theorem (Table 3) demonstrates that approximately 1 degree of off-axis rotation results in a loss of about 3.3% of lens cylinder power.[21] Consequently, if the lens rotates 5, 10, 15, or 30 degrees off-axis, 17%, 33%, 50%, or 100%, respectively, of the cylindrical power is lost. Using these calculations, 41% of the eyes in the study by Till et al.[18] lost 20% or more of their astigmatic correction due to IOL movement, and 14% lost more than half of the intended astigmatic effect.

Clinical trial results using the recently introduced AcrySof toric IOL (Alcon; Figure 2) have demonstrated greatly improved rotational lens stability with corresponding improvement in refractive cylinder reduction and UCVA results. Clinical investigation involving 494 subjects (211 eyes with AcrySof toric lenses and 210 control eyes with the SA60AT lens [Alcon]) showed that at the 6-month follow-up interval, the AcrySof toric IOL had a mean rotation of less than 4 degrees, with no IOL off axis by more than 15 degrees. Patients were three times more likely to achieve no more than 0.5 D of residual refractive cylinder with the AcrySof toric IOL compared with controls.[22] The mean absolute residual refractive cylinder for all patients with the AcrySof toric IOL was 0.55, compared with 1.22 D for control eyes. Additionally, 94% of patients achieved uncorrected distance visual acuity of 20/40 or better. The importance of more precise astigmatic correction translates directly into decreased spectacle dependence: 59.9% of patients with unilateral AcrySof toric IOL implantation (N = 207) achieved distance vision spectacle freedom (DVSF), and 97% (N = 37) of patients with bilateral AcrySof toric IOL implantation achieved DVSF[22] (Figures 3 and 4).

Perioperative Management

General Considerations

Before the toric IOL was developed, surgical management of astigmatism in patients with cataract was done primarily by the refractive surgeon, usually with laser vision correction, AK, or LRIs as a second procedure weeks to months after cataract surgery. With the advent of more accurate IOL calculations due to better measurement of corneal power and axial length, as well as newer IOLs to correct for corneal asphericity or presbyopia, patients have greater expectations for ideal spectacle-free outcomes. Uncorrected astigmatism has an underrecognized impact on visual quality after cataract surgery. Because as little as 0.50 to 0.75 D of uncorrected astigmatism can affect visual acuity dramatically in patients with multifocal and accommodating IOLs (who expect good UCVA at distance and near after surgery), corneal cylinder must be managed accurately and in a timely fashion. Additionally, many patients who have previously undergone laser vision correction are now developing cataracts. This subset of patients with cataracts, many of whom have been living spectacle-free for years, are likely to demand better refractive outcomes than the standard cataract patient, again reinforcing the need for precise methods to manage corneal astigmatism.

Costs of any proposed elective procedure(s) should be reviewed with the patient during the decision-making process. Toric IOLs, LRIs, presbyopic IOLs, and excimer laser procedures all require out-of-pocket expenses for the patient. It can be useful to have brochures, office information videos, Internet web site referrals, and other reading material as resources for patients to review before the informed consent discussion with the surgeon. Patients will need extra time to discuss these options and expenses with the surgeon or surgical coordinator, so this must be taken into consideration when scheduling patient evaluations for possible refractive cataract surgery.

Table 2. Gills and Gayton Nomogram for Limbal-Relaxing Incisions*[12]

Astigmatism (D)	Description of Limbal Relaxing Incisions
1.00	One 6.0-mm incision
1.00–2.00	Two 6.0-mm incisions
2.00–3.00	Two 8.0-mm incisions
3.00–4.00	Two 10.0-mm incisions
> 4.00	Two 10.0- to 12.0-mm incisions plus corneal-relaxing incision

* Blade depth setting at 600 microns. Exception: in patients over 80 years of age, set blade depth to 500 microns.

Table 3. Euler's Theorem[21]

Axis Deviation (Degrees)	Decrease in Effect (%)
1	3.3
5	17
10	33
15	50
30	100

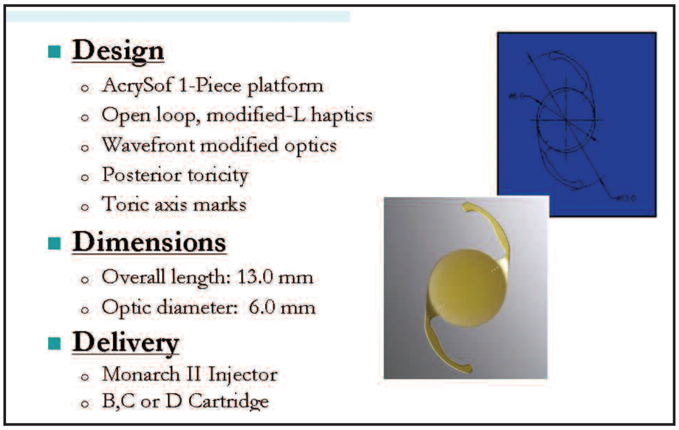

Figure 2. Characteristics of the AcrySof toric intraocular lens (IOL).

Preoperative Evaluation and Patient Selection

Careful preoperative planning and counseling is a crucial step for accurate correction of astigmatism. The importance of assessing the patient's visual needs cannot be overemphasized. A routinely administered preoperative questionnaire is an excellent way to obtain information about occupational and recreational needs, as well as the degree of importance a given patient places on reduced spectacle dependence.

After assessing visual needs and objectives, it is essential to obtain the patient's refractive history, including contact lens usage (or lack thereof), current spectacle prescription, and any history of refractive surgery. A history of refractive surgery is important, because it will affect the choice of methods used to determine the keratometry values and formulas used to calculate IOL power. Whenever possible, old records should be obtained, because some IOL calculation formulas for patients who have had previous refractive surgery use original manifest refraction and keratometry data. A discussion of IOL power calculation in patients who have undergone previous keratorefractive surgery is beyond the scope of this article, but it should be noted that it is very important to be certain regarding the magnitude, axis, and stability of the corneal cylinder to be treated. If the patient has previously worn contact lenses, it is important to know the type of lenses worn (toric or spherical only), as well as contact lens habits, including number of hours worn each day and length of cumulative time the lenses have been used. Patients who have worn astigmatic correction with either glasses or contact lenses may have a greater interest in correcting their astigmatism. This information may affect the timing of planned surgery, because a contact lens holiday of 2 weeks or longer may be needed to obtain accurate, stable corneal power measurements for IOL calculations.

Before the preoperative testing to determine keratometry readings, soft contact lens wearers should undergo a 2-week contact lens holiday, whereas rigid contact lens wearers should wait a minimum of 4 weeks before corneal topography is evaluated and keratometry readings are obtained, as significant warpage from prolonged contact lens wear could alter the results. Additionally, for rigid contact lens wearers who have used lenses for more than 10 years, an additional week should be added for each additional decade of rigid gas-permeable lens wearing time to the minimum 4-week contact lens holiday requirement. For rigid contact lenses users, it is prudent to repeat corneal topography 1 to 2 weeks after these initial measurements to document stability before selecting keratometry measurements on which to base IOL power calculations and, if indicated, LRI placement. Without the appropriate contact lens holiday, an IOL calculation error may result, and it is preferable to reschedule the patient's preoperative testing appointment even if surgery must be deferred.

After reviewing the goals for surgery and obtaining a careful refractive history, the patient should undergo manifest refraction followed by corneal topography, tomography (where available), automated keratometry readings, immersion A scan ultrasonography, and IOL master measurements. These tests should be done before the instillation of any topical anesthetics or dilation drops, as such diagnostic medications can alter the corneal epithelium and skew corneal power measurements. For this reason, immersion A scans should be obtained after the tests noted above.

Slit-lamp examination should be performed, with careful attention to the precorneal tear film and the presence of blepharitis, particularly meibomian gland dysfunction. A poor tear film in patients with dry eye syndrome or chronic blepharitis may alter keratometry measurements, resulting in inaccurate IOL calculations. The surgeon should look closely for signs of dry eye, (including reduced tear break-up time, punctate keratopathy, corneal scarring), Salzmann's degeneration, and anterior basement membrane dystrophy; all of which could cause irregular astigmatism and corresponding

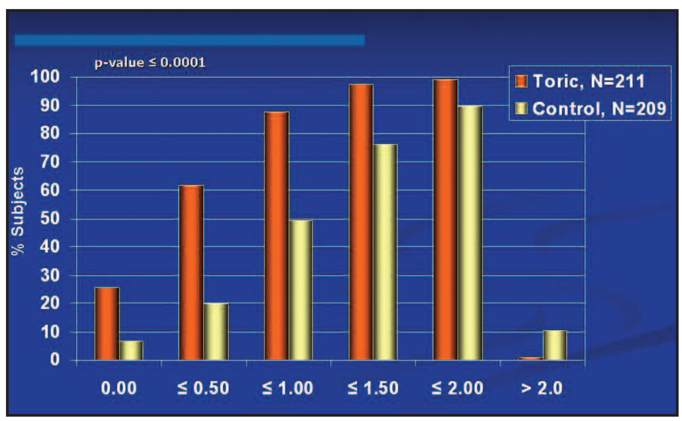

Figure 3. Cumulative absolute residual refractive cylinder at 6 months seen with bilateral AcrySof SA60TT toric IOL.

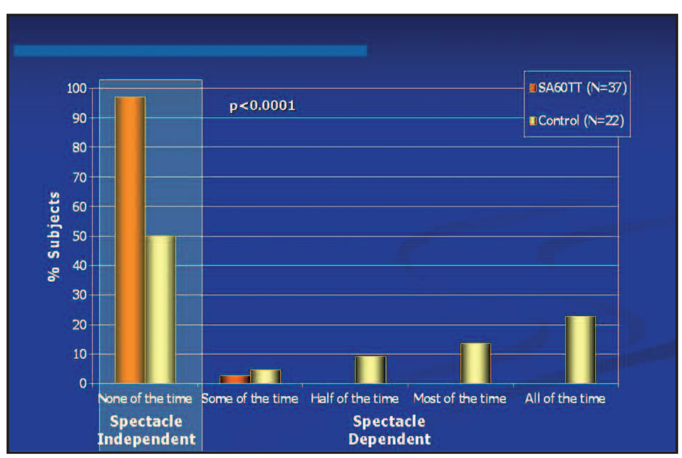

Figure 4. Distance vision spectacle freedom with bilateral AcrySof toric IOL implants.

changes seen on corneal topography and tomography. Patients with dry eye who have autoimmune diseases such as rheumatoid arthritis, Sjögren syndrome, and systemic lupus erythematosus may exhibit irregular corneal healing after corneal-based refractive procedures (e.g., AK, LRI, or laser vision correction) and therefore are poor candidates for surgical astigmatism treatments using anything other than a toric IOL.

In patients with anterior basement membrane dystrophy or Salzmann's nodular degeneration, superficial keratectomy should be performed to remove nodules and unhealthy epithelium prior to performing cataract surgery. This may allow for resolution of the irregular astigmatism and will markedly affect corneal power measurements, with many patients experiencing a marked reduction in corneal astigmatism following corneal debridement. Superficial keratectomy should be done at least 2 months before measurements are repeated for cataract surgery to allow for healing and stabilization; the keratometry readings should then be re-obtained before cataract surgery. The cornea also should be examined for other signs of irregular astigmatism indicative of an ectatic condition, such as form fruste keratoconus, keratoconus, post-LASIK keratectasia, pellucid marginal degeneration, keratoglobus, or Terrien's marginal degeneration. Specific signs of keratoconus to look for at the slit lamp include Fleischer rings, Vogt's striae, corneal thinning, as well as asymmetric inferior or superior steepening on topography images. The cornea also should be examined closely for signs of endothelial dystrophies such as the presence of guttae with or without corneal thickening (i.e., Fuchs endothelial dystrophy) or the often asymptomatic vesicular lesions, diffuse opacities, or band lesions seen in posterior polymorphous dystrophy.[23]

The manifest refraction or current spectacle prescription often may not coincide with keratometry measurements, even in patients without coexisting corneal pathology such as that described earlier. This is likely due to the induction of lenticular astigmatism by cataract. For example, if a patient has 1 D of corneal astigmatism (e.g., K reading 44 at 90 degrees and 45 at 180 degrees), but his or her refraction is –1.00–3.00 × 90, then one can assume that the additional astigmatism is probably lens-induced. The cataract surgeon must pay special attention to this mismatch, because treating a patient's lenticular astigmatism instead of the corneal astigmatism with LRI, laser vision correction, AK, or toric IOLs may lead to a poor refractive outcome. Discrepancies between keratometry or axial length measurements must also be addressed. Because keratometry values typically are obtained four or five ways (including with the Zeiss IOL Master, the automated keratometer, the manual keratometer, and corneal topography or tomography), and axial length measurements often are obtained with both immersion A scan and partial coherence biometry (Zeiss IOL Master), variations may be seen. If the measurements used are not the most representative of the actual central corneal power or axial length, the chosen IOL power will not give the best refractive results.

We typically create a spreadsheet of the measurements obtained and compare them directly against each other and for asymmetry between eyes. Any asymmetry between eyes should be explainable by the refractive history. If not, repeat measurements are indicated to confirm such discrepancies. It also is important to evaluate the quality of the measurements. If the measurements are of good quality, the keratometry readings typically are chosen in the following order: Zeiss IOL Master or manual keratometry, automated keratometry, followed by topography/tomography. Aberrant outlier keratometry readings often occur due to tear film instability. Instilling artificial tears and repeating measurements often solves the problem. If these approaches are not successful, consideration should be given to more aggressive treatment of any coexistent blepharitis and dry eye with lid hygiene, a trial of low-dose topical corticosteroids, topical cyclosporine, and punctual occlusion. If the quality of the signal is acceptable, axial length measurements are chosen, usually with Zeiss IOL master readings first, followed by A scan immersion readings for confirmation. Although both methods of axial length measurement may not be necessary in all cases, the redundancy of multiple measurements helps to ensure maximal accuracy.

As previously discussed, obtaining optimal refractive outcomes with the toric IOL is contingent on the rotational stability of the IOL in the capsular bag. Toric IOL implantation is therefore contraindicated in any eye where lens stability may be compromised.

Absolute contraindications include:

- Severe pseudoexfoliation with evidence of zonular compromise;
- Autoimmune diseases (e.g., systemic lupus erythematosus, rheumatoid arthritis, Sjögren syndrome) with cornea melting;
- Terrien's marginal degeneration;
- Keratoglobus;
- Pseudoexfoliation;
- History of significant blunt or other ocular trauma;
- Any other evidence of zonular compromise; and
- Tear in the posterior capsule or poor capsular stability after phacoemulsification.

Relative contraindications include:

- Advanced glaucoma or other optic neuropathies limiting vision;
- Uncontrolled severe keratoconjunctivitis sicca;
- Corneal scarring;
- Salzmann's nodular degeneration;
- Anterior basement membrane dystrophy;
- Corneal dystrophies;
- Post-LASIK ectasia;
- Keratoconus;
- Pellucid marginal degeneration;
- Maculopathies (i.e., age-related macular degeneration, diabetic macular disease, macular hole, epiretinal membrane);
- Optic neuropathies; and
- Amblyopia.

Patients with any of these findings should be evaluated thoroughly before considering refractive cataract surgery, because any ocular pathology potentially limiting vision may result in patient disappointment because of unrealistic expectations for visual outcomes.

Procedure Selection

LRIs can be performed alone or in combination with IOL implantation at the time of cataract surgery with a monofocal, multifocal, toric, or toric-multifocal lens (currently in clinical trials). The LRI surgical technique and nomogram applied should be modified depending on the type of lens used and the degree of astigmatism that must be corrected. For patients with 0.75 to 1.50 D of corneal astigmatism, the preferred choice of treatment would be LRI alone or toric IOL insertion. The Acrysof SN60T3, SN60T4, and SN60T5 can correct cylindrical power at the IOL plane (corneal plane) of 1.50 D (1.03 D), 2.25 D (1.55 D), and 3.00 D (2.06 D), respectively (Table 4). Spherical power availability ranges from +6.0 to +30.0 D. An aspheric version of this lens was released in April 2009 (SN6AT series). For patients with between 1.5 and 2.0 D of astigmatism, a toric IOL alone is indicated when possible, because predictability is likely greater than LRIs, although no peer-reviewed literature exists specifically comparing the two modalities in a prospective, randomized manner. The Acrysof T6, 7, 8, and 9 are in development and will be available in the future to treat 2.5, 3.0, 3.5, and 4.0 D of astigmatism at the IOL plane, respectively (Table 5).

If a patient has corneal astigmatism greater than approximately 2.0 D, an adjunctive treatment such as LRI or laser vision correction may be warranted. For corneal cylinder of 2 to 3 D, it may be prudent to perform toric IOL insertion first and then determine whether the patient needs adjunctive LRI or excimer later treatment secondarily at a later date. For corneal cylinder greater than 3 D, the likelihood of an additional corrective procedure is high, so concurrent LRI placement is appropriate at the time of cataract surgery. In patients who have already undergone cataract surgery with monofocal IOL placement, options include LRI or excimer laser vision correction, because no toric IOL design currently exists that would be amenable to placement in the ciliary sulcus as a piggyback lens.

Once the decision is made to use a toric IOL, the Acrysof Toric IOL Calculator (www.acrysoftoriccalculator.com) should be used to give the surgeon a surgical guideline for precise positioning of the IOL. After entering patient information, spherical equivalent IOL power, surgically induced astigmatism, incision location, steep and flat keratometry measurements, and the meridian of the steep and flat keratometry values, the Calculator will provide the lens type needed (i.e., T3, T4, T5) as well as the precise orientation of the three dots (found on the optic of the IOL at the haptic-optic junction) in the capsular bag (Figure 5D). A diagram that can be printed and used in the operating room is provided. This reference guide is helpful to prevent intraoperative alignment errors, and we recommend that this diagram be printed to use as a reference guide for lens placement during surgery.

If AK incisions or LRIs are to be done concurrently with cataract surgery, nomograms such as those listed in this article should be consulted ahead of time, and the appropriate incision size(s) and location(s) should be carefully noted in the surgery plan.

Surgical Technique

On the day of surgical toric IOL implantation, the surgeon should first place alignment reference marks in the preoperative area with the patient sitting upright (true axis of IOL alignment may be misrepresented if marks are made when the patient is in the supine position). This is done prior to administering anesthesia, including any type of ocular block (e.g., peribulbar, retrobulbar, or lid block) or intravenous sedation. Reference marks are made with a three-pronged marker or other device, with marks at the 3, 6, and 9 o'clock position after giving the patient a drop of topical anesthesia (Figure 5A). The patient should be in a seated upright position (while learning this technique, the use of the slit lamp is helpful). Corneal axis alignment marks are important, because the eye can significantly cyclorotate when the patient lies in the supine position, especially following intravenous sedation or peribulbar anesthesia. The preplaced reference alignment marks should be darkened with a marking pen so they do not fade during the cataract removal. After the patient is draped in the operating room and a lid speculum is placed, the steep axis is marked using the preoperative reference marks as a guide plus an axis-alignment instrument such as a Mendez gauge to ensure maximal precision (Figure 5B). These marks are used to align the two pairs of three radially oriented dots located on the toric IOL optic once it is placed in the capsular bag. To minimize the chance for alignment error it is very helpful to reference the AcrySof Toric Calculator diagram (discussed earlier) when marking the steep axis.

After marking the axis for toric IOL placement, the surgeon should perform a standard cataract procedure from capsulorrhexis through phacoemulsification. The capsulorrhexis should be less than 6.0 mm in order to overlap the 6.0 mm optic diameter of the AcrySof toric IOL. After the toric IOL is injected into the bag and has unfolded, it is grossly aligned so that the dots are approximately 15 degrees counterclockwise to the axis mark (Figure 5C). Viscoelastic material is then removed with irrigation/aspiration (I/A), taking particular care to remove material from beneath the IOL optic. The lens is stabilized during this step with a second instrument or the silicone I/A tip to prevent the IOL from rotating past the intended axis. The final alignment is then performed such that the IOL is dialed clockwise into its precise intended location

Table 4. Cylinder Powers of AcrySof Toric Intraocular Lenses

Model	Cylinder Power, IOL Plane	Cylinder Power, Corneal Plane*
SN60T3	1.50	1.03
SN60T4	2.25	1.55
SN60T5	3.00	2.06

*Based on an average pseudophakic human eye. Spherical powers: 10.0–30.0 D.

Table 5. Future Models of AcrySof Toric Intraocular Lens

Model	Cylinder Power, IOL Plane (D)
SN60T6	2.5
SN60T7	3.0
SN60T8	3.5
SN60T9	4.0

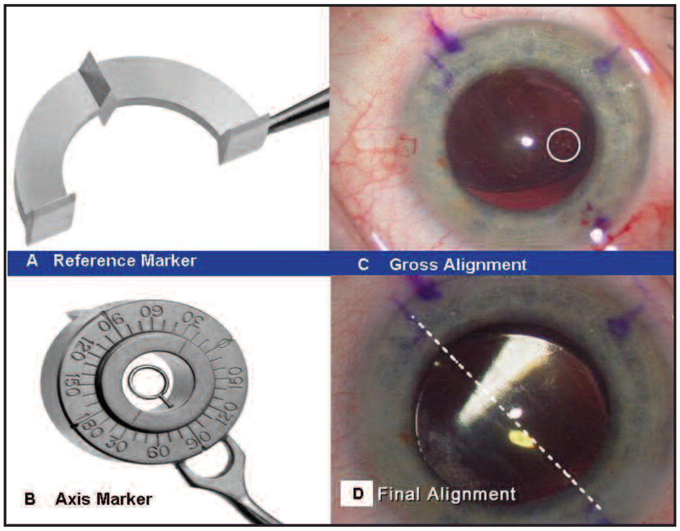

Figure 5. *A*, Three-prong reference marker to guide axis mark. *B*, Axis marker for proper positioning of IOL. *C*, Gross alignment of IOL. *D*, Final alignment of IOL.

(Figure 5D). The lens should then be tapped down into the capsular bag so that it is seated in place.

When planning LRI and cataract surgery on the same day, the LRI should be done first, as it is preferable to work with a firm, well-hydrated eye. At the end of cataract surgery, the cornea can be dehydrated and secondarily thinner, increasing the risk of perforation. Before beginning the surgery, it is important to review the topography and surgical plan. We find it very helpful to hang a copy of the corneal topography or surgical plan (oriented to the surgeon's view through the operating microscope) in the operating room so it can be referred to during the procedure. The LRI blade usually is preset to 600 microns (see Tables 1 and 2 for exceptions). Guarded LRI knives provide the safety benefit of a preset depth, which greatly decreases the chance of corneal perforation. The surgeon can feel confident, after measuring peripheral corneal depth and placing the incision in this planned peripheral location, that he or she is unlikely to cut "too deep." During the procedure, the episclera is grasped at the limbus with a 0.12 forceps (typically 180 degrees away from the incision) or stabilized with a toothed device such as a Thornton ring. The blade is then placed into the cornea with a moderate amount of pressure to obtain adequate depth, and then the incision is created. It is suggested that marks delimiting the extent of each incision as well as the axis be preplaced as a guide before making the incision.

Complications

Most of the potential complications associated with LRI are temporary or correctable. Possible complications include overcorrection with a 90-degree axis flip, undercorrection or regression of effect over time, infection, globe perforation, dry eye, discomfort, irregular astigmatism, incision gape with corneal melting, neovascularization, and decreased corneal sensation.

Patients who are either over- or undercorrected should be counseled to wait for at least 3 months to allow for complete healing before further treatment is contemplated. For large over-corrections, however, prompt suturing of the wound may be appropriate; small over-corrections may be handled with excimer laser photoablation. It is not advised to place LRIs perpendicular to the original LRI wounds, because doing so may induce irregular astigmatism.[16] Postoperative discomfort can be treated with topical nonsteroidal anti-inflammatory drugs or a bandage contact lens.

Complications related to toric IOL placement include overcorrection with axis flip, undercorrection, malrotation causing under- or overcorrection, and standard risks of cataract surgery. Additionally, is of utmost importance to maintain the IOL in the capsular bag to allow for rotational stability. If there is capsular or zonular compromise during phacoemulsification, the IOL should not be inserted.

Summary

The management of corneal astigmatism is an important adjunct to modern cataract surgery. The toric IOL is a precise, accurate, safe, convenient, and permanent means to achieve predictable outcomes in cataract patients with keratometric astigmatism. LRIs are an underutilized less-invasive treatment option for astigmatism, and are of great utility when using currently available presbyopic IOLs, none of which incorporate astigmatic correction. The combination of these two procedures allows for precise management of corneal astigmatism in most patients, and any surgeon performing refractive cataract surgery can and should master both procedures. In the future, it is likely that multifocal and possibly even accommodating IOLs with a toric component will be available, making LRIs less common and furthering the evolution of safe, simple, and precise refractive cataract surgery.

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1. The main problem with the Staar toric intraocular lens (IOL) is
A. limited availability of spherical powers
B. poor rotational stability
C. inability to correct 3.5 D of astigmatism at the IOL plane
D. lens material

2. According to Euler's theorem, if the toric IOL rotates 15 degrees, the amount of cylindrical power lost is
A. 17%
B. 25%
C. 50%
D. 100%

3. According to tests reviewed by the FDA for premarket approval, the proportion of patients who achieved distance vision spectacle freedom after receiving bilateral Acrysof toric IOLs was
A. 28%
B. 47%
C. 80%
D. 97%

4. All of the following are signs of either keratoconus or an ectatic condition, *except*
A. a focal area of corneal thinning corresponding to a steep area on topography
B. asymmetric inferior or superior steepening
C. endothelial vesicles
D. Vogt's striae

5. A patient's keratometry readings on topography are 43.50 at 180 degrees and 45.50 at 90 degrees. The manifest refraction is –2.25–1.00 × 180. The patient wishes to have the astigmatism corrected. Surgical correction for this patient is optimized by
A. cataract extraction with toric IOL implantation to correct 2.0 D of with-the-rule astigmatism
B. cataract extraction with toric IOL implantation to correct 1.0 D of with-the-rule astigmatism
C. excimer laser vision correction of current refraction, then cataract extraction with IOL implantation
D. limbal-relaxing incisions (LRIs) to correct the 2.0 D of against-the-rule astigmatism and cataract extraction with IOL implantation

6. Contraindications to toric IOL placement include all of the following, *except*
A. 6.0 D of against-the-rule astigmatism
B. pseudoexfoliation
C. a tear in the posterior capsule at time of surgery
D. macular scarring from age-related macular degeneration

7. The length of the LRI may depend on all of the following, *except*
A. the degree of astigmatism
B. corneal depth
C. patient age
D. the presence of against-the-rule astigmatism

8. What amount of astigmatism at the corneal plane does the SN60T4 treat?
A. 1.55 D
B. 2.06 D
C. 2.25 D
D. 2.75 D

9. The three initial prong alignment marks are made in the
A. operating room after the ocular block has been given, with the patient sitting up
B. operating room with the patient in the supine position
C. preoperative area with the patient laying flat
D. preoperative area with the patient sitting up, before receiving the ocular block

10. Complications of cataract surgery with toric IOL placement include
A. undercorrection of keratometric astigmatism
B. overcorrection of keratometric astigmatism
C. infection
D. all of the above