Toric Intraocular Lens Outcome Using the Manufacturer’s Prediction of Corneal Plane Equivalent Intraocular Lens Cylinder Power

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Objectives: To describe the refractive outcome of toric intraocular lens (IOL) implantation by comparing the postoperative refractive astigmatism with the preoperative keratometric astigmatism target.

Method: In a university department of a publicly funded hospital, 38 eyes of 29 patients underwent routine cataract surgery with insertion of a toric implant (SN60TT AcrySof Toric). Surgically induced astigmatism was derived using vector analysis of refractive outcome vs predicted postoperative keratometric astigmatism and compared with the targeted induced astigmatism.

Results: Postoperative remaining refractive astigmatism of 0.97 diopters (D) was achieved vs a target of 0.61 D. A mean (SD) surgically induced astigmatism value of 1.78 (0.89) D was derived compared with a mean (SD) targeted induced astigmatism value of 1.58 (0.47) D (calculated by the manufacturer’s online calculator, which predicts IOL corneal plane equivalent cylinder power and postoperative keratometric cylinder).

Conclusions: Toric IOLs are a safe, predictable method of astigmatic correction. However, some remaining astigmatism is commonly present owing to the necessary nonzero astigmatic targets imposed by the steps between IOL cylinder powers, variability of axis, and power effects of surgical incisions as well as by underestimation of the corneal plane cylinder power of the IOLs by the manufacturer.

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See also page 998

TORIC INTRAOCULAR LENSES are becoming a routine method of correcting postcataract extraction astigmatic refractive error.1 The principle of treatment rests on the perhaps unsafe assumption that the only significant source of astigmatic refractive error following removal of the crystalline lens is the anterior surface of the cornea.2 An appropriate toric intraocular lens (IOL) can be chosen to correct for the astigmatic error based on measurement of the preoperative corneal astigmatism (keratometric or topographic). However, the actual astigmatism that the surgeon plans to neutralize is the corneal astigmatism, as it is likely to be affected by the effects of the surgical incisions. This change can be calculated by vector addition of the surgically induced astigmatism (SIA) of the incisions to the measured preoperative corneal astigmatism. This keratometric SIA must also be predicted. This study examines the astigmatic effect of insertion of the SN60TT AcrySof Toric IOL (Alcon, Hünenberg, Switzerland).

METHOD

A total of 38 eyes of 29 patients (18 female; 11 male; mean [SD] age, 70 [14] years), underwent routine cataract surgery with insertion of a toric implant (SN60TT AcrySof Toric; Alcon, Hünenberg, Switzerland). Eighteen SN60T5 IOL, 13 SN60T3 IOL, and 7 SN60T4 IOL implants were used. The hospital Ethics of Human Research Committee decided approval was not required for this observational case series, and the research adhered to the tenets of the Declaration of Helsinki. Selection of suitable eyes was made on the basis of preoperative keratometric astigmatism, as measured using Nidek ARK-700 or Nidek ARK510A autorefractors (Nidek Corporation, Tokyo, Japan) that measured corneal curvature at a 3.3-mm central corneal zone. The influence on the keratometric astigmatism of corneal SIA from routine 2.2- to 2.3-mm, clear, corneal, 3-step incision coaxial phacoemulsification was derived using the Alpins method of vector analysis of data from surgical cases.

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carried out prior to this study. For the cases in this study, the power value of the SIA of this incision was set at mean (SD) of 0.62 (0.07) diopters (D) and the resultant effect on the power and axis of the keratometric astigmatism predicted. The axis of the corneal incision–induced SIA was set at 90° from the main phacoemulsification incision site because SIA, by convention, is deemed to be a steepening (increasing refractive power) effect. This predicted keratometric astigmatism value was used to choose the cylinder power of the IOL. The Alcon toric calculator Web site (http://www.acrysoftoriccalculator.com) correctly derives this value for surgeons. Our independent calculations of this predicted keratometric astigmatism agreed with that derived by this calculator in every eye. Eyes were considered suitable for a toric implant if the predicted postoperative keratometric astigmatism exceeded 1.25 D. Patients were excluded if the presence of other pathology suggested corrected distance acuity was likely to be worse than 6/9 postoperatively to ensure the ability of the patient to yield an accurate postoperative refraction. The mean (SD) predicted postoperative keratometric astigmatism was 2.26 (1.03) D. The IOL sphere equivalent power was chosen, in the conventional manner, on the basis of the keratometry and axial length measurement, using immersion ultrasound or laser interferometry, and on the SRK-T formula in all but 1 eye with an axial length of 21.67 mm where the Hoffer-Q formula was used. The cylinder power was chosen using the online Alcon AcrySof Toric Calculator (http://www.acrysoftoriccalculator.com). All eyes were operated on using peribulbar anesthesia by the same surgeon (M.G.). Before peribulbar anesthesia, with the patient in the erect position and the eye anesthetized with 2 drops of tetracaine, 1%, the 6 o’clock juxtalimbal epithelium was marked with a 25-gauge needle as described elsewhere. In the operating room, the appropriate incision meridian and IOL placement meridian were identified. A 2.2- to 2.3-mm, 3-step, temporal clear corneal incision was placed on the meridian of the predicted steepest keratometric value in cases where the flattening effect of the incision was needed to supplement the astigmatic effect of the IOL (on-axis incisions). In others, where a suitably powered IOL was sufficient, a temporal clear corneal 3-step incision on the horizontal meridian was used. A total of 39% (15 eyes) had on-axis incisions and 61% (23 eyes) had temporal clear corneal incisions. In all cases, 1 side-port, single-plane stab incision was made using a 1-mm diamond blade with the left hand at a comfortable forearm position of the right-handed surgeon. Conventional coaxial small-incision phacoemulsification was carried out, without perioperative complication in all cases and the IOL inserted, using an incision-assisted technique, through an unenlarged incision. The IOL was placed at or rotated to the planned meridian of placement was examined. Before removing the viscoelastic device, the meridia of both corneal 3-step, temporal clear corneal incision on the horizontal meridian was used. For the purposes of this study, the manufacturer’s corneal plane effective cylinder power is used as the targeted induced astigmatism (TIA), though there are some errors inherent in that approach, addressed elsewhere. Analysis of outcome included an analysis of the refractive astigmatism outcome vs the predicted postoperative keratometric astigmatism, the purpose of the surgery being to render a postoperative refractive astigmatism as near to 0 as the steps in cylinder power provided by the manufacturer will allow. Because toric IOLs are manufactured in cylinder power steps at the IOL plane (Table 1), these steps may not exactly match the astigmatism correction requirement of an individual eye. The exact therapeutic target for any given operation is, of course, dictated by the available IOL cylinder steps provided by the manufacturer. The cylinder step selected was picked to reduce the refractive effect of this predicted keratometric astigmatism to a value as close to 0 as possible without overcorrection. In fact, the TIA of any given toric IOL is the cylinder power of that lens. To avoid errors brought about by separation of the source of the refractive error (the corneal surface) and its correcting lens (the IOL), comparisons of TIA and SIA for the IOL must be made at 1 optical plane, the anterior corneal plane. The corneal plane power of the Alcon toric IOLs are advertised by the manufacturer as in Table 1, based on “average pseudophakic human eye” and are given as the same for all sphere (or sphere equivalent) IOL powers. These are the TIA values for each lens given by the manufacturer and used in this study. The error induced by this approach is addressed elsewhere. The axis of the TIA was the axis of the predicted postincisional keratometric astigmatism. Accuracy and stability of IOL meridional placement vs the planned meridian of placement was examined.

RESULTS

REFRACTIVE

At 6 weeks after surgery, 90.1% of 33 eyes targeted to achieve near emmetropia after surgery had unaided distance visual acuity of 6/12 or better and 75.8% had 6/9 or better. Distance corrected acuity was 6/9 or better in 100% of eyes. The mean (SD) spectacle plane sphere equivalent targeted preoperatively was −0.58 (1.21) D vs −0.65 (1.56) D achieved postoperatively. The mean (SD) predicted postoperative keratometric astigmatism (the er-

| Table 1. Manufacturer-Advertised IOL Plane and Corneal Plane Cylinder Powers |
|---------------------------------|-----------------|-----------------|
| **Cylinder Power by Location, D** | **IOL Plane** | **Corneal Plane** |
| Alcon Model |                |                 |
| SN60T3  | 1.50 | 1.03 |
| SN60T4  | 2.25 | 1.55 |
| SN60T5  | 3.00 | 2.06 |
| SN60T6  | 3.75 | 2.57 |
| SN60T7  | 4.50 | 3.08 |
| SN60T8  | 5.25 | 3.60 |
| SN60T9  | 6.00 | 4.11 |

Abbreviations: D, diopters; IOL, intraocular lens.

*Based on an “average pseudophakic human eye.”
The mean (SD) targeted corneal plane refractive astigmatism after surgery, as calculated by the manufacturer’s online calculator (www.acrysoftoriccalculator.com), was 0.61 (0.72) D. The mean (SD) achieved postoperative corneal plane refractive astigmatism power was 0.97 (0.72) D.

IOL MERIDIAN PLACEMENT

The IOL meridian placement was different from that planned in 7 eyes (18%); of these, 4 were clockwise and 3 counter-clockwise from the intended axis. The mean (SD) absolute deviation from the intended axis was $1° \pm 2.28°$ and the mean (SD), assigning a negative sign to a clockwise deviation and a positive sign to counter-clockwise deviation, was $-0.26° \pm 2.48°$. The maximum deviation was $8°$.

KERATOMETRIC OUTCOME

The mean (SD) postoperative keratometric astigmatism was 2.26 (1.23) D. This is compared with a preoperative mean (SD) of 2.55 (1.16) D and predicted postoperative keratometric astigmatism of 2.26 (1.03) D using a mean (SD) predicted keratometric SIA of 0.62 (0.07) D. Vector analysis of the actual keratometric change revealed a mean (SD) SIA of 0.81 (0.54) D compared with the predicted effect. The mean (SD) angle of error of the keratometric SIA (vs the targeted meridian) was $2.41° \pm 33°$, the target meridian being the meridian at the center of the main incision. This large standard deviation denotes a variable axis of effect of the incision similar to previous articles.7,8 The mean (SD) deviation of the achieved meridian of incision placement (measured after surgery) from the attempted was $0.53° \pm 4°$, indicating that the incisions were placed predictably but the axis of effect on corneal astigmatism was less so, also a common observation.

This prediction is a source of error. How well this keratometric SIA was predicted was examined using 1-sample $t$ tests of the “residual value” (the difference between the preoperative predicted value and the postoperative calculated value). The result is presented in Table 2. A significance of $P < .05$ suggests less accurate prediction for such a parameter.

The mean (SD) SIA for incisions centered on meridia between $0°$ and $45°$ and $136°$ and $180°$ (near the horizontal meridian) was 0.66 (0.47) D and 1.07 (0.67) D for incisions between the $46°$ and $135°$ meridia. Though clinically different, these means are not statistically different ($P = .07$) because of small numbers in each group.

VECTOR ANALYSIS OF ASTIGMATIC OUTCOME

CORNEAL PLANE REFRACTIVE VS PREDICTED POSTOPERATIVE KERATOMETRIC

The SIA of the insertion of the toric IOL was calculated by vector subtraction of the predicted postoperative keratometric astigmatism and the measured postoperative refractive astigmatism using the Alpins method (Table 3).3 (To avoid confusion, it should be pointed out that this SIA is the overall effect of the incisions and the toric IOL insertion. It therefore differs from the keratometric SIA mentioned above, which refers only to the corneal astig-
stability of the IOLs at a mean (SD) absolute value (11.87°). This reflects the high degree of rotational accuracy in the IOLs. The mean (SD) angle of the IOLs was 1.01 (0.72) D. This is equivalent to the TIA of these lenses. The astigmatism correction index (SIA/TIA, geometric mean, ideally a value of 1) was 1.01. An angle of error was derived (between the axes of the SIA and the TIA). A difference vector was derived (the vector difference between the TIA and the SIA), as was an index of success (the ratio of the difference vector magnitude to that of the TIA, ideally 1). A summated vector mean of the difference vector was derived to examine if a consistent combined axis and power error was occurring (Table 3).

**COMPLICATIONS**

A sphere equivalent refractive surprise of between 0.5 and 1.0 D was present in 4 eyes. Persistent cystoid macular edema was present in 1 eye. These eyes were not excluded. In only 1 of the 4 eyes with refractive surprises was the postoperative refractive cylinder error greater than that predicted by the manufacturer by more than 0.5 D. In this eye, a residual corneal plane refractive cylinder of 0.56 D yielded a magnitude of error (SIA-TIA) of 1.06 D using the manufacturer’s TIA value.

**COMMENT**

The mean (SD) preoperative predicted keratometric astigmatism (putatively the single most important source of postoperative refractive astigmatism in the aphakic eye) of 2.26 (1.03) D was reduced to a mean postoperative corneal plane refractive astigmatism of 0.97 (0.72) D. Using the manufacturer’s method of calculation, the mean (SD) targeted corneal plane refractive astigmatism after surgery was 0.61 (0.72) D. The difference of about 0.4 D between target and achieved values may represent overcorrection or undercorrection of astigmatic error. Which of these is the case can usually be derived from vector analysis. These target and outcome figures were based on the mean (SD) corneal plane equivalent cylinder power of the IOL predicted by the manufacturer as 1.58 (0.47) D. This is equivalent to the TIA of these lenses. The mean (SD) SIA was 1.78 (0.89) D. This is the astigmatism change induced by the lens from the predicted postoperative keratometric astigmatism to the postoperative measured refractive astigmatism. It is the observed refractive astigmatic effect of the IOL. The ratio of attempted vs achieved astigmatic change is called the astigmatism correction index (SIA/TIA, geometric mean, ideally a value of 1) and was 1.01 for values derived from the manufacturer’s corneal plane equivalent cylinder power of the IOLs (ie, 101% of the targeted astigmatic correction was achieved, by the manufacturer’s calculation). The mean (SD) angle of error (between the SIA and the TIA) was 2.54° (11.87°). This reflects the high degree of rotational stability of the IOLs at a mean (SD) absolute value of 2.28° with a signed mean (using a negative sign for clockwise deviation and a positive sign for counter-clockwise deviation) of −0.26° (2.48°). It also implies accurate marking of the cylinder axis on the IOL on the part of the manufacturer and accurate per-operative placement by the surgeon. This degree of rotational accuracy is considerably better than that reported for corneal incisional management of astigmatism at the time of cataract surgery and is similar to that reported for the Acryl Comfort IOL (Acry.Tec, Carl Zeiss Meditec, Jena, Germany).7,9 This suggests that IOL management of astigmatism has an advantage over incisions in this regard.

Since the astigmatism correction index of 1.01 (SIA/TIA) was so near the ideal of 1, the IOLs being placed accurately and the prediction of the postoperative keratometric astigmatism power being so accurate (mean [SD] after surgery, 2.26 [1.23] D measured vs 2.26 [1.03] D predicted), the presence of nearly 0.4 D of unexpected remaining astigmatism (0.97 D achieved vs 0.61 D targeted) needs some explanation. Similarly, a large difference vector (essentially the vector expression of the remaining astigmatic change that would need to be undertaken to reach the targeted astigmatism: mean [SD], 0.79 [0.39] D) and index of success (the ratio of this value to the TIA) of nearly 0.5 seem anomalous in conjunction with this “ideal” correction index. Sources of error include estimation errors for preoperative keratometry and postoperative refraction (including reliance on 0.25-D steps in refractive measurement vs 0.125-D for keratometric measurement), errors in the estimation of the axis of astigmatic effect of the incisions, and particularly, errors in estimation of the effective corneal plane power of the IOL cylinder. Taking these findings together, though the manufacturer’s target astigmatic change was reached, the clinically remaining astigmatic error suggests that the target was set too low, implying an underestimate of the corneal plane equivalent power of the cylinder on the part of the manufacturer. This latter source of error is addressed elsewhere.6,10

In conclusion, these data support the contention that toric IOLs are a safe and predictable method of astigmatic correction in lens surgery. However, some remaining astigmatism is commonly present, owing both to the necessary nonzero astigmatic targets imposed by the steps between IOL cylinder powers provided by the manufacturers and to some other sources of surgical and measurement error. Improved prediction of outcome could be achieved by using astigmatically neutral incisions. It would be useful for clinicians if the manufacturer more exactly indicated the corneal plane cylinder equivalent power of their lenses, taking into account the sphere power of the lens and the anterior chamber depth and pachymetry.

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REFERENCES


Archives Web Quiz Winner

Congratulations to the winner of our March quiz, Massood Mohammadi, MD, Department of Ophthalmology, Farabi Eye Hospital, Tehran University of Medical Sciences, Tehran, Iran. The correct answer to our March challenge was microsporidia keratitis. For a complete discussion of this case, see the Small Case Series section in the April Archives (Khandelwal SS, Woodward MA, Hall T, Grossniklaus HE, Stulting RD. Treatment of microsporidia keratitis with topical voriconazole monotherapy. Arch Ophthalmol. 2011;129[4]:509-510).

Be sure to visit the Archives of Ophthalmology Web site (http://www.archophthalmol.com) and try your hand at our Clinical Challenge Interactive Quiz. We invite visitors to make a diagnosis based on selected information from a case report or other feature scheduled to be published in the following month’s print edition of the Archives. The first visitor to e-mail our Web editors with the correct answer will be recognized in the print journal and on our Web site and will also be able to choose one of the following books published by AMA Press: Clinical Eye Atlas, Clinical Retina, or Users’ Guides to the Medical Literature.