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Comparison between Toric and Non-Toric Intraocular Lenses in Patients with Corneal Astigmatism: A One-Year Multicenter Study

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Abstract

Objective: To compare the clinical results obtained with a toric intraocular lens (IOL) and non-toric IOL in eyes with corneal astigmatism.

Methods: This multicenter retrospective study included eyes with corneal astigmatism ranging from 0.75 diopter (D) to 3.00 D that were implanted with a toric IOL and a non-toric IOL. Non-toric IOLs were implanted before toric IOLs were approved, and the eyes were divided into three groups (T3, T4, or T5) depending on the preoperative degree of corneal astigmatism. Residual refractive cylinder, uncorrected distance visual acuity (UDVA), and contrast sensitivity were compared more than 1 year after implantation.

Results: The toric group included 149 eyes (mean patient age, 73.7 ± 7.9 years standard deviation, SD) and the non-toric group included 121 eyes (mean patient age, 76.2 ± 5.9 years). One year postoperatively, the respective residual refractive cylinder values and ± SD of the toric/non-toric groups were -0.61 ± 0.43/-1.45 ± 0.98 D (all eyes), -0.58 ± 0.42/-1.14 ± 0.70 D (T3), -0.59 ± 0.42/-1.63 ± 0.99 D (T4), and -0.67 ± 0.47/-2.18 ± 1.27 D (T5). The respective logarithm of the minimum angle of resolution UDVA values was 0.00 ± 0.12/0.16 ± 0.20 (all eyes), 0.00 ± 0.11/0.13 ± 0.18 (T3), 0.00 ± 0.13/0.25 ± 0.23 (T4), and 0.00 ± 0.11/0.17 ± 0.16 (T5). The toric group had better cylinder and UDVA outcome values; the difference between the groups reached significance ($p<0.0001$). In the toric group, the IOL rotation after implantation was 4.3 ± 4.0 degrees.

Conclusion: Toric IOLs reduced the residual refractive cylinder in cases with corneal astigmatism between 0.75 and 3.00 D, and this effect was similar among different toric models. Toric IOLs are useful to improve the UDVA after cataract surgery.

Keywords: Cataract surgery; Contrast sensitivity; Corneal astigmatism; Toric intraocular lens; Uncorrected visual acuity

Introduction

Toric intraocular lenses (IOLs) were developed to improve the visual function after cataract surgery. Implantation of a single-piece acrylic IOL resulted in better surgical outcomes compared to a previously available toric IOL, which required a larger incision and tended to rotate postoperatively [1-3]. A multicenter study proved the efficacy of AcrySof toric IOL (Alcon Laboratories, Fort Worth, TX, USA) compared to non-toric AcrySof IOL (Alcon Laboratories) in cases with corneal astigmatism [4]. Over 100 published studies have reported preferable clinical results for uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), residual refractive cylinder, spectacle independence, and IOL rotation. Recent reviews have summarized these results [5] and analyzed the clinical outcomes in 11 studies [6].

Regarding the amount of preexisting corneal astigmatism, most reports have summarized the total results of toric IOL with different powers. A limited number of studies have evaluated the clinical outcomes with low to high powers [4,7-9]. To collect a reasonable number of cases with both toric and non-toric IOLs, we conducted this retrospective multicenter study.

Subjects and Methods

This study, which was conducted at seven sites in Japan (Department of Ophthalmology, Tokyo Dental College Suidobashi Hospital; Inoue Eye Clinic; Mikawa Eye Clinic; Ryuundo Eye Clinic; Okayama-Minami Eye Clinic; Nagayama Eye Clinic; and Shimokawabe Eye Clinic), adhered to the Declaration of Helsinki and good clinical practice for a medical device in Japan. The central and

institutional review boards at all sites approved the study protocol. The data were collected from the patients' record at each site.

Patients

The eligibility criteria included patients who underwent cataract surgery for age-related cataract with corneal astigmatism between 0.75 and 3.00 diopters (D), a postoperative CDVA of 20/25 or better, and a manifest spherical equivalent of ± 0.75 D or less. The eyes implanted with a toric IOL (toric group) included those with AcrySof toric IOL models SN6AT3, SN6AT4, and SN6AT5 (Alcon Laboratories). The eyes implanted with a non-toric IOL (non-toric group) included eyes with the SN60WF IOL (Alcon Laboratories) before toric IOLs were approved. The eyes were divided into three groups equivalent to T3 (indicating preoperative corneal astigmatism of 0.75-1.54 D), T4 (1.55-2.05 D), and T5 (2.06-3.00 D).

The exclusion criteria included the presence of uncontrolled glaucoma, progressive diabetic retinopathy, retinal detachment, significant macular changes, and corneal degeneration and a history of uveitis, refractive surgery, corneal transplantation, and IOL exchange.

Evaluations

Preoperatively, the UDVA, CDVA, and corneal astigmatism were measured with an autokeratometer (Nidek Co., Ltd., Gamagouri, Japan); the axial length and corneal diameter (white to white) were measured using the IOLMaster (Carl Zeiss Meditec, Jena, Germany). Postoperatively, the UDVA, CDVA, and residual refractive cylinder were evaluated between 1 and 3 months and more than 1 year after implantation. These results of toric and non-toric groups were compared in all eyes and subgroups of T3, T4, and T5. In addition, the results were compared to another subgroup with a different steep meridian; against-the-rule (ATR) group of eyes with axes between 0 and 30 degrees and 150 and 180 degrees and with-the-rule (WTR) group of eyes with an axis between 60 and 120 degrees. IOL misalignment from the intended axis and posterior capsular opacity were evaluated with the pupil dilated, and the contrast sensitivity was measured with the CSV-1000 (Vector Vision, Greenville, OH, USA) more than 1 year postoperatively.

Statistical analyses

Statistical analyses were performed with the Wilcoxon, Kruskal-Wallis, and Steel-Dwass tests using Microsoft Office Excel 2010 software (Microsoft, Redmond, WA, USA) and JMP® 10 software (SAS Institute Inc., Cary, NC, USA). The results are expressed as the mean ± standard deviation (SD). $p<0.05$ was considered statistically significant.

Results

The toric group included 149 eyes (T3, 61 eyes; T4, 43 eyes; T5, 45 eyes) of 109 patients and the non-toric group included 121 eyes (T3 equivalent, 68 eyes; T4 equivalent, 31 eyes; T5 equivalent, 22 eyes) of 102 patients. In the toric group, 42 patients were males and 67 patients were females, and 101 eyes were ATR and 43 eyes were WTR. In the non-toric group, 43 patients were males and 59 patients were females, and 74 eyes were ATR and 45 eyes were WTR.

Table 1 shows the patient demographics. The locations of the incisions differed; 56.3% of eyes had a temporal clear corneal incision, 13.3% a sclerocorneal incision, and 30.4% a scleral incision at either the superior or steep axis. In the toric group, the cylindrical power of the IOL was selected based on the web-based toric IOL calculator (http://www.acrysoftoriccalculator.com) with individual surgically induced astigmatism (SIA) at each site. As a reference point, 67.1% used axis registration [10] and the rest were either marked at the 6 o'clock position or matching vessels and the iris pattern of the anterior segment analyzer was used.

Characteristic	Toric group	Non-toric group	p value
	Mean ± SD	Mean ± SD	
Age (years)	73.7 ± 7.9	76.2 ± 5.9	0.0183
Follow up (years)	1.5 ± 0.5	2.0 ± 0.9	<0.0001
Preoperative cylinder (D)			
All	-1.77 ± 0.71	-1.59 ± 0.58	0.0347
Subgroup T3	-1.25 ± 0.27	-1.19 ± 0.21	0.2106
T4	-1.68 ± 0.28	-1.78 ± 0.14	0.0750
T5	-2.56 ± 0.70	-2.57 ± 0.43	0.7580
Preoperative UDVA (logMAR)			
All	0.54 ± 0.35	0.59 ± 0.36	0.2228
Subgroup T3	0.54 ± 0.36	0.57 ± 0.35	0.4762
T4	0.53 ± 0.38	0.53 ± 0.29	0.6158
T5	0.55 ± 0.33	0.71 ± 0.44	0.1921
Preoperative CDVA (logMAR)			

All	0.26 ± 0.30	0.36 ± 0.33	0.0019
Subgroup T3	0.23 ± 0.30	0.34 ± 0.35	0.0840
T4	0.30 ± 0.32	0.33 ± 0.18	0.0993
T5	0.27 ± 0.27	0.47 ± 0.41	0.0079

Table 1: Patient demographics.

Residual refractive cylinder

Table 2 shows the residual refractive cylinder in the toric and non-toric groups at 1 to 3 months and over 1 year postoperatively. In addition, the preoperative and postoperative cylinders were compared between the cases with ATR and WTR astigmatism. In cases with ATR astigmatism, the residual refractive cylinder decreased significantly in the toric group; however, in cases with WTR astigmatism, the residual refractive cylinder decreased in both the toric and non-toric IOL groups.

	Toric group	**Non-toric group**	**p value**
	Mean ± SD	Mean ± SD	
1-3 months (D)			
All	-0.54 ± 0.44	-1.38 ± 0.96	<0.0001
Subgroup T3	-0.50 ± 0.40	-1.04 ± 0.69	<0.0001
T4	-0.52 ± 0.41	-1.65 ± 0.98	<0.0001
T5	-0.62 ± 0.51	-2.05 ± 1.20	<0.0001
Subgroup ATR	-0.58 ± 0.47	-1.84 ± 0.90	<0.0001
WTR	-0.48 ± 0.35	-0.64 ± 0.52	0.2196
1 year (D)			
All	-0.61 ± 0.43	-1.45 ± 0.98	<0.0001
Subgroup T3	-0.58 ± 0.42	-1.14 ± 0.70	<0.0001
T4	-0.59 ± 0.42	-1.63 ± 0.99	<0.0001
T5	-0.67 ± 0.47	-2.18 ± 1.27	<0.0001
Subgroup ATR	-0.69 ± 0.42	-1.91 ± 0.93	<0.0001
WTR	-0.45 ± 0.42	-0.69 ± 0.50	0.0165

Table 2: Postoperative residual refractive cylinder.

Visual acuity

The postoperative UDVAs and CDVAs are shown in Tables 3 and 4. The toric group had better UDVA when all eyes were considered, as did the T3, T4, and T5 subgroups. There were significant differences in the CDVA in all eyes between the toric and non-toric groups. The UDVA in the toric group was significantly better in cases with ATR and WTR astigmatism.

	Toric group	**Non-toric group**	**p value**
	Mean ± SD	Mean ± SD	
1-3 months			
All	-0.01 ± 0.11	0.14 ± 0.18	<0.0001
Subgroup T3	-0.03 ± 0.09	0.07 ± 0.13	<0.0001

T4	-0.01 ± 0.13	0.21 ± 0.20	<0.0001
T5	0.02 ± 0.12	0.25 ± 0.21	<0.0001
Subgroup ATR	-0.01 ± 0.11	0.18 ± 0.2	<0.0001
WTR	-0.01 ± 0.12	0.06 ± 0.11	0.0032
1 year			
All	0.00 ± 0.12	0.16 ± 0.20	<0.0001
Subgroup T3	0.00 ± 0.11	0.13 ± 0.18	<0.0001
T4	0.00 ± 0.13	0.25 ± 0.23	<0.0001
T5	0.00 ± 0.11	0.17 ± 0.16	<0.0001
Subgroup ATR	0.01 ± 0.12	0.23 ± 0.20	<0.0001
WTR	0.00 ± 0.11	0.05 ± 0.14	P=0.0204

Table 3: Postoperative UDVA (logMAR).

	Toric group	**Non-toric group**	**p value**
	Mean ± SD	Mean ± SD	
1-3 months			
All	-0.11 ± 0.07	-0.08 ± 0.07	0.0003
Subgroup T3	-0.13 ± 0.07	-0.10 ± 0.07	0.0303
T4	-0.11 ± 0.08	-0.04 ± 0.07	0.0006
T5	-0.10 ± 0.07	-0.06 ± 0.08	0.0769
1 year			
All	-0.11 ± 0.07	-0.09 ± 0.08	0.0139
Subgroup T3	-0.12 ± 0.07	-0.11 ± 0.08	0.4807
T4	-0.10 ± 0.07	-0.04 ± 0.09	0.0031
T5	-0.11 ± 0.07	-0.08 ± 0.07	0.1095

Table 4: Postoperative CDVA (logMAR).

Contrast sensitivity

The contrast sensitivities measured in 135 eyes in the toric group and 86 eyes in the non-toric group are shown in Figure 1. The contrast sensitivities of both the toric and non-toric groups were within normal range, however, that of 18 cycle/degree was at the lower limit. There were no statistical differences in any spatial frequencies between the two groups.

IOL axis misalignment

In the toric group, the axis mark of the IOL was observed in all eyes at 1 year postoperatively. The differences between the planned axis and the position of the axis mark are shown in Table 5. These results were not correlated with the axial length or corneal diameter (Table 6).

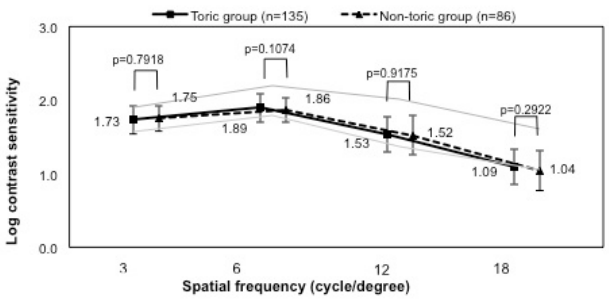

Figure 1: Contrast sensitivity. The gray lines indicate the normal range of upper and lower contrast sensitivity.

	Mean ± SD (minimum-maximum) (degrees)
All (n=132)	4.3 ± 4.0 (0-19)
Subgroup T3 (n=51)	4.0 ± 4.0 (0-17)
T4 (n=39)	4.6 ± 3.9 (0-19)
T5 (n=42)	4.3 ± 4.2 (0-19)

Table 5: Axis misalignment.

Parameter	Mean ± SD (minimum-maximum)	R	p value
Axial length (n=131)	23.40 ± 1.19 mm	0.03774	0.6687
	(20.89-29.25)		
WTW (n=47)	11.67 ± 0.41 mm	0.07837	0.6005
	(10.20-12.60)		

Table 6: Axis misalignment and axial length and white-to-white (WTW) diameter.

Discussion

The benefit of using toric IOLs during cataract surgery in cases with corneal astigmatism is confirmed and the number of implantations is increasing. The distribution of corneal astigmatism in cataract cases has been reported and most cases were within 3D [11,12]. In the current study, we evaluated the postoperative outcomes of toric IOLs with different levels of corneal astigmatism and compared the results to those with non-toric IOL. Some studies have reported cases with low or high astigmatism [7,8,13,14]; however, most studies did not separately evaluate those with T3, T4, and T5 models. A randomized, parallel-group, multicenter study compared the surgical outcomes of toric and non-toric IOL in three groups depending on the degree of predicted postsurgical refractive cylinder [4]. The IOL used in that study was the same single-piece IOL (aspheric and untinted model).

A limitation of the current study was its retrospective nature. In addition, the non-toric group was divided into three groups depending on the preoperative corneal astigmatism, since the SIA and surgical information were difficult to assess in most cases.

Residual refractive cylinder directly affects the UDVA. The percentages of eyes with refractive cylinder of 0.5 D or less and 1.0 D or less were evaluated, and 0.5 D seems to be a reasonable value by which to evaluate the benefits of a toric IOL [4,5,7]. In the current study, the mean residual refractive cylinder was between 0.50 D and 0.67 D, and that of the T5 subgroup was higher than those of the T3 and T4 subgroups. One study reported on the clinical performance of Tecnis toric IOL, which has a similar variety of cylindrical powers as AcrySof IQ Toric (Waltz et al. 2010) [9]. The postoperative refractive cylinder in cases with a toric IOL of each model with different cylinders from 1.5 D and 4.0 D showed preferable results compared to that of the non-toric IOL. The current cases with WTR astigmatism in the non-toric group had less residual refractive cylinder compared to the cases with ATR astigmatism. Some studies have reported less of an effect on VA in cases with WTR astigmatism [14,15]. A recent study of posterior astigmatism reported the amount of overestimated cylinder when the anterior astigmatism is measured in cases with WTR astigmatism and underestimated in cases with ATR astigmatism, and a new nomogram was recommended [16,17]. The predictability of residual refractive cylinder in cases with a toric IOL will improve when considering the cylindrical axis and total corneal astigmatism.

The UDVA in eyes with a toric IOL was significantly better than that in eyes with a non-toric IOL. At 1 to 3 months and 1 year postoperatively, the mean logarithm of the minimum angle of resolution VAs were equal to or better than 0.00 (20/20 Snellen equivalent). This was stable with different amounts of corneal astigmatism. When we compared the cases between ATR and WTR astigmatism, the UDVA in the toric group was significantly better than that of the non-toric group. The mean UDVA in the non-toric group was better in cases with WTR astigmatism, which also can be explained by the residual refractive cylinder.

To evaluate the benefit of a toric IOL, most studies have reported the UDVA but not the CDVA. In the current study, the CDVA also was significantly better in the toric group at 1 to 3 months and 1 year postoperatively. When we evaluated the different models, eyes with T4 were significantly better than those in the T4 equivalent group. Holland et al. compared the percentages of eyes that achieved cumulative best spectacle-corrected distance VA at 1 year postoperatively. In the toric group, 77.7% of eyes had 20/20 or better compared with 69.2% in the non-toric group [4]. The possibility of improving the CDVA by reducing the refractive cylinder should be studied further. In addition to the CDVA, we evaluated the contrast sensitivity to identify any differences in visual quality. However, there were no statistical differences between the toric and non-toric groups.

IOL axis misalignment has been evaluated using different methods. We used slit-lamp photographs to determine the IOL axis, and the mean misalignment of 4.3 degrees was comparable to a previous report [18]. In the current series, the misalignment was not correlated with axial length or corneal diameter; however, Shah et al. reported a strong correlation between the axial length and IOL rotation [19]. Although this effect was said to be small and not clinically relevant [5], we experienced spontaneous IOL rotation during aspiration of an ophthalmic viscosurgical device at the end of surgery. The possibility of rotation in eyes with longer axial lengths should be considered. The method of determining the steep axis at the time of IOL implantation is the key to successful implantation of a toric IOL. The recently developed image guided system to overlay the steep axis under the microscope and intraoperative aberrometry are expected to improve the accuracy of IOL alignment [20].

In conclusion, our retrospective multicenter study showed similar results to those of previous prospective reports and added information that the effect of toric IOL in cases with corneal astigmatism between 0.75 D and 3.00 D is similar in different models of toric AcrySof IOLs.

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