

Managing astigmatism in cataract surgery: A comprehensive approach

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Globally, uncorrected refractive errors remain a leading cause of vision impairment. Among these, astigmatism stands out as the most prevalent refractive error in both children and adults. The global prevalence of astigmatism is estimated at 44.4%, significantly higher than myopia (26.5%) or hyperopia (30.9%) alone.¹² Recent studies suggest that the prevalence of astigmatism could be as high as 57.4%, with a notable proportion (4.5%) presenting with higher degrees of astigmatism.¹² Given its impact, managing astigmatism before cataract surgery is crucial, especially considering the demands of modern patients, who increasingly seek spectacle-free vision.

Astigmatism management is particularly challenging in the context of cataract surgery, where careful planning is necessary for optimal surgical outcomes. Age-related changes in astigmatism are well-documented, with 59% of individuals experiencing astigmatic changes by their mid-40s and 41% by their mid-50s.¹³ Typically, this shift involves a progression from with-the-rule to against-the-rule astigmatism. Notably, oblique astigmatism is three times more likely to transform into against-the-rule astigmatism. Furthermore, male patients tend to develop more significant and earlier against-the-rule astigmatism compared to females, which has implications for surgical planning.

For patients undergoing cataract surgery, more than 40% will require at least 1 dioptre of astigmatic correction, with 10% needing more than 2 dioptres.¹¹ Left uncorrected, astigmatism can lead to considerable visual impairment, decreased quality of life, and economic burden. Impaired vision from astigmatism limits daily activities, increases the risk of falls, and can affect employment

and educational opportunities. One degree of astigmatism can reduce visual acuity by 1.5 lines, and oblique astigmatism increases the fall risk significantly more than with-the-rule or against-the-rule astigmatism. Hence, effective astigmatism management is essential in cataract surgery especially when the expected astigmatism is equal to or more than 0.75 dioptres.

Understanding Astigmatism

Astigmatism may arise from both the anterior and posterior corneal surfaces, with varying magnitudes and meridians. The integration of posterior corneal data in intraocular lens (IOL) calculations has been debated. Residual astigmatism post-Toric IOL implantation can be attributed to unaccounted posterior corneal astigmatism. Historically, anterior corneal astigmatism was measured via keratometry, while posterior astigmatism was estimated using a metric index. However, advances in technology now allow direct measurement of posterior corneal astigmatism, enhancing the accuracy of total corneal astigmatism assessments.²²

Generally, the relationship between posterior corneal astigmatism (PCA) and overall refractive astigmatism suggests that eyes with with-the-rule astigma-

tism have a higher contribution from PCA than those with against-the-rule astigmatism. Additionally, PCA tends to increase with higher with-the-rule anterior corneal astigmatism, as the posterior cornea is typically steeper along the vertical meridian in most eyes. Thus, understanding the posterior corneal contribution is vital when planning cataract surgery.

Impact on Premium IOL Outcomes

The implantation of Toric IOLs is a highly effective method for correcting both cataracts and refractive astigmatism. However, residual astigmatism greater than 0.5 dioptres can occur in up to 30% of eyes post-Toric IOL implantation.¹⁵ As residual astigmatism increases, uncorrected distance visual acuity declines. Moreover, residual astigmatism negatively impacts the outcomes of both mono-focal and multifocal Toric IOLs, highlighting the need for precise preoperative measurements.²¹ Both trifocal and Extended Depth of Focus (EDOF) IOLs appear to be more sensitive to oblique and against-the-rule astigmatism than with-the-rule astigmatism.

Comprehensive preoperative assessment

A thorough preoperative evaluation is essential to assess both cataracts and

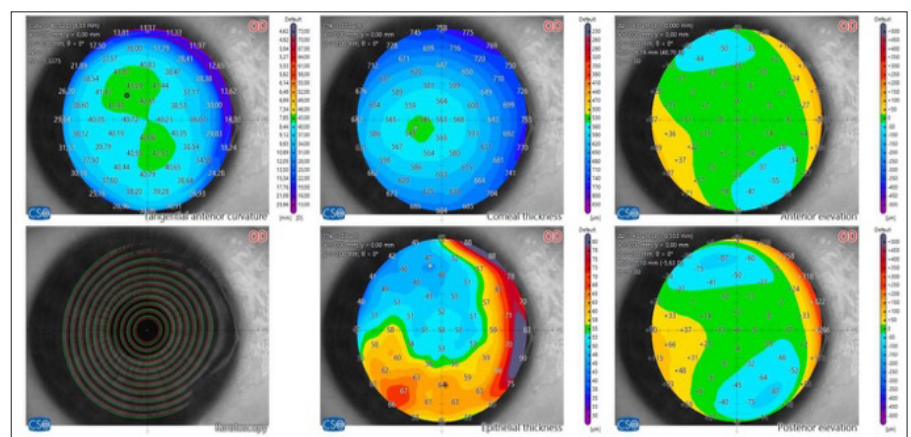


Figure 1. Axial corneal topography scan (MS39) of regular astigmatism.
(Courtesy of the author).

corneal astigmatism. Key components of this assessment include:

- **Visual acuity testing:** Evaluates the impact of cataracts and astigmatism on vision.
- **Corneal topography:** Provides a detailed map of corneal curvature, revealing the degree and type of astigmatism.
- **OCT swept-source tomography:** Assesses both anterior and posterior corneal curvatures and internal ocular structures.
- **Refraction assessment:** Determines the total refractive error, including astigmatism.
- **I-Trace measurements:** Separates corneal and lenticular astigmatism, providing comprehensive astigmatic data including axis and higher-order aberrations.
- **Total corneal astigmatism assessment:** Crucial for accurate IOL power and toricity planning.
- **Habitual refraction and old spectacles:** Offers historical insight into a patient's refractive stability.

Advances in corneal imaging for pre-operative assessment

Accurate evaluation of corneal astigmatism is critical in modern cataract surgery. Recent technological advances have improved our ability to assess both anterior and posterior corneal surfaces, significantly enhancing surgical planning:

Corneal topography limitations

Devices such as the IOL Master utilise partial coherence interferometry and measure reflections across a 2.3 mm zone on the anterior cornea. While widely used, they do not capture posterior corneal astigmatism, often leading to underestimation of total astigmatism - especially against-the-rule components.¹⁷

Corneal tomography

Scheimpflug-based devices like the Pentacam HR offer comprehensive anterior and posterior surface mapping through high-resolution elevation data, providing detailed topography, tomography, pachymetry, and anterior chamber photography. These systems are preferred by many surgeons for their superior accuracy in detecting total corneal astigmatism.

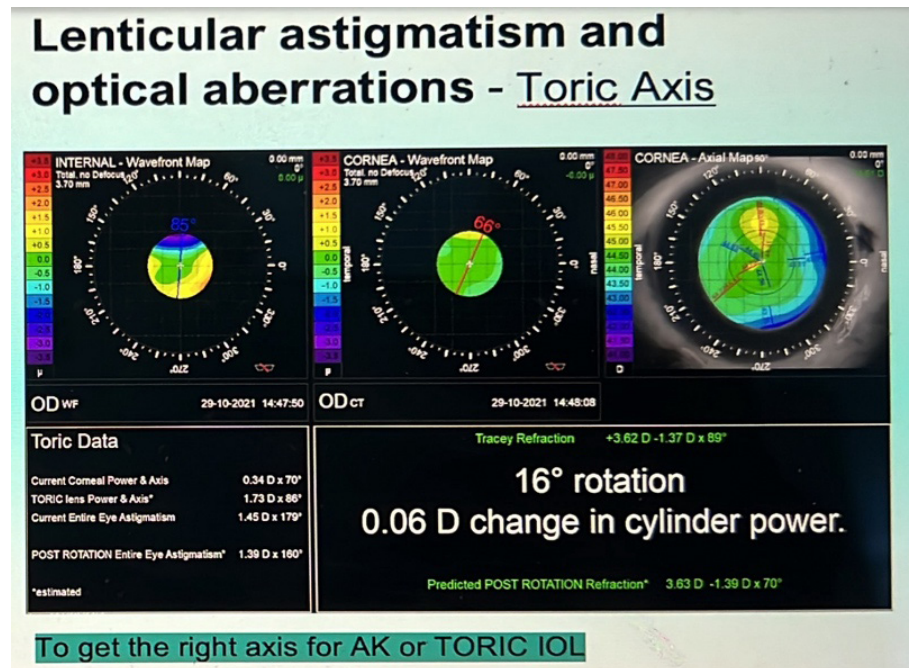


Figure 2. I-Trace (Tracey Technologies) displaying lenticular and corneal astigmatism and Toric Axis for implantation. Courtesy of the author.

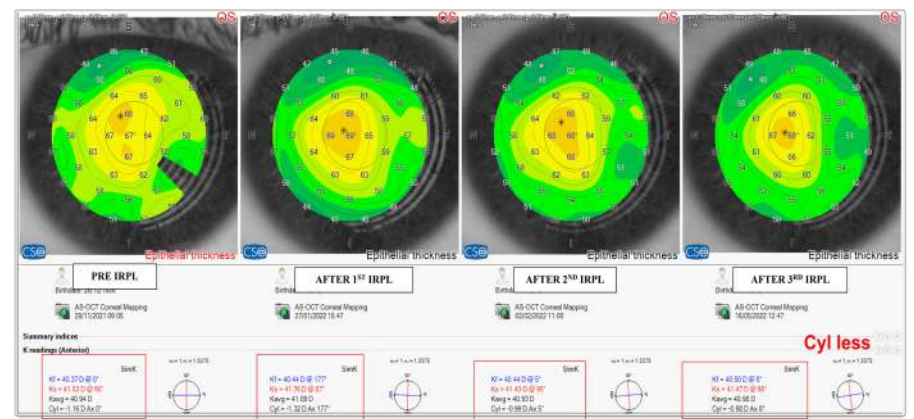


Figure 3. Effect of IRPL on corneal astigmatism. Improving the tearfilm can reduce the amount of astigmatism. Courtesy of the author.

Swept-source OCT

SS-OCT devices such as the IOL Master 700 and Argos provide high-resolution images of the entire anterior segment, including anterior and posterior corneal curvatures. Studies have shown that SS-OCT provides predictive accuracy comparable to Scheimpflug devices, with the Argos offering slightly better prediction of spherical equivalents in some cases.¹⁶

Corneal mapping

Corneal mapping can also be valuable in accessing the nature of the astigmatism. Irregular astigmatism or epithelial abnormalities can influence astigmatism management. (Ms 39)

Role of the I-Trace

The I-Trace system offers a unique ad-

vantage by combining corneal topography with ray-tracing aberrometry, distinguishing corneal from lenticular astigmatism and higher-order aberrations. This allows for a deeper understanding of the visual system and enhances IOL selection, particularly for patients being considered for multifocal or Toric lenses.

Calculation methods and Formulas

Several factors contribute to postoperative residual astigmatism, including imperfections in preoperative measurements, surgically induced astigmatism (SIA), alignment errors of the Toric IOL, and the choice of Toric calculator. Studies have shown that the Barrett Toric Calculator significantly reduces residual astigmatism compared to other calculators.^{18,22} Devices such as the Argos and

Ziemer Galileo G6 now incorporate the Barrett True-K formula, accounting for posterior corneal curvature and enhancing outcome predictability.

Preoperative ocular surface management

The stability of the tear film significantly affects the reliability of preoperative measurements. Tear film instability can alter cylinder power and axis measurements. In my own practice, I have documented a reduction in measured cylinder through improvement of the tear film using intense pulsed light therapy (IRPL), emphasising the importance of ocular surface optimisation before surgery (See **Figure 3** on page 5).

Corneal topography limitations revisited

While corneal topography remains a valuable tool for screening corneal pathology and ensuring regular astigmatism, it has limitations in fully characterizing the source of astigmatism. Determining whether astigmatism is anterior, posterior, lenticular, or related to higher-order aberrations is critical for personalized surgical planning.

Management of astigmatism in cataract surgery: Current strategies and outcomes

Posterior corneal astigmatism

The significant contribution of posterior corneal astigmatism to total astigmatism and its impact on postoperative outcomes is now well recognised. Sano et al. demonstrated that preoperative assessment including posterior corneal curvature reduced the discrepancy between refractive and total corneal astigmatism, thus minimising unexpected postoperative astigmatism.¹² Similarly, Srivannaboon et al. observed a trend toward lower refractive absolute errors when total keratometry was used, compared to conventional anterior keratometry alone.¹²

Reitblat et al. compared five methods for calculating posterior corneal curvature in toric IOL planning, finding that vector analysis combining posterior (Scheimpflug) and anterior (OLCR) astigmatism yielded the lowest residual astigmatism.²² Technologies such as total corneal refractive power (TCRP), true net power

(TNP), simulated keratometry (sim-K), and total keratometry (TK) have been explored, with TCRP showing greater accuracy and reliability. However, Shajari et al. found no significant differences between TK, sim-K, TNP, and TCRP.¹²

Surgically induced astigmatism

Clear corneal incisions (CCIs) induce surgically induced astigmatism (SIA) by flattening the cornea along the incision axis. SIA varies based on incision location, width, corneal diameter, instrumentation, and angle. Surgeons often place incisions along the steepest meridian to minimise pre-existing astigmatism, but variability among individuals persists. By entering the postoperative data our Argos on you can calculate your S.I.A. and your surgeon factor and improve outcomes.

Correction of low astigmatism

Steepest meridian clear corneal incision

Steepest meridian incisions effectively correct astigmatism of 0.75 to 1.5D. However, reported SIA values vary considerably between studies, reflecting inconsistent predictability.

Opposite clear corneal incisions (OCCIs)

OCCIs involve creating a second corneal incision opposite the primary incision to enhance corneal flattening, effectively treating astigmatism up to 2D.

Manual Corneal Relaxing Incisions

Limbal relaxing incisions (LRIs) and arcuate keratotomy (AK) address astigmatism through carefully placed peripheral corneal cuts. LRIs, often used for 0.75–2D of astigmatism, and AK for

greater effect centrally, remain effective but are susceptible to variability based on surgeon skill. They are placed 1 mm from the limbus and 500-600 micron depth.

Femtosecond laser-assisted arcuate keratotomy (FLAK)

Femtosecond laser-assisted AK (FLAK) enhances precision and reproducibility over manual techniques. Intrastromal and trans-epithelial options are available: trans-epithelial incisions penetrate up to 85% corneal depth, whereas intrastromal incisions remain within the central 60%, potentially reducing risks of epithelial hyperplasia and wound healing complications.

Though complications such as gas breakthrough or endothelial damage can occur but are rare, FLAK provides a safer alternative to manual techniques, with greater control and consistency. Cost remains a limiting factor.

In my own study I found that : Paired and single surface-penetrating keratotomies created with a low-energy femtosecond laser using the Castrop nomogram at the time of cataract surgery showed efficient astigmatism reduction. In this study the Castrop Nomogram showed a good accuracy in patients with low preoperative astigmatism (CI=0.82) and a tendency for under-correction in patients with moderate to high astigmatism (CI=0.58). A total of 51 astigmatic eyes (27 right and 24 left) of 51 patients with mean preoperative cylinder of -1.05 ± 0.45 diopters (D) (range: -0.37 to -2.35 D) underwent femtosecond laser-assisted arcuate incisions with the Castrop Nomogram using the FEMTO LDV Z8 laser



Figure 4. Steep axis digital marking for clear corneal incision. Courtesy of the author.

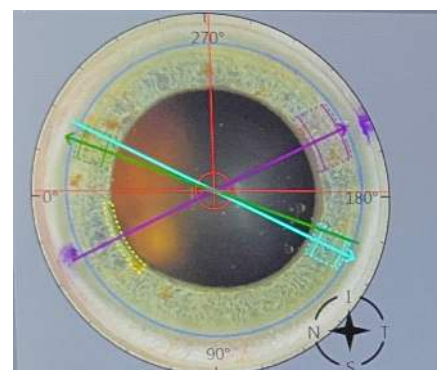


Figure 5. Single FLAK incision and opposite main incision. Courtesy of the author

(Ziemer Ophthalmic Systems AG). 38 eyes (74.51%), with mean preoperative cylinder of -1.13 ± 0.46 D, received paired corneal arcuate incisions (PAK), while 13 eyes (25.49%), with mean preoperative cylinder of -0.84 ± 0.28 D, received single arcuate incision (SAK). Preoperative and postoperative objective astigmatism vectors were assessed using i-Trace (Tracey Technologies Corp.). Postoperative cylinder accuracy was evaluated between 6 and 8 weeks after the surgery.

Arcuate keratotomy vs. toric IOL implantation

Comparative studies, such as those by Yoo et al., found no significant differences between refractive outcomes of FLAK and Toric IOL implantation for low astigmatism (0.75–2D). However, Toric IOLs trended toward slightly better postoperative outcomes particularly for larger than 2 dioptres of astigmatism.²

Toric intraocular lenses (IOLs)

Originally designed for moderate-to-high astigmatism, Toric IOLs are now used successfully even in low astigmatism cases (0.5–1.5D). Heinert et al. demonstrated superior visual acuity outcomes with Toric IOLs versus non-Toric IOLs, although cost remains a factor for consideration.³

Light adjustable lenses (LALs)

The LAL represents a revolutionary advance, allowing postoperative adjustment of lens power. UV light activation modifies lens optics in 0.25D increments. Mosharraf et al. showed that 71% of patients achieved ≤ 0.5 D of residual astigmatism one year postoperatively, offering a customisable solution for residual refractive errors.¹² There cost considerations and some limitations as there is a delay before the lens is locked in, and can inconvenience patients.¹³

Correction of moderate-to-high astigmatism

Toric intraocular lens

For moderate to high astigmatism (1.25–3D), Toric IOL implantation remains the standard, providing high predictability and stability, as confirmed by Hernandez et al.¹²



Figure 6. Checking the alignment of a Toric IOL in a patient at the slitlamp with the Haagstreit Slitlamp Reticule attachment. Courtesy of the author.

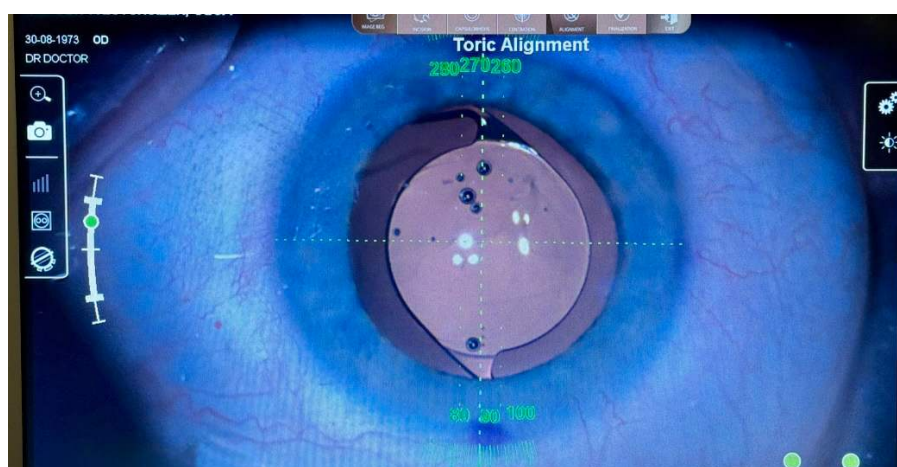


Figure 7. Verion (Alcon) digital alignment system. Courtesy the author.

Intraoperative alignment technology

Precise alignment of Toric IOLs is critical. Software like Callisto and the Verion (Alcon) aids in compensating for cyclotorsion by matching intraoperative views to preoperative imaging. Even minor misalignments ($>10^\circ$) substantially reduce the corrective effect.

Studies show automated systems yield slightly less misalignment than manual marking, though the final visual outcomes are comparable.

Intraoperative aberrometry

Intraoperative aberrometers (IA) offer a real-time guidance during surgery. Although some studies support modest improvements in refractive outcomes with IA use, others found no significant advantage over preoperative planning alone.

Postoperative residual astigmatism

Prevalence and etiology

Residual astigmatism following cataract surgery remains common, with rates between 28–47% for >0.5 D errors.¹⁹ Causes include inaccuracies in preoperative measurement, Toric misalignment, IOL tilt, posterior corneal astigmatism, dry eyes and surgically induced astigmatism.¹⁹

Astigmatism can also shift toward against-the-rule (ATR) patterns with age, irrespective of baseline corneal profile.¹³

Management

Residual astigmatism can lead to patient dissatisfaction and can be addressed via:²⁰

- **Limbal Relaxing Incisions (LRIs):** Performed manually or with femto-second laser.

- **IOL repositioning:** Preferably delayed until after capsular contraction stabilizes (1 to 3 weeks).
- **Surface ablation (LASIK/PRK):** Effective for correcting moderate residual errors. Wait for stabilisation.
- **Spectacles or contact lenses:** For non-surgical correction based on individual needs.
- **Femtosecond laser assisted keratotomy (Flak).** (Castrop nomogram)
- **Add-on lenses.** Astigmatism and spherical ametropia can be managed – to wait 3 months
- Remove all Visco-elastic, also behind the lens
- Press IOL against the posterior surface of the bag
- Do not make the capsulorhexis too large, (I use 4.8 mm).

Conclusion

Astigmatism management is integral to optimising outcomes in cataract surgery. With modern patients expecting exceptional unaided vision, meticulous preoperative planning - including evaluation of posterior corneal curvature and tear film stability - is essential.

Treatment strategies span from manual techniques and laser-assisted keratotomies to Toric IOLs and emerging adjustable lens technologies. Assistive tools such as femtosecond lasers, intraoperative aberrometers, and automated axis marking have significantly improved precision and reproducibility.

Ultimately, choice of intervention should balance clinical indication, surgeon expertise, patient preferences, and economic considerations. As technology

evolves, the potential to minimise residual refractive error and maximize patient satisfaction continues to advance.²⁰

References

1. Hernandez, et al. J Cataract Refract Surg. 2020;46(2):215-223.
2. Yoo A, et al. J Cataract Refract Surg. 2021;47(5):606-613.
3. Heinert J, et al. Ophthalmology. 2021;128(9):1272-1278.
4. Moshirfar M, et al. Clin Ophthalmol. 2021;15:2805-2814.
5. Raucau J, et al. Eye (Lond). 2021;35(2):529-536.
6. Kose HC, et al. Int Ophthalmol. 2022;42(4):1113-1119.
7. Davison JA, et al. J Cataract Refract Surg. 2021;47(1):22-28.
8. Kramer BA, et al. Ophthalmol Ther. 2022;11(1):179-191.
9. Hayashi K, et al. Am J Ophthalmol. 2019;207:218-224.
10. Hirschschall N, et al. J Refract Surg. 2020;36(5):290-295.
11. L Zhang et Al. Frontiers in Medicine. 2023; July 11; 10:1202793.

Notably, newer light-adjustable lenses can correct residual astigmatism non-invasively postoperatively.

Studies reveal different IOL designs exhibit varying stability, with TECNIS Toric IOLs showing higher rotation rates compared to AcrySof lenses', closed-loop haptic lenses or quadripod IOLs (eg. Crystallens). Plate IOLs also exhibit instability.

Preventing toric IOL rotation

- Do not overfill the anterior chamber

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