Comparison of Surgically-induced Astigmatism after Combined Phacoemulsification and 23-Gauge Vitrectomy: 2.2-mm vs. 2.75-mm Cataract Surgery

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Purpose: The 2.2-mm microincision cataract surgery and small-gauge vitrectomy system is known to result in less surgically-induced astigmatism (SIA) in comparison to conventional surgical methods. We compared the amounts of SIA after combined phacoemulsification and 23-gauge transconjunctival sutureless vitrectomy (23G-TSV) using the 2.2-mm microincision and 2.75-mm standard incision methods.

Methods: We studied 59 patients (61 eyes) who underwent combined phacoemulsification and 23G-TSV from November 2008 to September 2012. Twenty-eight patients (28 eyes) underwent 2.2-mm microincision coaxial phacoemulsification, and 31 patients (33 eyes) underwent 2.75-mm standard incision phacoemulsification. SIA was evaluated using Naeser's polar method with the simulated keratometric values obtained from corneal topography. Preoperative and 1-week and 1-month postoperative KP (Naeser's polar value along the specific axis) and ΔKP values were compared between the 2.2-mm microincision and 2.75-mm standard incision groups.

Results: One week after surgery, both groups exhibited similar amounts of SIA (-ΔKP[120], 0.40 ± 0.41 vs. 0.51 ± 0.56 diopters [D]; p = 0.390). One month after surgery, however, the amount of SIA was significantly smaller in the 2.2-mm microincision group as compared to the 2.75-mm standard incision group (-ΔKP[120], 0.31 ± 0.54 vs. 0.56 ± 0.42 D; p = 0.045).

Conclusions: In combined phacoemulsification with 23G-TSV, 2.2-mm microincision coaxial phacoemulsification induces less SIA than does 2.75-mm standard coaxial phacoemulsification.

Key Words: Microincision, Phacoemulsification, Surgically-induced astigmatism, Transconjunctival sutureless vitrectomy

Owing to the development of new surgical tools and techniques, numerous ophthalmic surgeries can now be performed non-invasively. New small-gauge instruments are continually developed, and most retinal surgeries are now performed by transconjunctival sutureless vitrectomy (TSV) [1-3]. Cataract surgeries through small corneal incisions are also increasing in popularity [4,5]. Small-gauge TSV (23- or 25-gauge) requires a smaller incision and therefore involves less surgically-induced astigmatism (SIA) than does its 20-gauge counterpart [5-12]. Microincision coaxial cataract surgery requires a smaller incision than

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that required for standard coaxial cataract surgery, but does not carry the steep learning curve of the bimanual microincision technique [4,13]. However, it remains unknown whether microincision coaxial cataract surgery combined with vitrectomy will produce less SIA than does the standard coaxial cataract surgery combination. In this study, we compared 2.2-mm microincision coaxial cataract surgery and 2.75-mm standard coaxial cataract surgery, both in combination with 23-gauge transconjunctival sutureless vitrectomy (23G-TSV), with respect to the severity of SIA.

Materials and Methods

Patients

This retrospective study comprised 59 patients (61 eyes) who underwent combined phacoemulsification and 23G-TSV from November 2008 to September 2012 at the retina and vitreous disease referral center of Seoul National University Bundang Hospital. All operations were performed by a single surgeon (SJW). Twenty-eight patients (28 eyes) underwent 2.2-mm microincision coaxial phacoemulsification, and 31 patients (33 eyes) underwent 2.75-mm standard incision phacoemulsification. This study adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board of Seoul National University Bundang Hospital. Those patients with a history of corneal trauma or corneal disease (dystrophies, degenerations, infections, etc.) that might influence corneal topography were excluded from the study. Patients who underwent additional scleral buckling or cryotherapy and those who were not available for serial corneal topography were also excluded. Two patients, one from each group, required intraoperative sclerotomy site sutures for persistent leakage after cannula removal. No intraoperative or postoperative complications occurred. The patient demographic characteristics, preoperative diagnoses, and operative procedures are summarized in Table 1.

Surgical procedure

Preoperatively, the pupil was dilated with a topical combination of 0.5% tropicamide and 0.5% phenylephrine hydrochloride (Mydrin-P; Santen Pharmaceutical, Osaka, Japan). All surgeries were performed under local anesthesia using a sub-Tenon injection of 2 mL of 2% lidocaine. A clear corneal incision was made at 11 o'clock. For the 2.2-mm microincision surgery, the initial incision was made with a 2.2-mm double-blade corneal knife. A 2.75-mm double-blade corneal knife was used for the 2.75-mm standard incision surgery. An additional puncture for insertion of the second instrument was made using a super-sharp blade at the 2 o'clock position of the limbus. Sodium hyaluronate 1.0% (Healon; Abbott Laboratories, Abbott Park, IL, USA) was used to stabilize the anterior chamber and to protect the corneal endothelium during the surgery. A 5.5-mm continuous curvilinear capsulorhexis was performed using a 25-gauge needle and capsulorhexis forceps. Hydrodissection and hydrodelineation were performed with balanced salt solution. Phacoemulsification was performed using the Intrepid Infiniti system (Alcon Laboratories, Fort Worth, TX, USA). After phacoemulsification, the remnant cortical lens material was removed with a coaxial irrigation/aspiration tip. An acrylic foldable intraocular lens (IOL), either an Akreos MI60 (Bausch & Lomb, Rochester, NY, USA) or an AcrySof SN60WF (Alcon Laboratories), whichever was available at the time of the operation, was inserted into the capsular bag. The Akreos MI60 was inserted into the capsular bag using a Viscoject injector and Viscoglide cartridge system (Medicel AG, Widnau, Switzerland), while the AcrySof SN60WF was inserted into the capsular bag with a Monarch injector and C-cartridge system (Alcon Laboratories). Before vitrectomy, the corneal incision was sutured temporarily with a single stitch of 10-0 nylon to prevent eyeball collapse during the vitrectomy. Upon conclusion of the surgery, the 10-0 nylon sutures were removed according to standard clinical practice. No case required suturing of the corneal incision due to wound leakage.

Upon completion of the cataract surgery, 23G-TSV was performed using the Accurus vitrectomy system (Alcon Laboratories). A 23-gauge stiletto blade (45° angle; DORC, Zuidland, The Netherlands) was inserted at a 15° to 30° angle through the conjunctiva, sclera, and pars plana, 3.5 mm from the corneoscleral limbus, at the superotemporal, superonasal, and inferotemporal quadrants, respectively. A microcannula (DORC) was then inserted through the conjunctival incision and into the scleral tunnel using a specially designed blunt inserter. At the end of the operation, the cannulae were withdrawn from their scleral tunnels, and the conjunctiva was pushed laterally with a cotton wool applicator to seal the puncture site. If there was per-

Table 1. Patient demographic information, preoperative diagnoses, and operative procedures

	2.2-mm microincision group	2.75-mm standard incision group	p-value[*]
Demographics			
No. of eyes (patients)	28 (28)	33 (31)	-
Male : female	16 : 12	15 : 18	0.363
Age	63.6 ± 8.8	64.6 ± 7.7	0.616
Right : left	14 : 14	14 : 19	0.554
Preoperative diagnosis (%)			0.155
RRD, retinal tear	2 (7.1)	2 (6.1)	
Macular hole	1 (3.6)	8 (24.2)	
Idiopathic ERM	13 (46.4)	13 (39.4)	
PDR TRD, VH	7 (25.0)	9 (27.3)	
RVO VH	1 (3.6)	1 (3.0)	
AMD SRH, VH	3 (10.7)	0	
Asteroid hyalosis	1 (3.6)	0	
Operative procedures (%)			0.183
PE & PCL	28 (100)	33 (100)	
Membrane peeling, removal	17 (60.7)	26 (78.8)	
Endolaser	11 (39.3)	12 (36.4)	
Intravitreal gas (SF$_6$) injection	1 (3.6)	10 (30.3)	
Intravitreal bevacizumab injection	1 (3.6)	3 (9.1)	
Intravitreal SO injection	0	2 (6.1)	
Sutured sclerotomy wound (%)	1 (3.6)	1 (3.0)	>0.999

RRD = rhegmatogenous retinal detachment; ERM = epiretinal membrane; PDR = proliferative diabetic retinopathy; TRD = tractional retinal detachment; VH = vitreous hemorrhage; RVO = retinal vein occlusion; AMD = age-related macular degeneration; SRH = subretinal hemorrhage; PE & PCL = phacoemulsification and posterior chamber lens insertion; SF$_6$ = sulfur hexafluoride; SO = silicone oil.
[*]p-value from Student's t-test, chi-square test, or Fisher's exact test.

sistent leakage from the wound, the sclerotomy site was sutured with 8-0 vicryl. Postoperative treatment consisted of 0.5% levofloxacin (Cravit, Santen Pharmaceutical) and fluorometholone acetate 0.01% (Flarex, Alcon Laboratories) eye drops 4 times a day for 4 weeks.

Topographic and astigmatic evaluation

Corneal topography was performed using the Orbscan II system (Bausch & Lomb) before surgery and 1 week and 1 month after surgery. In this study, we evaluated astigmatism using the polar method proposed by Naeser [14], Naeser and Hjortdal [15], and Naeser et al. [16]. Any pair of polar values separated by an arc of 45° (e.g., KP[90] and KP[135], KP[120] and KP[165], etc.) indicates the presence of net astigmatism [17]. Because the main corneal incision was made at the 11 o'clock position (120° from the horizon-

tal baseline), we evaluated astigmatism using KP(120) and KP(165) as follows:

$$KP(120) = M\{\sin^2(\alpha - 30) - \cos^2(\alpha - 30)\}$$
$$KP(165) = M\{\sin^2(\alpha - 75) - \cos^2(\alpha - 75)\}$$

SIA expressed as $KP(120) = \Delta KP(120) = KP(120)_{postop} - KP(120)_{preop}$
SIA expressed as $KP(165) = \Delta KP(165) = KP(165)_{postop} - KP(165)_{preop}$

KP = Naeser's polar value along the specific axis
M = magnitude of the net astigmatism (diopters, D) taken from simulated keratometry (Sim K) values obtained from corneal topography
α = direction of the steepest meridian (degrees)
SIA = surgically-induced astigmatism

In this setting, a positive $\Delta KP(120)$ indicates a steepening of the meridian in which the incision was made, or

with-the-rule change. A negative $\Delta KP(120)$ indicates flattening of the meridian in which the incision was made, or against-the-rule change. A positive $\Delta KP(165)$ indicates induced anticlockwise torque, while a negative $\Delta KP(165)$ indicates induced clockwise torque [16].

Statistical analysis

SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Preoperative and postoperative Sim K astigmatism, KP(120) and KP(165), were compared using repeated-measures ANOVA. The ΔKP values were compared between the 2.2-mm microincision group and the

Table 2. Serial changes in Sim K astigmatism and KP values in the 2.2-mm microincision and 2.75-mm standard incision groups

	2.2-mm microincision group (n = 28)	2.75-mm standard incision group (n = 33)	p-value[*]
SimK astigmatism			
Preoperative	0.91 ± 0.66	0.70 ± 0.38	0.129
Postoperative (1 wk)	1.01 ± 0.73	1.00 ± 0.54	0.965
Postoperative (1 mon)	0.93 ± 0.59	0.89 ± 0.44	0.798
p-value[†]	0.493	0.009	
KP(120)			
Preoperative	0.21 ± 0.77	-0.03 ± 0.47	0.141
Postoperative (1 wk)	-0.19 ± 0.68	-0.54 ± 0.55	0.030
Postoperative (1 mon)	-0.10 ± 0.73	-0.59 ± 0.38	0.001
p-value[†]	<0.001	<0.001	
KP(165)			
Preoperative	-0.04 ± 0.81	-0.03 ± 0.66	0.991
Postoperative (1 wk)	-0.26 ± 1.01	-0.01 ± 0.85	0.308
Postoperative (1 mon)	-0.02 ± 0.83	-0.07 ± 0.71	0.807
p-value[†]	0.103	0.800	

Sim K = simulated keratometry.
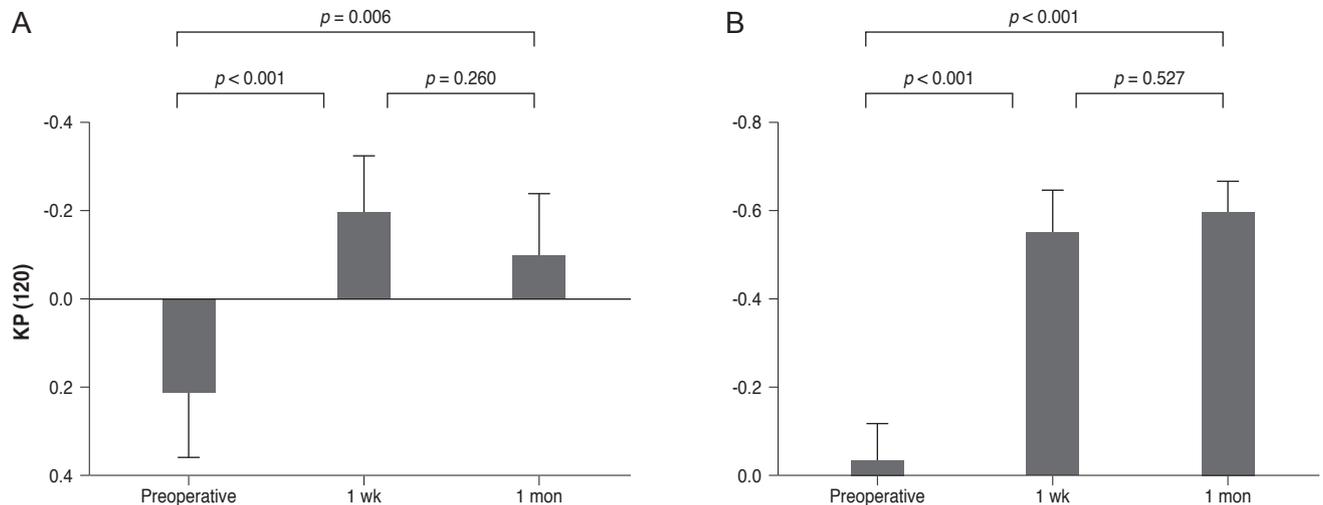[*]Student's t-test; [†]Repeated-measures ANOVA.

Fig. 1. Serial changes in KP(120) in the 2.2-mm microincision group (A, n = 28) and the 2.75-mm standard incision group (B, n = 33). A p-values was calculated using the paired t-test.

Table 3. Comparison of surgically-induced astigmatism in the 2.2-mm microincision group vs. the 2.75-mm standard incision group

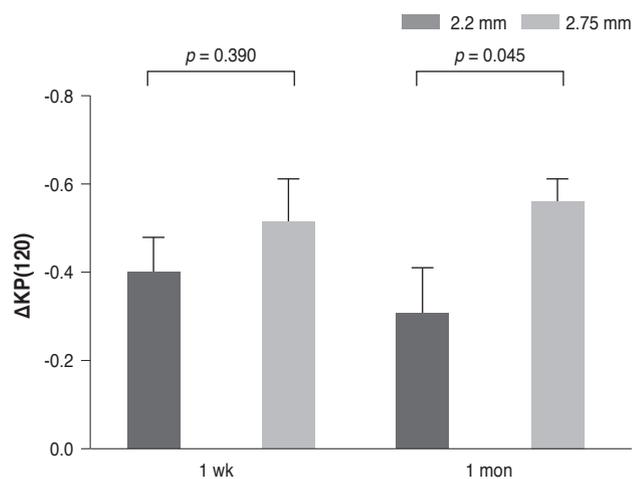|	2.2-mm microincision group (n = 28)	2.75-mm standard incision group (n = 33)	*p*-value[*]
ΔKP(120)			
Postoperative (1 wk)	-0.40 ± 0.41	-0.51 ± 0.56	0.390
Postoperative (1 mon)	-0.31 ± 0.54	-0.56 ± 0.42	0.045
ΔKP(165)			
Postoperative (1 wk)	-0.22 ± 0.55	0.02 ± 0.65	0.126
Postoperative (1 mon)	0.01 ± 0.48	-0.04 ± 0.55	0.705

[*]Student's *t*-test.

Fig. 2. Comparison of surgically-induced astigmatism (represented as ΔKP[120]) between the 2.2-mm microincision group and the 2.75-mm standard incision group. A *p*-values was calculated using Student's *t*-test.

2.75-mm standard incision group using Student's *t*-test. A *p*-value less than 0.05 was considered statistically significant.

Results

The 2.2-mm microincision group showed no significant serial changes related to Sim K astigmatism ($p = 0.493$), while the 2.75-mm standard incision group did show significant changes ($p = 0.009$) (Table 2). However, both groups showed significant changes ($p < 0.001$ for both) when we evaluated serial astigmatic changes using KP(120) (Table 2 and Fig. 1). Both groups showed similar negative changes in KP(120) 1 week after surgery (ΔKP[120], -0.40 ± 0.41 for 2.2 mm vs. -0.51 ± 0.56 for 2.75 mm; $p = 0.390$) (Table 3 and Fig. 2). However, 1 month after surgery, the amount of SIA had decreased in the 2.2-mm microincision group (ΔKP[120] = -0.31 ± 0.54), but had not changed in the 2.75-mm standard incision group (ΔKP[120] = -0.56 ± 0.42). The SIA values 1 month after surgery differed significantly between the two groups ($p = 0.045$) (Table 3 and Fig. 2). There was no significant induced torque along the surgical meridian (ΔKP[165]) in either group (Table 3). There were no significant differences in postoperative intraocular pressure (IOP) when the 2.2-mm microincision group was compared to the 2.75-mm standard incision group, or when the intraocular tamponade group was compared to the non-tamponade group (Table 4).

Discussion

In this study, we compared SIA between 2.2-mm-microincision and 2.75-mm standard incision coaxial phacoemulsification combined with 23G-TSV. Stabilization of the corneal curvature and astigmatic and refractive changes after cataract surgery have been reported to be complete by two weeks after surgery when the incision size is <3.0 mm [18,19]. We evaluated astigmatic changes one week and one month after surgery to identify early postoperative astigmatic changes and serial changes in corneal astigmatism.

Both groups showed similar negative changes in KP(120) one week after surgery, with no significant difference in ΔKP(120) between the groups at this time. This means that both groups showed flattening of the cornea along the incision site to a degree that did not differ significantly between the groups. However, after one month, the difference in SIA expressed as ΔKP(120) between groups increased significantly. The measurements obtained one-month postoperatively therefore suggest that the 2.2-mm microincision surgery induced less SIA than the 2.75-mm standard incision surgery.

Table 4. Comparison of preoperative and postoperative IOP changes (mmHg)

	2.2-mm microincision group (n = 28)	2.75-mm standard incision group (n = 33)	*p*-value*	Gas or silicone oil tamponade (n = 13)	No tamponade (n = 48)	*p*-value†
Preoperative	12.2 ± 3.0	12.2 ± 2.7	0.996	11.3 ± 2.1	12.4 ± 2.9	0.231
Postoperative (1 wk)	12.1 ± 3.7	11.6 ± 3.4	0.542	10.9 ± 3.5	12.1 ± 3.6	0.264
Postoperative (1 mon)	11.3 ± 3.0	12.4 ± 3.3	0.165	11.2 ± 2.9	12.1 ± 3.3	0.477
ΔIOP (1 wk − preoperative)	-0.1 ± 4.0	-0.6 ± 3.1	0.540	-0.5 ± 2.9	-0.4 ± 3.7	0.852
ΔIOP (1 mo − preoperative)	-0.9 ± 3.4	0.2 ± 3.0	0.168	-0.2 ± 2.0	-0.3 ± 3.5	0.775
ΔIOP (1 mo − 1 wk)	-0.8 ± 4.0	0.9 ± 3.0	0.066	0.3 ± 2.9	0.04 ± 3.8	0.783

IOP = intraocular pressure.
*Student's *t*-test; †Mann-Whitney *U*-test.

Table 5. Summary of previous studies comparing surgically-induced astigmatism after cataract surgeries with different incision sizes

Researcher	Methods*	Results†
Kim et al. (2011) [12]	1.8-mm vs. 2.2-mm vs. 2.75-mm	2 mon
		1.8-mm (0.21 D) ≈ 2.2-mm (0.29 D) < 2.75-mm (0.44 D)
Can et al. (2010) [13]	1.2 to 1.4-mm (biaxial) vs. 2.2-mm vs. 2.8-mm	90 day
		1.2 to 1.4-mm (biaxial) (0.13 D) < 2.2-mm (0.24 D) < 2.8-mm (0.46 D)
Wang et al. (2009) [9]	2.2-mm vs. 2.6-mm vs. 3.0-mm	30 day
		2.2-mm (0.5 D) ≈ 2.6-mm (0.6 D) < 3.0-mm (0.9 D)
		90 days
		2.2-mm (0.4 D) ≈ 2.6-mm (0.5 D) < 3.0-mm (0.6 D)
Masket et al. (2009) [10]	2.2-mm vs. 3.0-mm intra-patient control	6 wk
		2.2-mm (0.35 D) < 3.0-mm (0.67 D)

D = diopter.
*Corneal incision sizes are shown here; those without parentheses were all performed using the coaxial technique; †The symbol ≈ denotes a statistically insignificant difference and < denotes a statistically significant difference. The numbers in the parentheses are mean surgically-induced astigmatism represented in D.

The KP(165) value did not change significantly in either group, which means that no significant torque was induced. Although we studied cases with combined cataract and vitrectomy surgery, our result is comparable to those of previous studies on the effect of incision size on SIA after cataract surgery. We summarized the results of such previous studies in Table 5. Most of the studies measured astigmatic changes 1 to 3 months after surgery and showed a trend of decreasing SIA as the size of the corneal incision decreased. Furthermore, SIA as measured 1 to 3 months after surgery differed significantly between patients treated with 2.2-mm versus ≥2.75-mm incisions. In our study, the SIA one month after surgery was significantly smaller in the 2.2-mm microincision group as compared to the 2.75-mm standard incision group. Therefore, the advantage of small-incision cataract surgery in terms of reducing SIA remains valid for the combination cataract and 23G-TSV surgery.

We speculate that the combined vitrectomy surgery did not greatly influence the overall SIA patterns associated with corneal incision size due to the use of small-gauge sclerotomies without sutures. In previous studies comparing SIA between 23-gauge and 20-gauge vitrectomy combined with 2.2-mm microincision cataract surgery, the 20-gauge group showed significantly larger SIA at all postoperative times from 1 week through 12 weeks [20]. Although scleral incisions and sutures have less influence on corneal astigmatism in comparison to corneal incisions, vitrectomy alone induced astigmatism of approximately 3.0 D with a maximum change of almost 9.0 D during the first postoperative week [21]. This means that we cannot guarantee results similar to those of our present study in the setting of 20-gauge vitrectomy.

Our study was limited by its small size, retrospective design, and short follow-up periods, as well as our inability to match the two groups fully with respect to their preoperative diagnoses and operative procedures. The numbers of patients who underwent intravitreal gas injection differed significantly. However, we used sulfur hexafluoride (SF_6) gas, which is retained in the eye for only a short period (less than two weeks). Among patients who underwent microincision cataract surgery and 23G-TSV, SIA one week after surgery was significantly larger in the gas tamponade group than in the non-gas tamponade group. However, this difference was diminished and statistically insignificant four weeks after surgery [20]. There were also no significant differences between the gas tamponade group and the non-gas tamponade group in the magnitude of IOP changes after surgery (Table 4). We therefore believe that the gas tamponade procedure did not affect our results significantly. Furthermore, the follow-up period of one month was relatively short. Although we found significantly less SIA in the 2.2-mm microincision group as compared to the 2.75-mm standard incision group after one month, the degree of astigmatism varied significantly from that observed preoperatively. In the 2.2-mm microincision group, SIA decreased at 1 month as compared to the SIA at 1 week, but this difference was not significant. Further study is needed to demonstrate the slow progression of any astigmatic changes in patients who have undergone 2.2-mm microincision surgery.

SIA was even less pronounced after biaxial microincision surgery, which can be performed using an even smaller incision (1.2 to 1.4 mm) [13]. This implies that further reduction of the incision size would further decrease SIA. However, biaxial microincision surgery has some disadvantages, including a longer surgery, a steep learning curve, and poor corneal wound integrity [13,22]. Microincision coaxial phacoemulsification has advantages over other methods in this regard.

In conclusion, 2.2-mm microincision coaxial cataract surgery produced less SIA than did 2.75-mm standard coaxial cataract surgery in cases of combined phacoemulsification and 23G-TSV surgery. The combination of 23G-TSV and microincision cataract surgery, two less invasive surgeries that require smaller incisions, improved patients' chances of successful visual rehabilitation.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgements

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