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Optomizing the visual outcomes with toric intraocular lenses

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Abstract:
Toric intraocular lenses (IOLs) are the procedure of choice to correct corneal astigmatism of 1 D or more in cases undergoing cataract surgery. Comprehensive literature search was performed in MEDLINE using "toric intraocular lenses," "astigmatism," and "cataract surgery" as keywords. The outcomes after toric IOL implantation are influenced by numerous factors, right from the preoperative case selection and investigations to accurate intraoperative alignment and postoperative care. Enhanced accuracy of keratometry estimation may be achieved by taking multiple measurements and employing at least two separate devices based on different principles. The importance of posterior corneal curvature is increasingly being recognized in various studies, and newer investigative modalities that account for both the anterior and posterior corneal power are becoming the standard of care. An ideal IOL power calculation formula should take into account the surgically induced astigmatism, the posterior corneal curvature as well as the effective lens position. Conventional manual marking has given way to image-guided systems and intraoperative aberrometry, which provide a mark-less IOL alignment and also aid in planning the incisions, capsulorhexis size, and optimal IOL centration. Postoperative toric IOL misalignment is the major factor responsible for suboptimal visual outcomes after toric IOL implantation. Realignment of the toric IOL is needed in 0.65%–3.3% cases, with more than 10° of rotation from the target axis. Newer toric IOLs have enhanced rotational stability and provide precise visual outcomes with minimal higher order aberrations.

Keywords: *Astigmatism; cataract surgery; toric intraocular lenses.*

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Toric intraocular lenses (IOLs) were first introduced in 1992 by Shimizu *et al*. as 3-piece nonfoldable polymethyl methacrylate implants to be inserted through a 5.7 mm incision. Since then, the increased predictability and enhanced safety of toric IOL implantation has firmly established it as the procedure of choice to correct significant corneal astigmatism in cases undergoing cataract surgery.

A preoperative corneal astigmatism of 1 D or more may be present in up to one-third of the cases undergoing cataract surgery, with 22% having more than 1.5 D of astigmatism and 8% having more than 2.0 D of astigmatism

In these cases, toric IOLs help to achieve postoperative spectacle independence and optimal patient satisfaction. Technological advancements in terms of IOL material as well as design have resulted in better rotational stability and precise visual outcomes.

This review provides a comprehensive overview of toric IOLs along with the preoperative planning, various marking methods, intraoperative alignment, and postoperative management to achieve optimal outcomes. The literature search was performed in MEDLINE using "toric intraocular lenses," "astigmatism," and "cataract surgery" as keywords. The relevant references cited in those articles were also searched. Abstracts of relevant non-English articles were used. All articles were reviewed since the first use of toric IOLs in 1992. For statements that are frequently mentioned in the literature, we chose the earliest publication and other important articles.

Patient Selection:

Ideal case selection is a prerequisite before surgery to ensure patient satisfaction as well as optimal outcomes. The decision to implant a toric IOL is governed by the magnitude and axis of corneal astigmatism, patient expectations, type of IOL, and the presence of other ocular comorbidities.

At present, standard toric IOLs are available in cylinder powers of 1.5 D to 6.0 D (1.03 D to 4.11 D at the corneal plane) and are intended to correct preexisting regular corneal astigmatism ranging from 0.75 D to 4.75 D.

Extended series and customized toric IOLs to correct higher cylinder powers are also available.

Toric IOLs are universally recommended in cases with significant preoperative corneal astigmatism of 1.5 D or more. Even in cases with low astigmatism with a magnitude of around 1 D, the superiority of toric IOLs over monofocal IOLs has been demonstrated in terms of better-uncorrected distance visual acuity (UDVA). However, patients undergoing premium IOL implantation such as multifocal IOLs may not tolerate residual astigmatism of even <1 D and a toric multifocal IOL may be required in such cases.

A comprehensive ocular examination should be undertaken to rule out any ocular comorbidities that may interfere with the postoperative outcomes. Cases with irregular astigmatism resulting from corneal scars or ectatic disorders are not ideal candidates for toric IOL implantation. They are unlikely to achieve complete refractive correction with toric IOLs; however, the amount of astigmatism may be reduced with a decreased dependence on spectacles or contact lenses and such cases may be considered for surgery after adequate counseling.

Zonular instability and posterior capsular dehiscence are contraindications for implanting toric IOLs, as a stable capsular bag-IOL complex is essential for the rotational stability of the IOL. Poor pupillary dilatation is also a relative contraindication, as it may hamper the visualization of the alignment marks which are located in the periphery of the toric IOL. Patients that have undergone prior vitreoretinal procedures, buckling, and glaucoma drainage surgeries may not achieve the intended results with toric IOLs due to their primary pathology as well as the surgically induced changes in the anatomical configuration.

Preoperative patient counseling is of paramount importance, and it is essential to address unrealistic patient expectations at the stage of planning itself. Patients who desire good uncorrected near vision may be counseled for toric multifocal IOLs.

Preoperative Investigations :

A detailed preoperative ocular examination should be undertaken in all cases to evaluate the ocular surface and tear film status, characterize the type and grade of cataract and rule out any posterior segment pathology or other ocular comorbidities.

An accurate biometry is a prerequisite for precise IOL power calculation. The axial length may be estimated by either ultrasonic biometry or optical systems such as IOL Master (Carl Zeiss Meditec, Germany) and Lenstar (Haag Streit, Switzerland). Keratometry estimation is of paramount importance to determine the power as well as the axis of the toric IOL. Various instruments based on different principles may be used for keratometry estimation, such as manual and automated keratometers, placido-based corneal topographers, slit scanning systems, Scheimpflug imaging systems, aberrometers and optical coherence tomography (OCT)-based systems. Enhanced accuracy of keratometry estimation may be achieved by taking multiple measurements and employing at least two separate devices based on different principles.Cases with similar steep corneal meridian on different devices are good candidates for toric IOL implantation. However, if significant variability in both the axis and magnitude of toric IOL is observed on different devices, the patient should be evaluated to rule out coexistent ocular comorbidities. The visual outcomes may not be satisfactory in such cases.

Intraocular Lens Power Calculation:

Various formulae and toric calculators are available for IOL power calculation, which determine the axis as well as the magnitude of the toric IOL to be implanted. An ideal formula should take into account the SIA, the posterior corneal curvature as well as the effective lens position (ELP).

Intraocular Lens Selection:

Various toric IOLs are available commercially, with different material, design, and range of toricity

The choice of IOL depends on the surgeon comfort, patient expectations, financial considerations and availability. A monofocal or multifocal toric IOL may be selected based on patient's preference and preoperative assessment.

Marking Techniques :

Accurate alignment of toric IOL is a prerequisite to achieve successful outcomes. Various methods have been described to place the preoperative reference and axis marks and may be broadly categorized as manual methods, iris fingerprinting techniques, image-guided systems, and intraoperative aberrometry-based methods.

Manual techniques:

The three-step technique is commonly used for toric IOL alignment, which involves the preoperative marking of the reference axis, intraoperative alignment of the reference marks with the degree gauge of the fixation ring and intraoperative marking of the target axis.

The reference marks are commonly placed in the 3’o, 6’o, and 9’o clock positions to improve predictability, though some surgeons may prefer to mark only the horizontal 3’o and 9’o clock positions, or only the inferior

6'o clock position. The marking may be performed with a skin-marking pen in a free-hand manner, or with the help of various devices such as a thin slit-beam, weighted thread, pendulum marker or Nuijts-Solomon bubble marker. This is followed by the intraoperative alignment of these reference marks to the degree gauge on a fixation ring, and the target axis is then marked with a corneal meridian marker. One-step axis marking may be done with the help of various devices such as tonometer markers, electronic toric markers, Neuhann one-step toric bubble marker, and Geuder-Gerten Pendulum marker

A change in patient position from sitting to supine may induce significant cyclotorsion, and up to 28° of cyclotorsion has been observed in 68% cases. Hence, the patient should be sitting erect with the back resting against a wall and a straight-ahead gaze while marking the reference axis to avoid inadvertent errors. The cornea should be dry, and adequate topical anesthesia should be administered to improve patient comfort during marking.

The three-step marking method is fairly accurate, and a mean error of 2.4° ± 0.8° has been observed during axis marking with a bubble marker, with a total error of 4.9° ± 2.1° in toric IOL alignment

The manual marking methods have inherent sources of errors, such as smudging of the dye, irregular, and broad marks. Moreover, they are associated with a significant learning curve, and intersurgeon variability may be observed in the accuracy of marking.

Intraoperative Toric Intraocular Lens Alignment:

In cases with manual marking, the target axis is marked at the beginning of surgery after aligning the preoperatively placed reference marks with a degree gauge. In addition to intraoperative alignment of the toric IOL along the desired corneal meridian, the clear corneal incisions, capsulorhexis and IOL centration also play a significant role in achieving optimal outcomes. Self-sealing clear corneal incisions that are astigmatically neutral or induce minimal astigmatism should be created. Uniformity of corneal incisions in terms of location and size is essential to prevent variations in SIA. Image-guided systems compensate for cyclotorsion and assist in the precise placement of incisions.

A well centered circular continuous capsulorhexis providing adequate IOL coverage of around 0.5 mm is essential to ensure IOL stability in the postoperative period. Posterior capsular rent is a relative contraindication for in-the-bag toric IOLs, as there is a high risk of IOL tilt as well as rotation. The IOL should be centered along the coaxially sighted corneal light reflex, as represented by the first Purkinje image while the patient is fixating on the microscope light. Perfect centration is especially significant in cases undergoing toric multifocal IOLs to prevent the occurrence of dysphotic visual symptoms.

During IOL alignment, the IOL should be left about 3°–5° anticlockwise of the final desired lens position. The final alignment should be done after complete OVD removal and hydration of the wounds, as most open-loop IOLs can be rotated only clockwise and a complete re-rotation will be needed if the IOL rotates further clockwise of the target axis during these maneuvers.

The precise capsulotomy created in FLACS may further improve the outcomes of toric IOL implantation. A significant decrease in higher order aberrations has been observed with FLACS as compared to standard phacoemulsification with toric IOL implantation

Postoperative Outcomes :

The postoperative outcomes after implantation of toric IOL may be assessed in terms of anatomical outcomes, such as precision and stability of IOL alignment, and functional outcomes, such as visual acuity and quality

Anatomical outcomes:

The precision of IOL alignment along the intended target axis is influenced by various factors, such as the type of marking method, IOL material and design, intraoperative factors such as capsulorhexis size, IOL coverage, sealing of corneal incisions, and surgeon experience.

Conventional three-step manual marking techniques result in fairly accurate alignment of toric IOLs, with a mean deviation from target axis of 4.9° ± 2.1°

The image-guided systems and intraoperative aberrometry have improved the precision of toric IOL alignment, with <5° of deviation from the intended axis in the majority of cases.

Rotational stability of the IOL varies with design and material, and maximum rotational stability has been observed with hydrophobic acrylic lenses This may be attributed to the development of strong adhesions between the IOL and lens capsule in the early postoperative period.

A long-term prospective study of AcrySof toric IOLs observed the significant postoperative rotation of more than 10° in only 1.68% eyes, and maximum rotation occurred within the initial 10 days in the postoperative period in cases with high axial length.

A total of 76.7% eyes were within 5 degrees of the intended target axis even 2 years after surgery.

Intraocular Lens Misalignment :

Postoperative toric IOL misalignment is the major factor responsible for suboptimal visual outcomes after toric IOL implantation. It may be attributed to three factors, namely, inaccurate preoperative prediction of the axis of IOL alignment, inaccurate intraoperative alignment, and postoperative IOL rotation. Newer investigative modalities and advanced image-guided and aberrometry systems help to minimize the incidence of pre- and intra-operative alignment errors and have been discussed in detail in the previous sections.

Misalignment of the toric IOL axis can cause reduction of the cylinder power along the desired meridian and induction of cylinder in a new meridian when misalignment exceeds 30°. The new residual cylinder may be estimated by the formula $R = |2C \sin \theta|$, where C is the cylinder power of the toric lens and θ is the degree of misalignment. One degree of misalignment causes a loss of approximately 3% of the effective cylinder power, and the entire toric effect is lost in cases with 30° of misalignment.

The UDVA is significantly worse in misaligned multifocal toric IOLs as compared to monofocal toric lenses. IOL rotation may be observed as early as 1 h after surgery, and a majority of rotations occur within the initial 10 days. Early IOL rotation likely results from incomplete OVD removal, whereas late postoperative rotation, is influenced by the IOL architecture, design, and axial length. The axis of IOL implantation is associated with postoperative rotation, and an increased incidence of rotation has been observed in cases with vertical axis of IOL implantation (with-the-rule astigmatism). Capsulorhexis extension or inadequate IOL coverage also contribute to postoperative rotation.

The axis of implanted toric IOL may be assessed at the slit-lamp with a rotating slit and rotational gauge. This method requires adequate mydriasis to visualize the IOL optic marks. The 10° steps on the slit-lamp measuring reticule limit the accuracy of this method. A simple and inexpensive method to measure the toric IOL axis using a camera-enabled cellular phone and (ImageJ) computer software has also been described.

Intraoperative techniques to rotate toric IOLs depend on the length of time from the initial surgery and the degree of adhesions between the IOL and the capsular bag. Optimal results have been observed in cases with early rotation using a long cannula mounted on a balanced salt solution-filled syringe to rotate the IOL through the paracentesis incision. The new target axis is determined relative to the current axis; therefore, intraoperative marking is only necessary relative to the implanted IOL. This reduces repositioning variability and maximizes outcomes after IOL rotation.

In cases with the large residual cylinder not amenable to correction by rotation alone, an IOL exchange, piggyback IOLs or corneal ablative procedures may be considered. LASIK has been observed to be superior to lens exchange and piggyback IOLs, with a greater reduction in spherocylinder refractive error. Customized surface ablation or femtosecond laser-assisted intrastromal keratotomies may also be attempted to correct residual astigmatism.

Conclusion:

The outcomes after toric IOL implantation are influenced by numerous factors, right from the preoperative case selection and investigations to accurate intraoperative alignment and postoperative care. The importance of posterior corneal curvature is increasingly being recognized in various studies, and newer investigative modalities that account for both the anterior and posterior corneal power are becoming the standard of care. The conventional manual marking has given way to image-guided systems and intraoperative aberrometry, which provide a mark-less IOL alignment and also aid in planning the incisions, capsulorhexis size, and optimal IOL centration. Newer IOLs are being introduced for commercial use, with superior design, expanding the range of cylinder powers, enhanced rotational stability, and minimal induction of higher-order aberrations.

The applications of toric IOLs are expanding to include cases with high astigmatism, irregular astigmatism, corneal ectatic disorders, and postkeratoplasty cases.

Future technological advancements may further refine the outcomes of toric IOL, with more precise visual results and enhanced IOL stability. Newer customized IOLs are being introduced that may be implanted at the 0°–180° axis without a need for rotational alignment such as the Ultima Smart Toric Customised Hydrophilic IOL (EyePharma, Care Group, Cape Town, South Africa). Cirle surgical navigation system (Bausch and Lomb, Rochester, New York, USA) is being developed for commercial use, which will provide 3-D guidance using microscope oculars during cataract surgery. We may see the development of integrated image-guided systems that incorporate preoperative keratometry and IOL power estimation, intraoperative surgical guidance, and toric alignment as well as postoperative assessment in a single platform.

Conflicts of interest

There are no conflicts of interest.

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