Effect of Toric Intraocular Lens Implantation on Visual Acuity and Astigmatism Status in Eyes Treated With Microhook Ab Interno Trabeculotomy

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Précis: Use of toric intraocular lenses is a reasonable option for better visual outcomes when a combined minimally invasive glaucoma surgery (MIGS) and cataract surgery is performed in eyes with preexisting corneal astigmatism.

Purpose: To assess the efficacy of toric intraocular lenses (IOLs) in combined cataract and MIGS surgeries, visual and refractive outcomes were compared between eyes implanted with nontoric and toric IOLs during microhook ab interno trabeculotomy triple procedures.

Methods: Glaucomatous eyes with preexisting corneal astigmatism exceeding −1.5 D implanted with nontoric (n = 10) or toric (n = 10) IOLs were evaluated retrospectively. The uncorrected visual acuity (UCVA) and refractive astigmatism were measured preoperatively and postoperatively.

Results: Preoperatively, the groups had similar logarithm of the minimum angle of resolution (logMAR) UCVAs and refractive astigmatism. Postoperatively, the logMAR UCVA (toric, 0.07 ± 0.07; nontoric, 0.33 ± 0.30; P = 0.0020) was significantly better and the refractive astigmatism (toric, −0.63 ± 0.56 D; nontoric, −1.53 ± 0.74 D; P = 0.0110) significantly less in the toric group. The toric group had postoperative improvements in the logMAR UCVA (−0.58, P = 0.0039) and refractive astigmatism (+1.45 D, P = 0.0195). Vector analyses showed the postoperative centroid magnitude of refractive astigmatism was less in the toric group (0.23 D at 83 degrees) than the nontoric group (1.03 D at 178 degrees). Postoperatively, 70% of eyes in the toric group had 1.0 D or less refractive astigmatism compared with 10% in the nontoric group. Surgically induced astigmatism (nontoric group, 0.62 D at 10 degrees; toric group, 0.50 D at 113 degrees) and intraocular pressure reduction (22% in both groups) did not differ between groups.

Conclusions: Better visual outcomes may be achieved with toric IOLs when a combined MIGS/cataract surgery is performed in eyes with corneal astigmatism.

Key Words: microhook ab interno trabeculotomy, surgically induced astigmatism, vector analysis, minimally invasive glaucoma surgery (MIGS), visual acuity, primary open angle glaucoma, exfoliation glaucoma

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rabeculectomy (LEC) remains the standard surgical procedure for glaucoma when medical and laser treatments fail to control the intraocular pressure (IOP). However, the astigmatic changes after LEC can lead to decreased visual acuity (VA).1 Trabeculotomy reduces IOP by eliminating aqueous flow resistance by cleaving the trabecular meshwork (TM) and inner walls of Schlemm’s canal at the point of outflow resistance of the aqueous humor. A new technique, which we refer to as microhook ab interno trabeculotomy (μLOT), for performing LOT includes incision of the TM using a specialized device under direct observation of the anterior-chamber angle structure.2,4 The features of μLOT, which include conjunctival and scleral sparing with the ab interno technique, short surgical time, moderate IOP reduction, and no bleb-related complications, fulfill the conditions of minimally invasive glaucoma surgery (MIGS).5,6

Previously, we compared the surgically induced astigmatism (SIA) among 4 glaucoma surgeries, that is, LEC, ExPRESS shunt (Alcon Inc., Fort Worth, TX), ab externo LOT, and μLOT, and found that SIA after μLOT alone (0.12 D at 97 degrees) was substantially lower than after LEC (1.01 D at 56 degrees).7 Considering the small amount and predictability of the SIA associated with μLOT, we started to use toric intraocular lenses (IOLs) during combined μLOT and cataract surgery to correct preoperatively existing corneal astigmatism. In addition to solo cataract surgery, toric IOLs have been used during combined microincision vitrectomy surgery8;9; however, use of toric IOLs during MIGS is unique in the literature. The current study compared the visual and refractive outcomes between eyes implanted with nontoric and toric IOLs during μLOT triple procedures.

SUBJECTS AND METHODS

Subjects
This retrospective study included 20 eyes of 20 subjects implanted with a nontoric IOL (Vivinex iSert XY1, Hoya, Tokyo, Japan; n = 10) or a toric IOL (Vivinex Toric XY1, Hoya; n = 10) during μLOT and simultaneous small-incision cataract surgery performed at Shimane University Hospital or Matsue Red Cross Hospital. Since we started to use the toric IOL model in July 2019, the subjects who met the inclusion criteria were selected from our departments’
glaucoma database in a chronological order of surgical date from July 2019 ascends for nontoric group and descendingly for toric group to include 10 eyes in each of surgical group.

The study adhered to the tenets of the Declaration of Helsinki; the institutional review board (IRB) of Shimane University Hospital reviewed and approved the research. Preoperatively, all subjects provided written informed consent for surgery; however, the IRB approval did not require that each patient provide written informed consent for publication; instead, the study protocol was posted at the study institutions to notify participants about the study. Only anonymous data were used in the statistical analyses. The inclusion criteria included the following: patients underwent the surgery performed by the same surgeon (M.T.); the presence of preoperative corneal astigmatism measured by keratometry exceeded −1.5 D; a target postoperative spherical refractive error of 0 D; absence of visually significant ocular diseases other than glaucoma and cataract; data included uncorrected visual acuity (UCVA), best-corrected VA (BCVA), refractive error for BCVA, IOP, number of glaucoma medications, and keratometric corneal astigmatism recorded preoperatively and 3 months (2 to 4 mo) postoperatively; no intraoperative complications; and postoperative decimal BCVA of 0.8 or better. If both eyes of a patient were eligible, the eye that initially underwent surgery was included. The BCVA measured using a decimal VA chart was converted to the logarithm of the minimum angle of resolution (logMAR) VA. The IOP was measured by Goldmann applanation tonometry. The keratometry was recorded at the central 3-mm diameter by autorefract-keratometry (TonoRef III, Nidek, Gamagori, Japan at Shimane University Hospital, and RC5000, Tomey, Nagoya, Japan at Matsue Red Cross Hospital).

**Surgical Procedure**

The surgical procedure was performed through 2 corneal side ports as reported previously (Video 1, Supplemental Digital Content 1, http://links.lww.com/IJG/A472). Before μLOT, phacoemulsification cataract surgery was performed through a 2.2-mm wide clear corneal incision created at the 9 to 10 o’clock position (ie, temporal incision for the right eye and nasal incision for the left eye); a 1-piece soft acrylic IOL (nontoric or toric) was inserted into the capsular bag through the same clear corneal incision. Spatula-shaped microhooks (M-221SS, 221SR, and 221SL, Inami, Tokyo, Japan) that had been designed specifically for use during μLOT then were used. Viscoelastic material (1% sodium hyaluronate, Healon, AMO Japan, Tokyo, Japan or 1% sodium hyaluronate, Opegan Hi, Santen Pharmaceutical, Osaka, Japan) was injected into the anterior chamber through the clear corneal ports created using a 20-gauge micro-vitreoretinal knife (Mani, Utsunomiya, Japan) at the 2 to 3 and 9 to 10 o’clock positions. A microhook was inserted into the anterior chamber through the corneal port using a Swan-Jacob goniprism lens (Ocular Instruments, Bellevue, WA) to observe the angle opposite to the corneal port. The microhook tip then was inserted into Schlemm’s canal and moved circumferentially to incise the inner wall of Schlemm’s canal and TM over 3 clock hours. Using the same procedure, LOT was performed in the opposite angle using a microhook inserted through the other corneal port. Accordingly, the LOT extended more than half of the circumference. In cases implanted with toric IOLs, the axes of the IOLs were aligned by referencing the positions of the episcleral/conjunctival vessels, the viscoelastic material was aspirated, and the corneal ports were closed by corneal stromal hydration. At the end of surgery, a steroid (2 mg of betamethasone sodium phosphate, Rinderone, Shionogi Pharmaceutical at Shimane University Hospital, and 1.65 mg of dexamethasone sodium phosphate, Decadron, Aspen Japan, Tokyo, Japan at Matsue Red Cross Hospital) was injected subconjunctivally and 0.3% ofloxacin ointment (Tarivid, Santen Pharmaceutical) was applied. Finally, 1.5% levofloxacin (Nipro, Osaka Japan) and 0.1% betamethasone (Sanbetason, Santen Pharmaceutical) were applied topically 4 times daily for 3 to 4 weeks postoperatively in all cases.

**Lens Power Calculation**

The IOL spherical power was calculated in all patients using Barrett’s formula using the refraction and axial length measured by OA2000 (Tomey, Nagoya, Japan), and the targeted refraction was emmetropia. Preoperatively, absence of remarkable irregular astigmatism was confirmed by using a corneal topography map of OA2000. In the toric IOL group, the IOL cylindrical power and alignment axis were calculated...

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**TABLE 1. Demographic Data, IOPs, and Medication Scores**

|                  | Nontoric | Toric | P   |
|------------------|----------|-------|-----|
| No. Eyes/subjects| 10/10    | 10/10 |     |
| Age (y)          |          |       |     |
| Mean ± SD        | 73.8 ± 6.6 | 71.4 ± 9.1 | 0.5697*  |
| 95% CI           | 69.0-78.6  | 64.9-77.9   |       |
| Sex, n (%)       |          |       |     |
| Male             | 5 (50)   | 4 (40) | 1.000†  |
| Female           | 5 (50)   | 6 (60) |       |
| Glaucoma type, n (%) |     |       |     |
| POAG             | 7 (70)   | 6 (60) |     |
| EXG              | 2 (20)   | 4 (40) |     |
| PACG             | 1 (10)   | 0 (0)  |     |
| Preoperative IOP (mm Hg) |     |       |     |
| Mean ± SD        | 15.8 ± 2.5 | 16.7 ± 5.1  | 0.8197*  |
| 95% CI           | 14.0-17.7  | 13.1-20.3   |       |
| Postoperative IOP (mm Hg) |     |       |     |
| Mean ± SD        | 12.4 ± 2.3 | 13.0 ± 2.8  | 0.7020*  |
| 95% CI           | 10.7-14.1  | 11.0-15.0   |       |
| Changes in IOP (mm Hg) |     |       |     |
| Mean ± SE        | −3.4 ± 0.9 | −3.7 ± 1.5  |       |
| 95% CI           | −5.5 to −1.3 | −7.2 to −0.2 |       |
| P‡               | 0.0039    | 0.0313 |     |
| Preoperative medications |     |       |     |
| Mean ± SD        | 3.0 ± 0.9  | 2.9 ± 1.1   | 0.8739*  |
| 95% CI           | 2.3-3.7    | 2.1-3.7     |       |
| Postoperative medications |     |       |     |
| Mean ± SD        | 2.4 ± 0.8  | 2.1 ± 0.7   | 0.3280†  |
| 95% CI           | 1.8-3.0    | 1.6-2.6     |       |
| Changes in medications |     |       |     |
| Mean ± SE        | −0.6 ± 0.2 | −0.8 ± 0.4  |       |
| 95% CI           | −1.1 to −0.1 | −1.6 to −0.0 |     |
| P values$        | 0.0625    | 0.1250 |     |

P-values are calculated between the nontoric and toric groups using the Mann-Whitney U test (*) for continuous variables and the Fisher exact probability test (†) for categorical variables. In the nontoric and toric groups, the P-values are calculated by Wilcoxon signed-rank test (!) between the preoperative and postoperative values. The postoperative values are collected 3 months postoperatively.

95% CI indicates 95% confidence interval; EXG, exfoliation glaucoma; IOP, intraocular pressure; PACG, primary angle-closure glaucoma; POAG, primary open-angle glaucoma.
Postoperative refractive astigmatism (D)
Change in refractive spherical error (D)
Postoperative refractive spherical error (D)
Preoperative refractive spherical error (D)
Change in BCVA (logMAR)
Preoperative BCVA (logMAR)
visual acuity.
logMAR, logarithm of the minimum angle of resolution; UCVA, uncorrected
The postoperative values are collected at 3 months postoperatively.

Sample Size Calculation
using a web-based toric IOL calculator (HOYA toric calcu-
lator, https://www.hoyatoric.com). Based on the information
provided by the manufacturer, the XY1AT3 (1 eye), XY1AT4
(3 eyes), XY1AT5 (2 eyes), XY1AT6 (1 eye), and XY1AT7 (3
eyes) toric IOLs were selected for use when the preoperative
corneal astigmatism levels were approximately 1.04, 1.56,
2.08, 2.60, and 3.12 D, respectively.

Sample Size Calculation
The main outcome measures were intergroup
(i.e., between the nontoric and toric groups) comparisons of the
UCVA and residual refractive astigmatism at postoperative
month 3. Because previous reports on the postoperative
refraction of the toric IOL models used in our study
were unavailable in the literature, we referred to the data
from another toric IOL model (i.e., AcrySof toric IOL,
Alcon Inc.).11,12 In a previous report that compared the
absolute residual refractive astigmatism after cataract surgery
between eyes implanted with the AcrySof toric and nontoric
IOLs in subjects with cataracts and preexisting corneal astig-
matism, the mean absolute residual refractive cylinder was
0.59 D after toric IOL implantation and 1.22 D after nontoric
IOL implantation.11 If the difference in the residual refractive
cylinder between the 2 groups was set at 0.33 D12 with a
significance level of 0.05 and a power of 0.8, an estimated sample
size of at least 6 eyes in each group was required to detect
significant differences between the 2 groups. Considering the
possibility of increasing the standard deviation, 10 eyes each
were enrolled in each group.

Analysis of Astigmatism Parameters
In addition to the arithmetic analyses of the astigmatism
magnitudes, the astigmatic data were analyzed using American
Society of Cataract and Refractive Surgery’s Astigmas-
tism Double Angle Plot Tool version 1.1.0 (https://ascrs.org/
tools/astigmatism-double-angle-plot-tool) based on the vector
analysis algorithm.13 Using this tool, the distributions of the
astigmatic data were analyzed using Amer-
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refraction of the toric IOL models used in our study
were unavailable in the literature, we referred to the data
from another toric IOL model (i.e., AcrySof toric IOL,
refractive astigmatism, and corneal astigmatism were calculated between preoperatively and postoperatively using the Wilcoxon signed-rank test. \( P < 0.05 \) was considered significant. All statistical analyses were performed using the JMP version 14.2 statistical software (SAS Institute Inc., Cary, NC).

**RESULTS**

Subject age, sex, glaucoma types, preoperative and postoperative IOPs, and medication scores were equivalent between the 2 groups (Table 1). The IOPs in both groups are significantly reduced postoperatively without changes in glaucoma medications (Table 1).

**FIGURE 1.** Double-angle plots for preoperative corneal and postoperative refractive astigmatism values in the nontoric (A) and toric (B) groups.
Preoperatively, the UCVA, BCVA, refractive spherical error, and refractive astigmatism were equivalent between the groups (Table 2). Postoperatively, the UCVA values (toric, 0.07 logMAR; nontoric, 0.33 logMAR; \( P = 0.0020 \)) were significantly better and the refractive astigmatism values (toric, −0.63 D; nontoric −1.53 D; \( P = 0.0110 \)) were significantly smaller in the toric group than the nontoric group (Table 2). Postoperative improvements in the UCVA (−0.58 logMAR; \( P = 0.0039 \)) and refractive astigmatism values (+1.45 D; \( P = 0.0195 \)) occurred in the toric group, while the UCVA (−0.19 logMAR; \( P = 0.1543 \)) and refractive astigmatism (+0.45 D; \( P = 0.2500 \)) were unchanged in the nontoric group (Table 2).

The preoperative and postoperative corneal astigmatism levels were equivalent between the groups; the arithmetic mean of the corneal astigmatism magnitude was unchanged postoperatively in both groups (Table 3). Vector analyses showed that the SIAs in both groups (nontoric, 0.62 D at 10 degrees; toric, 0.50 D at 113 degrees) did not differ markedly (Table 3). Double-angle plots for the preoperative corneal astigmatism and postoperative refractive astigmatism in both groups are shown in Figure 1. The preoperative centroid magnitudes in the toric group (0.47 D at 16 degrees) (Fig. 1B) and nontoric group (0.51 D at 155 degrees) (Fig. 1A) were equivalent. Postoperatively, the centroid magnitude in the toric group (0.23 D at 83 degrees) (Fig. 1B) was obviously smaller than in the nontoric group (1.03 D at 178 degrees) (Fig. 1A). Postoperatively, 70% of eyes in the toric group had refractive astigmatism of 1.0 D or less (Fig. 2B), while 10% of eyes in the nontoric group had refractive astigmatism of 1.0 D or less (Fig. 2A).

**DISCUSSION**

In the current subjects, the postoperative UCVA was significantly better in the toric group than the nontoric
group as a result of the lower refractive astigmatism in the former compared with the latter group, clearly indicating the efficacy of toric IOLs to correct preoperatively existing corneal astigmatism. This observation in a MIGS procedure is unique in the literature.

The SIA after µLOT did not differ greatly from that after microincisional cataract surgery (mean SIA magnitude, 0.42 D after a 1.8-mm incision coaxial phacoemulsification and 0.5 D after 1.7-mm incision bimanual phacoemulsification). Combined cataract extraction and use of a trabecular micro bypass stent, another MIGS procedure, have been reported to be refractively neutral. In contrast, toric IOLs were used in combination with limbal-relaxing incisions to manage corneal astigmatism in combined cataract and LEC because of large and unpredictable SIA. The reason for astigmatism induction after LEC remains unclear, but a couple of mechanisms have been postulated. A surgically induced gap around the scleral flap rather than the number of flap sutures, sinking of the corneal edge due to removal of tissue under the scleral flap, tissue contraction around the LEC site secondary to extensive scleral cautery, the subconjunctival wound-healing process, and corneal steepening provoked by the pressure of a large drainage bleb under the eyelid, and postoperative hypotony have been expected to be mechanisms of SIA after LEC. None of these is present in µLOT and recent gonio-bypass MIGS procedures; thus, we speculated that the astigmatism-correcting efficacy of toric IOLs also can work in MIGS procedures other than µLOT.

In the current patients, the IOP reduction was 22% in both groups in glaucomatous eyes with low preoperative IOP (15.8 mm Hg in nontoric and 16.7 mm Hg in toric groups); this coincided well with our previous study results in combined µLOT and cataract surgery, and suggested that use of toric IOLs did not affect the surgical efficacy of µLOT. The BCVA improved postoperatively in the toric group (−0.10 logMAR; P = 0.0391) and remained unchanged postoperatively in the nontoric group (−0.05 logMAR; P = 0.3750) (Table 2). Since the MIGS are the procedures for which eyes with early-to-moderate glaucoma are good candidates, and the efficacy of LOT was enhanced by the simultaneous cataract surgery, inclusion of eyes with relatively good preoperative BCVA (0.07 logMAR for nontoric and 0.09 logMAR for toric groups) and mild cataract (ie, visually insignificant cataract) explains the absence of a large improvement of BCVA in the current patients.

The limitations of the current study included the retrospective study design, analysis of the VA and refractive status at 1 postoperative time point, absence of the information regarding misalignment of toric IOL axis, and inclusion of various glaucoma types. Although we could not exclude the possibility that our observation may change if we assess patients at different time points, we believe that our study design was reasonable for comparing the visual outcomes between eyes implanted with toric and nontoric IOLs in the early postoperative period after combined MIGS and cataract surgery. Future studies are needed to confirm the long-term efficacy of toric IOL use in glaucoma eyes and roles of implanted toric IOL when eyes will be needed LEC.

In conclusion, use of toric IOLs is a reasonable option for better visual outcomes when the combined MIGS and cataract surgery are performed in eyes with corneal astigmatism.

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