ARTICLE

# Effect of astigmatism on visual acuity after multifocal versus monofocal intraocular lens implantation

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**Purpose:** To determine whether there is a difference in how much residual astigmatism impacts uncorrected distance visual acuity (UDVA) after multifocal versus monofocal intraocular lens (IOL) implantation.

**Setting:** Database study.

**Design:** Retrospective data review.

**Methods:** An online toric IOL back-calculator allows users to input preoperative toric planning information and postoperative IOL orientation and refractive results. These data are used to determine the optimal orientation of the IOL to minimize residual refractive astigmatism. Aggregate data were extracted from this calculator to investigate factors associated with UDVA and relative magnitudes of residual astigmatic refractive error up to 2.5 diopters (D) after implantation of toric IOLs.

**Results:** Of 1919 pertinent records (455 multifocal toric IOLs and 1464 monofocal toric IOLs), a statistically significant difference by refractive cylinder category ($P < .01$) and a statistically significant difference by IOL type ($P = .042$) were noted. This difference was mostly driven by patients with residual refractive astigmatism of 1.5 D. The mean change in UDVA was 0.16 logarithm of the minimum angle of resolution per 1.0 D of astigmatism. Evaluating a more homogenous dataset with the same monofocal and multifocal IOL design, there was a statistically significant effect of refractive cylinder ($P < .01$) but no significant effect of IOL type (monofocal or multifocal, $P = .45$). The differences in UDVA at different refractive cylinder values was not statistically significantly different by orientation of the current astigmatism ($P = .28$).

**Conclusion:** Residual astigmatism after toric IOL implantation impacts visual acuity similarly in patients who had multifocal and monofocal toric IOL implantation.

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Most patients corrected with a monofocal intraocular lens (IOL) for optimal distance vision at the time of cataract surgery will find their intermediate and near vision reduced. As such, implantation of multifocal IOLs is an option of interest to many patients presenting for surgery. Although cost might be a consideration, reservations regarding multifocal IOLs might also be related to the increased potential for visual disturbances.[1,2] It is also important that the residual refraction achieved with multifocal IOLs be near emmetropia because any correction required for distance vision would reduce the perceived value of the IOL.

Although satisfaction with multifocal IOLs is generally high, studies related to dissatisfaction after implantation suggest that residual refractive error is a key contributor. Blurry vision after multifocal IOL implantation was present in 95% of dissatisfied patients in studies by de Vries et al.[2] and Woodward et al.[3] De Vries et al.[2] found that the most common reason for blurry vision was residual refractive error and/or astigmatism, impacting nearly 50% of cases. Woodward et al.[3] found that complaints of blurry vision related to ametropia had an average of approximately 1.5 diopters (D) of astigmatism. Gundersen et al.[4] noted that residual astigmatism (averaging 1.25 D) was significantly associated with high retreatment rates in patients implanted with a multifocal IOL. It is clear that minimizing postoperative residual astigmatism is a key factor in the success of multifocal IOLs.

One of the most effective ways to reduce residual astigmatism is by using toric IOLs,[5] but even with these IOLs

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there can be some residual astigmatism; Visser et al.[6] found residual astigmatism more than 0.50 D in approximately 30% of eyes in a broad review of toric IOL outcomes in the literature. Residual astigmatism after surgery might be the result of inaccurate preoperative measurements, limitations with toric calculators, or variability in patient and surgical factors.[7]

In young healthy and pseudophakic eyes, studies demonstrate that astigmatism magnitude is positively correlated with reduced visual acuity.[8,9] However, there have been few studies looking precisely at the effect of residual astigmatism on visual acuity in patients implanted with multifocal versus monofocal IOLs. One study by Hayashi et al.[10] suggested that in eyes with 1.5 D or 2.0 D of astigmatism, the mean corrected distance visual acuity was worse with a +3.0 D addition (add) diffractive bifocal IOL when compared with a monofocal IOL; there were 30 eyes in each IOL group in which astigmatism was simulated using lenses.

The purpose of the current study was to objectively determine the relationship between residual astigmatism and uncorrected distance visual acuity (UDVA), and whether that relationship was different in eyes implanted with a monofocal toric or a multifocal toric IOL.

## MATERIALS AND METHODS

The data available from a website designed to assist with postoperative analysis of residual astigmatism after toric IOL implantation were reviewed.[A] All users acknowledge that the Terms and Conditions for the site permit the use of de-identified patient data for research and other purposes. The website requires the current refraction (sphere, cylinder, and axis) to be entered and includes the option to record UDVA. Data from the site were filtered based on range limit criteria and whether cases were repeat cases and/or theoretical cases. In addition, only those cases with UDVA reported were retained. Cases were also limited to those with residual refractive cylinder (after toric IOL implantation) of 2.50 D or less because values outside this range are likely to be both infrequent and suggestive of transcription or other errors. Results were limited to those eyes where a specific IOL model was identified, so that they could be categorized as monofocal or multifocal. Eyes with previous corneal surgery were also excluded.

The toric IOLs implanted were categorized on the basis of whether they were designed to correct vision at only 1 focus (single vision or monofocal) or designed for presbyopia correction (multifocal, including extended depth-of-focus IOLs). Unspecified IOLs (eg, "other") were deleted from the dataset. The UDVA data were recorded on the website in Snellen notation, which was converted to logarithm of the minimum angle of resolution (logMAR) for the purposes of this analysis. The mean spherical equivalent (SE) refraction was calculated to provide an indication of the degree of ametropia. Only eyes with a mean SE refraction within ±0.50 D of plano were included to minimize the potential effects of spherical refractive error on the visual acuity results. Although the effect of SE refractions on visual acuity is somewhat subjective, the uniformity of the inclusion criteria should not impact the validity of the results.

The dataset of interest included all calculations collected since revision of the website to include a field for UDVA (January 23, 2017 to February 9, 2018). A total of 20 932 raw data records were available from the website; these calculation requests were from an estimated 2800 different surgeons. Range criteria (eg, "eye" was specified as right or left, axes of astigmatism were between 0 and 180 degrees, absolute residual refractive cylinder was ≤10.0 D, absolute residual refractive sphere was ≤6.0 D) were used to identify and qualify valid records. Applying these preliminary data qualifications left 7766 data records. Of these, 4700 were identified as "unique," being the only calculation on a given day for a given user for a specific IOL. The other 3066 records were considered possible duplicates. For this latter set of data, grouping by day, surgeon, IOL, and current refraction, as well as the refractive result (expected residual astigmatism magnitude and orientation) yielded 781 aggregated records. The "First" record of these duplicates was arbitrarily retained, whereas the other duplicate records were discarded. These aggregated records, combined with the "unique" records, provided a dataset of 5481 records, of which 3237 included a specific IOL model, had a current residual refractive cylinder of 2.50 D or lower, did not involve previous corneal surgery, and included UDVA data. Finally, only records with a mean SE refraction within ±0.5 D of plano were included to increase the likelihood that refractive cylinder was the principal cause of worsened UDVA. This left 1919 records in the final dataset; Figure 1 shows the data cleanup and filtering process.

The primary measure of interest was the difference in observed UDVA reported with differences in residual cylinder when either monofocal or multifocal IOLs were implanted. This was evaluated by calculating the slope of the best-fit regression for the uncorrected logMAR visual acuity as a function of the current (presenting) refractive cylinder. The effect of both IOL manufacturer and multifocal IOL type were considered when sufficient numbers were available for analysis.

The data file from the website was downloaded as a text file that was imported into Access software (Microsoft Corp.) for preliminary filtering and analysis. The relevant data were then imported into the Statistica data analysis software system (version 13, Tibco Software, Inc.) for the more detailed analysis. Where statistical comparisons were made, a $P$ value less than 0.05 was considered statistically significant.

## RESULTS

The study comprised 1919 pertinent records (455 multifocal toric IOLs and 1464 monofocal toric IOLs). As a preliminary data check, a box-and-whisker plot of the uncorrected logMAR visual acuity was prepared, categorized by the degree of refractive cylinder present and the type of IOL; results are shown in Figure 2. The UDVA worsens as refractive cylinder increases, but any difference between the results with multifocal and monofocal IOLs is less evident. An analysis of variance (ANOVA) of the uncorrected logMAR acuity by refractive cylinder category

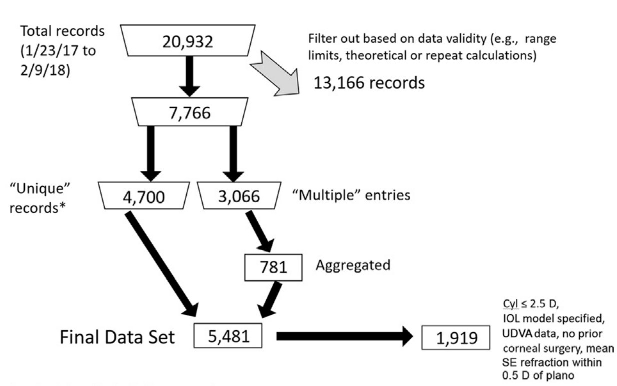


Figure 1. The data filtering process (IOL = intraocular lens; SE = spherical equivalent; UDVA = uncorrected distance visual acuity).