

Effects of preoperative corneal astigmatism orientation on results with a low-cylinder-power toric intraocular lens

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PURPOSE: To evaluate refractive results with a low-cylinder-power toric intraocular lens (IOL) and the effect of preoperative corneal astigmatism orientation on results.

SETTING: Private practice, Jackson, Michigan, USA.

DESIGN: Comparative case series.

METHODS: This retrospective review of clinical records comprised patients with 0.75 to 1.38 diopters (D) of preoperative corneal astigmatism who had uneventful cataract surgery and AcrySof T3 toric or AcrySof IQ spherical monofocal IOL implantation. Surgically induced astigmatism (SIA) was calculated for eyes with postoperative keratometry results. Postoperative refractive astigmatism between groups and subgroups was compared based on the orientation of preoperative corneal astigmatism.

RESULTS: Of the eyes, 185 had a toric IOL and 138 had a spherical IOL. The mean preoperative corneal astigmatism was 1.06 D, with no significant difference between IOL groups or by axis of astigmatism. The mean SIA was 0.25 D, with no significant difference between IOL groups. The mean postoperative refractive astigmatism was statistically significantly lower in the toric IOL group than in the spherical IOL group (0.31 D versus 1.06 D; $P < .001$). The axis of preoperative corneal astigmatism was not a significant factor in the toric IOL group. In the spherical IOL group, the residual astigmatism was slightly higher for with-the-rule than for against-the-rule astigmatism (1.07 D versus 0.70 D; $P < .001$).

CONCLUSIONS: The mean refractive astigmatism after cataract surgery in patients with 0.75 D to 1.38 D of corneal astigmatism was significantly lower when a toric IOL was implanted. Postoperative refractive astigmatism with the toric IOL was independent of preoperative corneal astigmatism axis orientation.

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For several years, surgeons have had access to toric intraocular lenses (IOLs). The first U.S. Food and Drug Administration–approved toric IOL was the Staar toric IOL. The lowest cylinder power available in this IOL is 2.00 diopters (D) at the IOL plane, or approximately 1.40 D at the corneal plane.¹ The Alcon AcrySof toric IOL was approved in September 2005; its lowest cylinder power (model T3) is 1.50 D at the IOL plane, or approximately 1.03 D at the corneal plane.^A The latter IOL may be considered for patients with corneal cylinder as low as 0.75 D, depending on the direction of the astigmatism relative to the incision and the degree of surgically induced astigmatism

(SIA). Simulations using 0.50 D of SIA suggest that this toric IOL has a significant benefit with a low likelihood of overcorrection in patients with 0.75 D to 1.25 D of corneal astigmatism.²

There is considerable interest in correcting lower degrees of astigmatism because an estimated 65% of older patients have preoperative corneal astigmatism between 0.25 D and 1.25 D; 12% of older patients have astigmatism between 0.75 D and 1.00 D.³ The challenge in using toric IOLs in this population is to show that accurate correction of this low a magnitude of astigmatism is possible. A related objective is to show that such correction is better than alternative

methods of astigmatism correction, such as limbal relaxing incisions. Finally, it is important to show that such correction is clinically meaningful.

A significant hurdle in accurately correcting low amounts of preoperative corneal astigmatism is that SIA matters more and more. The SIA is a vector quantity, so both its magnitude and direction matter. Hill⁴ provides a useful overview of the issue. Surgically induced astigmatism of 0.50 D may have a negligible effect on a 2.50 D astigmatism correction (relative magnitude is only 20%) but could be significant when the astigmatic correction is only about 1.00 D (relative magnitude is 50%).

The issue of whether small amounts of residual astigmatism affect vision has received considerable attention in recent years as eyecare professionals seek to better understand the limitations of residual refractive error. Conventional wisdom is that 0.50 D of astigmatism is roughly equivalent to 0.25 D of spherical error and changes high-contrast visual acuity by approximately 1 logMAR line.⁵ More recent studies of blur limits⁶ suggest that the effect of residual astigmatism may be somewhat greater than conventionally presumed.

With regard to cataract surgery, 1 small study⁷ found that correcting low amounts of corneal cylinder with a toric IOL improved visual acuity by almost 2 logMAR lines, with a mean postoperative cylinder difference of 0.54 D. The effect of astigmatism on multifocal correction, which may become more important as companies develop multifocal toric IOLs, has also been studied. Distance visual acuity decreased by more than 1 line when 0.50 D of astigmatism was added to the best distance refraction, presumably reducing the likelihood of spectacle independence; the reduction in acuity was greatest at distance and less for intermediate and near.⁸ In general, it can be surmised that any reduction in postoperative astigmatism greater than 0.50 D should produce a noticeable improvement in visual acuity.

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The data presented here were collected to determine the extent to which postoperative refractive astigmatism can be reduced using a low-cylinder-power IOL in a patient population with low amounts of preoperative corneal astigmatism. A secondary objective was to determine whether the axis of preoperative corneal astigmatism was associated with differences in results between eyes. The intent was to evaluate the success of the IOL in reducing astigmatism; therefore, refraction data, not visual acuity data, were the measures of interest.

PATIENTS AND METHODS

Patients

A retrospective patient chart review was performed at 1 site (P.E.) to identify all patients with documented preoperative corneal cylinder between 0.75 D and 1.38 D at the time of surgery. Patients in the practice who have this range of cylinder are presented the option of having implantation of an AcrySof T3 toric IOL. Corneal cylinder was confirmed with the IOLMaster biometry, keratometry (automated or manual), or simulated keratometries from corneal topography. Charts from January to December 2009 were reviewed. A high percentage of patients chose the toric IOL option, although some did not for economic or other reasons. Those who did not were included in the review as a control population and received an AcrySof IQ spherical monofocal IOL (Alcon Laboratories, Inc). Patients who elected a presbyopia-correcting IOL were excluded. Eyes were excluded if they had irregular (nonorthogonal) corneal astigmatism or if they had previous corneal surgery.

This retrospective review of data included no protected health information, and the test and control IOLs are routinely used in the practice. In addition, patients entering the practice sign an acknowledgement that their unidentified protected health information data may be used for research purposes. As such, there was no need for a specific informed consent or institutional review board approval for the data collection.

For each eye, preoperative keratometry data and all keratometric and refractive data available in the chart were recorded. Follow-up was at 2 to 4 weeks, between 1 month and 6 months, or after 6 months. Corneal astigmatism was designated as with the rule (WTR) when the steep corneal cylinder axis was within 30 degrees of the horizontal axis (the steep meridian of the cornea being vertical in this case), against the rule (ATR) when the cylinder axis was within 30 degrees of vertical, and oblique if it was not WTR or ATR. Refractive astigmatism expressed in plus cylinder form is opposite to this; it is WTR when the plus cylinder axis is vertical, ATR when it is horizontal, and oblique in other cases. Oblique astigmatism is specifically identified here because these eyes would have an axis orientation farthest from the orthogonal effects of the temporal incision, which could potentially affect results if the SIA were more variable in these eyes.

Surgical Technique

The preoperative routine for all patients was similar, with corneal astigmatism measurements taken using an autokeratometer, an IOLMaster, and a manual keratometer. The level

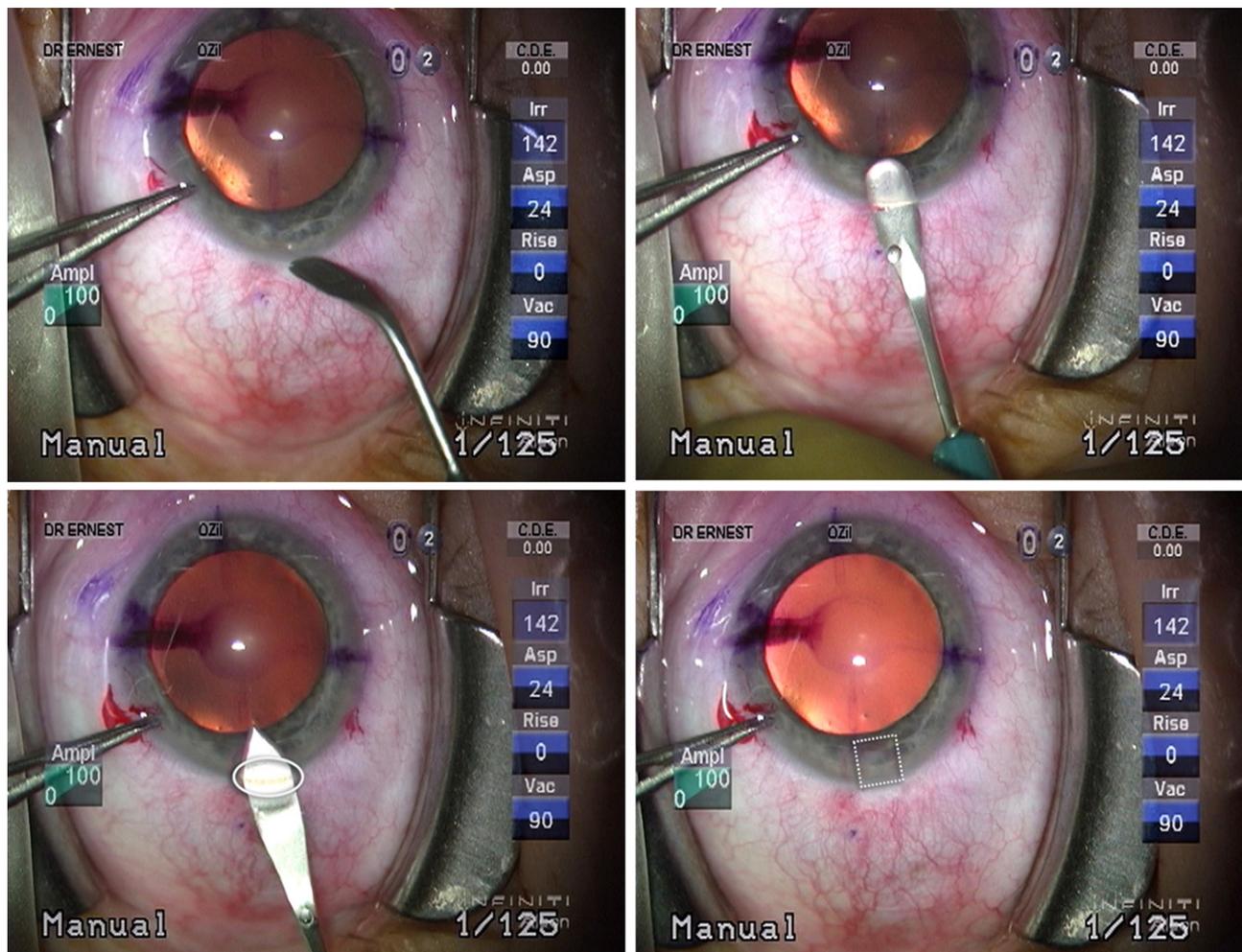


Figure 1. Construction of a posterior limbal incision.

of agreement between all devices was evaluated, and preoperative corneal astigmatism was recorded on the basis of these findings.

Calculation of the toric IOL to be used was based on IOLMaster printouts. Because the historical level of SIA for the incision being used had been calculated in the past and was known to be less than 0.25 D, no adjustment was made to compensate for this when choosing the IOL or marking the axis for IOL alignment. Intraocular lens alignment was based on the axis of preoperative corneal astigmatism, with eyes marked at the appropriate angle at the slitlamp with the patient sitting upright.

The surgical technique used in the time period in which the retrospective data were collected was constant for all patients. All incisions were temporal, 2.2 mm square, and posterior limbal as previously described.⁹ Figure 1 shows photographs of the technique. With the low amount of SIA, the incision axis was never adjusted for the axis of preoperative corneal astigmatism.

Statistical Analysis

Results were tabulated in Excel (Microsoft Corp.) and analyzed using Statistica statistical software (version 9.1,

StatSoft, Inc.). Differences between groups were calculated with *t* tests and analysis of variance. A *P* value less than 0.05 was considered statistically significant.

RESULTS

A review of the available clinical records identified 323 eyes that met the criteria for inclusion and had available postoperative data for analysis. Of these, 185 eyes received an AcrySof T3 toric IOL and 138 eyes received an AcrySof IQ spherical monofocal IOL. There were no complications in any case, and no sutures were used in any surgery. One hundred twenty-nine eyes (69.7%) in the toric IOL group and 124 eyes (89.8%) in the spherical IOL group were seen 2 to 4 weeks postoperatively; 43 eyes (23.2%) and 10 eyes (7.2%), respectively, were seen between 1 month and 6 months; and 13 eyes (7.0%) and 4 eyes (2.9%), respectively, were seen after 6 months. There was no statistically significant difference in postoperative refractive cylinder by time of follow-up between the 2 IOL

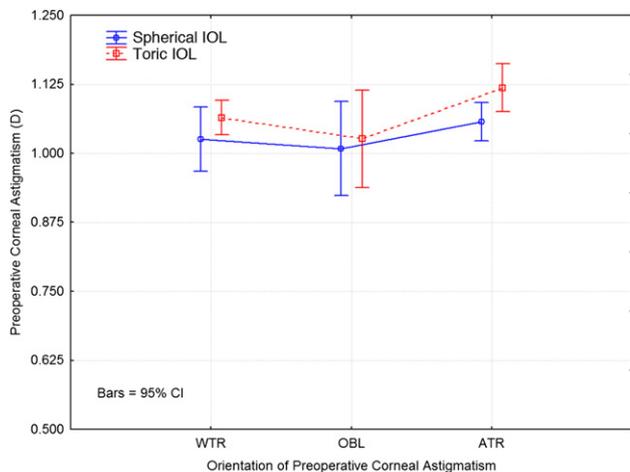


Figure 2. Mean preoperative corneal astigmatism by orientation (ATR = against the rule; IOL = intraocular lens; OBL = oblique; WTR = with the rule).

groups ($P > .05$). Postoperative keratometry data were available for 38 patients.

There was no statistically significant difference in the magnitude of preoperative corneal astigmatism between the toric IOL group and the spherical IOL group ($P > .05$), which was expected given the relatively narrow inclusion criteria. The mean preoperative corneal astigmatism was 1.08 D in the toric IOL group and 1.04 D in the spherical IOL group.

Approximately 10% of eyes in both groups had oblique astigmatism (30 degrees to 60 degrees from horizontal). In the spherical IOL group, 83 eyes (60.0%) had WTR corneal astigmatism and 41 eyes (29.7%) had ATR. This ratio was reversed in the toric IOL group. The difference between the 2 groups was statistically significant ($P < .05$, chi-square test); however, there was no intentional selection process preoperatively to generate this difference.

The mean levels of preoperative corneal astigmatism were not statistically significantly different by the orientation of that astigmatism ($P > .05$). Figure 2 shows the mean values in both IOL groups. The mean values differed by less than 0.125 D between all groups.

The SIA (vector difference between preoperative and postoperative corneal astigmatism) was calculated using available postoperative keratometry for 38 eyes. The mean SIA was $0.25 \text{ D} \pm 0.13 \text{ (SD)}$. There was no statistically significant difference in calculated SIA between the 2 IOL groups ($P = .6$). The middle 50% of eyes had an SIA between 0.14 D and 0.31 D. Previous analyses of SIA by the surgeon yielded similar results, and on that basis no adjustment for IOL power was made for this low level of SIA.

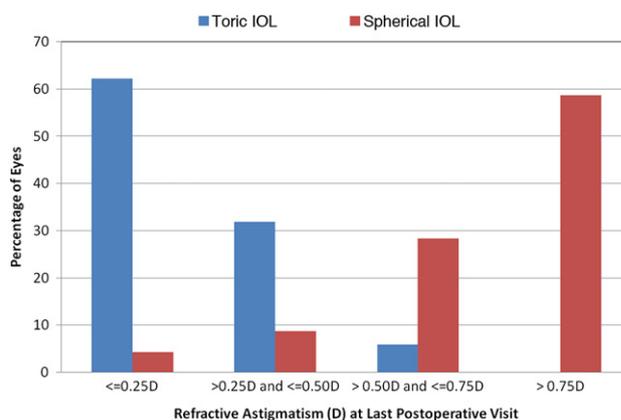


Figure 3. Distribution of postoperative refractive astigmatism by IOL type (IOL = intraocular lens).

The mean residual postoperative astigmatism was statistically significantly lower in the toric IOL group ($P < .001$), which had a mean of 0.31 D; the mean was 1.06 D in the spherical IOL group. Figure 3 shows the distribution of results. There was no significant effect related to the time of follow-up ($P > .05$). The residual refractive astigmatism was 0.50 D or lower in 170 eyes (91.9%) in the toric IOL group and 18 eyes (13.0%) in the spherical IOL group.

Figure 4 shows the mean refractive astigmatism by IOL and axis of preoperative astigmatism. In the toric IOL group, there was no statistically significant difference by preoperative axis orientation ($P > .05$). In the spherical IOL group, there was a statistically significant effect ($P < .001$), although it was not very large

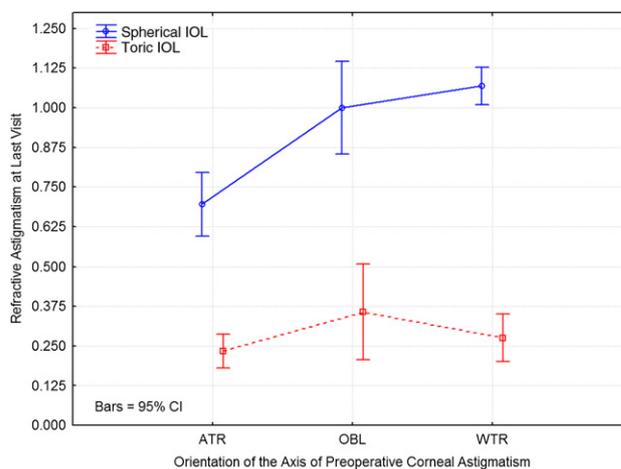


Figure 4. Refractive astigmatism at the last visit by orientation of preoperative corneal astigmatism (ATR = against the rule; IOL = intraocular lens; OBL = oblique; WTR = with the rule).

clinically. Eyes with preoperative ATR corneal astigmatism had 0.70 D of refractive astigmatism postoperatively, and eyes with WTR corneal astigmatism preoperatively had 1.07 D of refractive astigmatism postoperatively.

DISCUSSION

The most important finding in this group of eyes was that correcting relatively small amounts of corneal astigmatism with the low-powered AcrySof T3 toric IOL significantly reduced postoperative refractive astigmatism relative to a spherical IOL. There was roughly a 0.75 D difference in postoperative astigmatism between the spherical IOL group and the toric IOL group. Recent research⁵⁻⁷ of the effects of astigmatism on blur suggests that this would equate to a 1- to 2-line difference in high-contrast visual acuity in these patients.

The challenge with low levels of astigmatism is the precision with which the astigmatism can be corrected. In this regard, SIA is a critical factor. The lower the degree of astigmatism induced at the time of surgery, the more precise the postoperative correction is likely to be because the variability in that SIA will be lower and lower. A low average amount of SIA is generally less variable than a high amount because both the magnitude and direction of SIA will vary.⁴ When the magnitude of the SIA vector is higher, a small random axis shift will matter more in terms of vector addition than when the magnitude of the vector is lower.

The low degree of SIA induced in these patients is presumed to be a function of using the corneal lip incision technique and initiating the incision at the posterior limbus. Wound stability and relative reductions in variability in induced astigmatism were shown with this technique as far back as 1994, although incisions overall were somewhat larger at that time.⁹ Because SIA can have a significant impact on the success of correcting low amounts of preoperative corneal astigmatism with a toric IOL, it would be useful for surgeons considering this level of correction to carefully analyze their personal SIA, for both magnitude and direction, as well as variability in both these terms.

As to the effect of the orientation of the preoperative corneal cylinder, there was no significant effect when the toric IOL was used. It would appear that the astigmatism correction from the toric IOL is sufficiently large that any relative SIA effects, given the low amount of SIA observed, are modest and do not affect the final outcome. There was an observed effect with the spherical IOL; however, the effect was small and as expected. With a calculated SIA

near 0.25 D, one would expect ATR patients to have approximately 0.75 D of resulting astigmatism (subtracting the 0.25 D from the mean 1.00 D preoperative corneal astigmatism) and WTR patients to have approximately 1.25 D of resulting astigmatism (adding the 0.25 D from the mean 1.00 D preoperative corneal astigmatism); these values are based on WTR and ATR corneal astigmatism meridians being at 90 degrees and 180 degrees, respectively (corresponding to axes at 180 degrees and 90 degrees, respectively). The vector subtraction of SIA will yield slightly lower differences (as observed) when the axes of astigmatism for a given eye vary from these orthogonal positions. The results in this study are consistent with these theoretical values.

In summary, the AcrySof T3 toric IOL can provide significantly lower postoperative astigmatism than a spherical IOL when the preoperative corneal astigmatism is in the range of 0.75 to 1.38 D. The mean 0.75 D reduction in postoperative astigmatism is likely to produce significant improvements in patients' visual acuity and contribute to the likelihood of spectacle independence for distance vision. Orientation of preoperative corneal astigmatism did not significantly affect the results. To achieve good results with this level of astigmatism correction requires careful control of SIA.

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