TECHNIQUE

# Evaluation of postoperative toric intraocular lens alignment with anterior segment optical coherence tomography

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We describe the use of a simple tool to evaluate the postoperative alignment of toric intraocular lenses (IOLs). The entire anterior segment is scanned using anterior segment optical coherence tomography and analyzed with an internal dedicated tool. A topographic map is displayed along with an anterior segment image, including a linear axis marker centered on the corneal apex. The marker can be rotated until it is aligned with the line connecting the IOL marking dots, precisely reproducing the IOL astigmatic axis, which is measured in angle degrees. The value of the IOL astigmatic axis is compared with the value of the astigmatic axis shown in real time on the same screen in the topographic map. Evaluating the alignment of a toric IOL axis simultaneously with the topographic astigmatic axis eliminates the potential errors that result from head tilting and strictly correlates with the astigmatic correction achieved.

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Toric intraocular lenses (IOLs) have been used to correct corneal astigmatism during small-incision phacoemulsification.[1,2] Although most of the IOLs have shown good postoperative stability,[3] rotation from the intended preoperative and intraoperative positioning may occur, often necessitating additional surgery.[4,5] Accurate evaluation of the effective alignment of the IOL is mandatory to determine the possible causes of postoperative residual refractive errors and to plan further surgery.

Several techniques have been used to evaluate postoperative toric IOL stability. These include less technically demanding methods such as slitlamp evaluation in combination with digital overlay or smartphone recording, as well as more complex systems combining corneal topography, vector analysis, and wavefront aberrometry.[6–9]

We describe the use of new software integrated into an anterior segment optical coherence tomography (AS-OCT) system for postoperative assessment of toric IOL misalignment.

## TECHNIQUE

An AS-OCT system (Casia SS-1000, Tomey Corp.) is used to simultaneously evaluate the topographic astigmatic axis and the postoperative position of a toric IOL's axis. This noncontact noninvasive 3-dimensional (3-D) imaging system is based on the principle of swept-source OCT, achieving high-resolution imaging of 10 μm (axial) and 30 μm (transverse) with high-speed scanning of 30 000 A-scans per second.

Before evaluation, mydriatic eyedrops (tropicamide 1.0%) are administered to enable visualization of the marking dots in the periphery of the toric IOL. The patient is seated at the instrument and initially instructed to fixate on a green target light while maintaining a vertical head position. The corneal map icon is clicked on the 3-D scan type selection panel and a single scan is performed. To evaluate the influence of the head position on the IOL orientation, the scan is also obtained after tilting the patient's head slightly to the left and to the right. The dedicated internal AS-OCT software tool is then used to analyze the scan. Finally, a screen layout is produced, showing the topographic map on the left side and an anterior segment image on the right side (Figure 1).

The toric IOL analysis tool shows an image of the anterior segment with an overlapped green linear marker that can be rotated on a fulcrum automatically centered on the corneal apex. The linear marker is aligned parallel to the line connecting the marking dots of the toric IOL, and the direction of this alignment is expressed in angle degrees on the right side of the screen. The corneal topography obtained from the same scan is shown on the left side of the screen together with the power of steeper and flatter meridians, their axes, as well as the amount of the resulting

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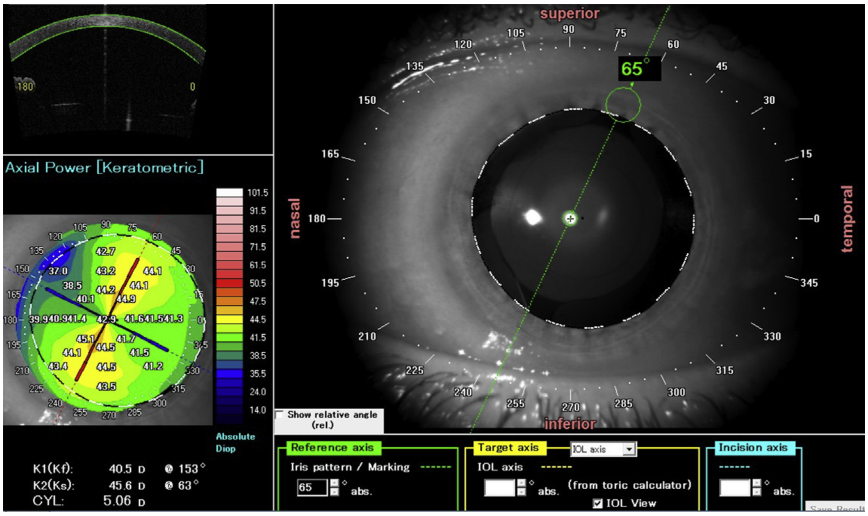


**Figure 1.** Evaluation of postoperative toric IOL alignment with the AS-OCT. On the left side, corneal topography is presented in the axial algorithm and curvature data are listed in the box on the bottom. On the right side, the image of a mydriatic eye is shown and a linear marker is automatically displayed on the fixation axis; the marker is rotated and aligned on the reference marks of the IOL, indicating the implantation axis (103 degrees). Correspondence between the axis identified on the image and the steeper meridian confirm proper toric IOL alignment.

topographic cylinder. The rotation of the toric IOL from the intended position can be expressed by the difference in degrees between the topographic axis and the value calculated for the linear marker.

## Results

The postoperative IOL rotation was assessed in 15 eyes of 9 patients who had phacoemulsification with implantation of a toric IOL. The necessary pupil dilation (at least 5.5 mm) was obtained in all cases, and the time required to complete the scan acquisition did not exceed 0.3 second. The amount of postoperative rotation determined with this technique along with the residual postoperative refractive astigmatism provided fundamental information for the surgical realignment of the IOL (Table 1). Considering only the data obtained from the scans performed with the patient's head in a vertical orientation, the mean IOL misalignment from the intended topographic steep axis was 1.4 degrees ± 1.5 (SD). When the patient's head was tilted to the right and the left, the mean rotation of the steep corneal meridian was 8.4 ± 1.9 degrees and 7.8 ± 2.1 degrees, respectively. In these 2 conditions, an identical IOL rotation was recorded, thus maintaining the values of misalignment recorded in the primary position.

## DISCUSSION

To date, several techniques have been used to evaluate the postoperative alignment of a toric IOL and measure the deviation from the intended axis. The most commonly used is based on slitlamp examination, using the alignment of the rotating slit in combination with different systems of digital overlay. To determine the toric IOL position, Nguyen and Miller[8] used a computerized analysis of digitally scanned retroilluminated photographs and Teichman et al.[9] used a camera-enabled cellular phone. Both techniques partially depend on the operator's subjective judgment, require a multistep analysis related to the use of several instruments,

**Table 1.** Preoperative and postoperative measurements in the 15 patients.

| Eye | Preoperative | | Cyl IOL (D) | IOL Rotation (º) | Postoperative | | Astigmatism Correction Achieved (%) |
|---|---|---|---|---|---|---|---|
| | Top Ax (º) | Top Cyl (D) | | | IOL Ax (º) | Refr Cyl (D) | |
| 1 | 103 | 2.58 | 2.5 | 0 | 103 | 0.00 | 100.0 |
| 2 | 68 | 3.78 | 4.0 | 3 | 65 | 0.25 | 93.3 |
| 3 | 25 | 3.60 | 3.5 | 4 | 21 | 0.25 | 93.0 |
| 4 | 93 | 2.80 | 2.5 | 0 | 93 | 0.25 | 91.0 |
| 5 | 88 | 2.98 | 3.0 | 1 | 87 | 0.00 | 100.0 |
| 6 | 83 | 3.04 | 3.0 | 2 | 81 | 0.00 | 100.0 |
| 7 | 96 | 5.72 | 5.0 | 3 | 93 | 0.75 | 86.8 |
| 8 | 88 | 3.85 | 3.5 | 0 | 88 | 0.50 | 87.0 |
| 9 | 107 | 3.55 | 3.5 | 1 | 106 | 0.00 | 100.0 |
| 10 | 91 | 3.25 | 3.0 | 0 | 91 | 0.25 | 92.3 |
| 11 | 65 | 5.06 | 4.5 | 0 | 65 | 0.50 | 89.3 |
| 12 | 75 | 2.67 | 2.5 | 4 | 71 | 0.25 | 90.6 |
| 13 | 78 | 3.12 | 3.0 | 1 | 77 | 0.00 | 100.0 |
| 14 | 164 | 3.41 | 3.5 | 2 | 162 | 0.00 | 100.0 |
| 15 | 12 | 3.44 | 3.0 | 0 | 12 | 0.50 | 85.4 |

Cyl IOL = intraocular lens cylinder power; IOL = intraocular lens; IOL Ax = intraocular lens alignment; Refr Cyl = refractive astigmatism; Top Ax = topographic steep axis; Top Cyl = topographic cylinder and do not take into account the patient's head tilting and/or cyclotorsion during fixation, leading to measurement variability of up to 11.5 degrees.[10]

To minimize the errors related to eye cyclotorsion, Shah et al.[11] proposed a specially designed grid and software that used the episcleral vessels as a reference in the follow-up examinations. Although the introduction of an anatomic landmark may add reproducibility to the technique, the complexity limits widespread use.

An alternative, somewhat complicated way to indirectly calculate toric IOL postoperative rotation is through the assessment of residual refractive astigmatism using vector analysis, taking into account the residual refractive error and the postoperative keratometric values.[12] This calculation is not instantaneous and requires specific knowledge by a surgeon experienced in this analysis.

To identify proper toric IOL alignment, the position of the steep topographic meridian (on which the toric IOL is always centered) and the postoperative position of the toric IOL axis must be assessed; any difference between these 2 indicates the amount of IOL rotation. Unlike what is generally done with other systems, the toric IOL software of the AS-OCT simultaneously analyses corneal topography and acquires an image of the anterior segment with a single fast scan of 0.3 second without moving or repositioning the patient; any changes in the patient's head position at the various follow-up visits will result in identical rotation of the topographic axis and IOL axis, thus maintaining the relationship between the 2.

When investigating the possible causes of residual refractive astigmatism after implantation of a toric IOL, substantial changes in corneal topography must be ruled out. As the AS-OCT analysis enables evaluation of corneal topography and IOL alignment in a single and fast acquisition, the evaluation can be done immediately, with no additional examination required. Acquisition and evaluation processes of the image are automatic, independent of the operator's skills, and have a resolution power of 1 degree, providing high interobservation and interobserver repeatability.

A system that combines a corneal topographer with a wavefront aberrometer (ARK-1000 OPD-Scan, Nidek Co., Ltd.) has been proposed to objectively measure the postoperative alignment of toric IOLs.[13] However, this system deducts the corneal aberrations from the total aberrations of the entire eye, which provides information about the postoperative lenticular astigmatism rather than visualization of the IOL alignment.

A limitation of the toric IOL software is that it requires good visualization of the IOL marks. A pupil smaller than 6.0 mm, intense anterior capsule fibrosis, or corneal opacities may interfere with the use of the software; however, none of these conditions was seen in any patient examined in this study.

In conclusion, the toric IOL software tool of the AS-OCT provides an objective method, independent of the observer's experience, to evaluate IOL alignment. The acquisition time is fast and easy and not affected by head tilting or cyclorotation.

### WHAT WAS KNOWN

- Accurate assessment of postoperative toric IOL axis is crucial to ensure optimal refractive results.

### WHAT THIS PAPER ADDS

- Evaluation of postoperative IOL alignment with the AS-OCT integrated toric tool is fast and reproducible.
- Corneal topography and IOL position are simultaneously acquired with a single scan, enabling easy evaluation of IOL rotation from the steep corneal steep axis.

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