

Effect of cataract incision type on corneal spherical aberration

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Abstract

Corneal spherical aberration (CSA) plays an important role in the ocular refractive system. However, ophthalmologists have not considered the effect of difference cataract incisions on it. The purpose of this study is to investigate the effect of transparent corneal incision (TCI) and scleral tunnel incision (STI) on CSA after the cataract phacoemulsification with foldable IOLs. One hundred ninety-three eyes (61 males and 79 females) for 1-month observation and 114 eyes (29 males and 51 females) for 3-month observation with age-related cataracts (ARC) were included in this study. CSA was measured with dilated pupil by Pentacam Scheimpflug system at 1 day preoperative and 1, 3-month postoperative. Preoperative CSA >1.00 μm was excluded. Both TCI and STI are 3mm incisions with Infiniti system and Ozil handpiece. No significant difference of age or gender was found between TCI and STI groups in 1 or 3-month observation. In 1-month observation, preoperative CSA for TCI and STI are 0.31 ± 0.29 and 0.41 ± 0.19 μm , which of postoperative are 0.42 ± 0.17 and 0.44 ± 0.35 μm , respectively. The change of CSA is 0.11 ± 0.32 and 0.04 ± 0.33 μm ($P = .233$). For 3-month observation, preoperative CSA for TCI and STI are 0.32 ± 0.28 and 0.36 ± 0.23 μm , which of postoperative are 0.43 ± 0.16 and 0.39 ± 0.26 μm , respectively. The change of CSA is 0.10 ± 0.34 and 0.03 ± 0.21 μm ($P = .312$). For the phacoemulsification combined with foldable IOL implantation, STI has minimal effect on CSA, but TCI might increase postoperative CSA.

Abbreviations: CSA = corneal spherical aberration, IOL = intraocular lens, IOP = Intraocular pressure, SA = spherical aberration, STI = scleral tunnel incision, TCI = transparent corneal incision, UCVA = Uncorrected visual acuity, VA = visual acuity.

Keywords: cataract operation, corneal spherical aberration, scleral tunnel incision, transparent corneal incision

1. Introduction

As the only treatment of cataract, cataract extraction and intraocular lens (IOL) implantation could improve the postoperative visual acuity (VA), which is decided by the aberration of ocular refractive system mainly. Spherical aberration (SA) (Z4(0)) plays a major role in this system beside the low-order aberration, so the ophthalmologists keep working on the elimination its bad effect for those cataract patients. Over the past years, new IOL designs, such as aspheric IOL, which introduce a negative or zero SA to the ocular system and compensate the positive SA of cornea by replace the crystalline lens, have resulted in marked advances in cataract surgery.^[1] The previous studies of aspheric IOLs had reported the reduction in SA, and indicated that it provided better contrast sensitivity compared to various spherical IOLs.^[2-8] However, there were some recent trials showing no

significant advantages in terms of subjective visual function.^[9-11] And more work still needed to figure the effect of SA.

The types of incision in cataract surgeries had been researched for the effects of postoperative astigmatism and infection, and so on. Even the corneal SA (CSA) play a major role in the ocular system, ophthalmologists have not considered the effect of difference cataract incisions on it. Our study compared the effects of transparent corneal incision (TCI) and scleral tunnel incision (STI) on the CSA of age-related cataract (ARC) surgeries.

2. Methods

2.1. Subjects

This retrospective study was conducted in Peking University People's Hospital, Beijing, China. The study was approved by the

XL, XC, and X-RH contributed equally to this work and are co-first authors.

How to cite this article: Li X, Cao X, Hou X-R, Yuan L, Yu Y-Y, Bao Y-Z. Effect of cataract incision type on corneal spherical aberration. *Medicine* 2022;101:35(e30292).

This work was supported by the National Natural Science Foundation of China (NSFC, No. 21173012) and National Key R&D Program of China, No. 2020YFC2008200.

Written informed consent was obtained from all patients.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are publicly available.

The study was in accordance with the tenets of the Declaration of Helsinki and has been approved by the institutional review board of Peking University People's Hospital.

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Received: 21 March 2021 / Received in final form: 14 July 2022 / Accepted: 18 July 2022

<http://dx.doi.org/10.1097/MD.000000000030292>

local ethical review boards in accordance with the Declaration of Helsinki, and all patients provided written informed consent.

One hundred ninety-three eyes (61 males and 79 females, aged 41–90 years) for 1-month observation and 114 eyes (29 males and 51 females, aged 41–91 years) for 3-month observation with ARCs were included in this study. Inclusion criteria: patients with significant ARC. Exclusion criteria: axial length longer than 26.00 mm, previous intraocular surgery, previous corneal refractive surgery, ocular trauma, corneal degeneration and dystrophy, optic nerve disease, macular or retinal disease, shallow anterior chamber, glaucoma, systemic disease (e.g., diabetes or vascular pathology), operative complications (e.g., capsular rupture, vitreous loss, IOLs not in bag, sulcus fixation), and the absolute value of preoperative CSA >1.00 μm .

2.2. Clinical observations

Preoperative clinical examination was performed by slit-lamp microscopy, indirect ophthalmoscopy, and uncorrected visual acuity (UCVA) logMAR were tested. Intraocular pressure (IOP), corneal endothelium counting, axial length, corneal topography and CSA were also measured. IOP was measured by Goldmann applanation tonometer, corneal endothelium counting with Konan Specular Microscope Xiii (nsp-9900II, KONAN MEDICAL, INC., Hyogo, Japan); axial length was measured with IOLMaster (Carl Zeiss Meditec, AG., Jena, Germany) and A/B-scan ultrasound (ODM-2100, MEDA Co., Ltd. Tianjin, China). Corneal topography and CSA were measured using the Pentacam anterior segment measurement and analysis system (Oculus, Germany). Pentacam system and indirect ophthalmoscopy were performed after the pupils were dilated fully with Tropicamide Phenylephrine Eye Drops (Santen Pharmaceutical Co., Ltd. Osaka, Japan) in the same dark room as lamp-off, closed windows with stucked opaque black papers.

All procedures were performed by experienced surgeons using topical anesthesia (Benoxil, Oxybuprocaine Hydrochloride Eye Drops, Santen Pharmaceutical Co., Ltd. Osaka, Japan) with the Alcon Infiniti Vision System (Alcon Laboratories, Inc., Fort Worth, Texas) at Peking University People's Hospital from December 2012 to September 2013. No surgical complications were reported. A 3.0 mm clear corneal incision for TCI or STI for STI was made firstly. After introduction of medical sodium hyaluronate gel (Shanghai Jianhua Fine Biological Products Co., Ltd, China) into the anterior chamber, a 1.0 mm side clear corneal puncture and a 5.5 mm capsulorhexis were made, followed by hydrodissection, phaco-chop technique phacoemulsification using an Ozil handpiece (Alcon Laboratories, Inc., Fort Worth, TX), aspiration of cortical masses, anterior and posterior capsular polish, and implantation of foldable IOLs. After removal of sodium hyaluronate, the wound was closed with hydration.

Postoperative evaluations were performed at 1 day, 1 week, 1 month, and 3 months. UCVA, slit-lamp examination, indirect ophthalmoscopy, and IOP were done at all visits. VA was measured using the Early Treatment Diabetic Retinopathy Study

charts under photopic conditions. CSA measurements were obtained after the pupils were dilated fully with Tropicamide Phenylephrine Eye Drops (Santen Pharmaceutical Co., Ltd. Osaka, Japan) by Pentacam system before and 1 and three months after surgery.

2.3. Statistical analysis

Statistical analysis was performed with SPSS 20.0 (SPSS Inc., Chicago, Illinois), and P -values <.05 were considered to indicate a significant difference. All variables in each group were tested for normality (Kolmogorov–Smirnov 1 sample test) and homogeneity of variances (Levene test) for parametric test. Independent t tests were used to compare variables between 2 groups. Mann–Whitney U tests were used to analyze the few data that did not meet parametric criteria. The Chi-square test was used for gender data.

3. Results

3.1. General conditions

There was no statistical significance ($P > .05$) between the number of eyes in the TCI and STI groups, the gender or age of the patients (Table 1) for 1 and 3-month observations. The intraocular lenses in all of the patients were positioned normally at follow-up. No significant opacity was observed in the posterior capsule of the lens in the postoperative follow-up, and postoperative complications were not found.

3.2. Pre- and postoperative parameters of cornea

There was no statistical significance ($P > .05$) of flat and steep K , axis of flat K , K average, corneal endothelium counting and corneal pachy at the day before cataract surgeries between TCI and STI groups for either 1 or 3-month observation as Table 2 show.

Similarly, as Table 3 shown, at the 1 and 3-month follow-up, the statistical significance of flat and steep K , axis of flat K , K average, and corneal pachy was either not found between TCI and STI groups.

3.3. Effects of different cataract incision on the cornea and CSA

At the 1-month follow-up, STI made smaller changes on flat and steep K , and K average than TCI as Table 4 shown, statistical significance was found for flat K and K average. Although postoperative and difference of CSA showed no statistical significance for these 2 groups, the statistical significant difference of preoperative CSA might indicate STI had made no effect (0.41 ± 0.19 to $0.44 \pm 0.35 \mu\text{m}$) on CSA as while TCI might make a positive increase of it (0.31 ± 0.29 to $0.42 \pm 0.17 \mu\text{m}$). Even there no statistical significant difference, STI might make milder effect than TCI on CSA (0.04 ± 0.33 and $0.11 \pm 0.32 \mu\text{m}$, respectively).

Table 1

Age-related cataract patients in TCI and STI groups for 1 and 3-month observation.

Parameters	One month observation				Three months observation			
	Total number of eyes (n)	Gender		Age (years)	Total number of eyes (n)	Gender		Age (years)
		Males	Females			Males	Females	
TCI	38	13	25	70.68 \pm 8.98	29	9	20	69.38 \pm 8.89
STI	155	68	87	70.59 \pm 9.13	85	31	54	70.34 \pm 9.87
t			1.169*	−0.053			0.281*	0.464
P			.280	.958			.596	.644

STI = scleral tunnel incision, TCI = transparent corneal incision.

* The χ^2 value.

Table 2
The preoperative parameters of cornea in TCI and STI groups for 1 and 3-month observation.

	One month observation				Three months observation			
	TCI	STI	t	P	TCI	STI	t	P
Preoperative flat K (D)	44.49 ± 1.73	44.25 ± 1.48	-0.863	.389	44.362 ± 1.572	44.593 ± 1.412	0.739	.462
Preoperative steep K (D)	45.38 ± 1.75	45.03 ± 1.44	-1.301	.195	45.352 ± 1.494	45.338 ± 1.696	0.042	.967
Preoperative axis of flat K (°)	89.54 ± 53.85	86.99 ± 52.17	-0.268	.789	99.686 ± 50.423	89.299 ± 56.545	-0.877	.382
Preoperative K average (D)	44.93 ± 1.68	44.64 ± 1.44	-1.100	.273	44.850 ± 1.558	44.972 ± 1.428	0.389	.698
preoperative corneal endothelium counting (numbers/mm ²)	2568.29 ± 318.48	2503.04 ± 455.44	-0.722	.471	2548.27 ± 334.19	2536.11 ± 364.48	-0.140	.889
Preoperative thickness of central cornea (um)	555.04 ± 26.42	556.87 ± 31.09	0.283	.778	556.870 ± 29.431	545.456 ± 31.554	-1.524	.131
Preoperative thickness of thinnest cornea (um)	544.79 ± 29.41	542.77 ± 30.56	-0.367	.714	546.276 ± 26.652	534.976 ± 29.629	-1.817	.072

STI = scleral tunnel incision, TCI = transparent corneal incision.

Table 3
The postoperative parameters of cornea in TCI and STI groups for 1 and three-month observation.

	One month observation				Three months observation			
	TCI	STI	t	P	TCI	STI	t	P
Postoperative flat K (D)	44.24 ± 1.67	44.24 ± 1.46	0.009	.993	44.117 ± 1.705	44.306 ± 1.594	0.541	.590
Postoperative steep K (D)	45.14 ± 1.45	45.05 ± 1.46	-0.344	.731	44.893 ± 1.488	45.232 ± 1.415	1.099	.274
Postoperative axis of flat K (°)	108.84 ± 42.05	99.23 ± 50.69	-1.080	.281	104.259 ± 40.172	103.626 ± 48.086	-0.064	.949
Postoperative K average (D)	44.69 ± 1.54	44.64 ± 1.44	-0.168	.867	44.505 ± 1.570	44.769 ± 1.426	0.838	.404
Postoperative thickness of central cornea (um)	557.03 ± 52.92	551.09 ± 30.64	-0.881	.380	551.929 ± 31.576	545.638 ± 49.834	-0.624	.534
Postoperative thickness of thinnest cornea (um)	537.29 ± 37.22	539.20 ± 32.63	0.314	.754	539.897 ± 33.694	521.094 ± 48.000	-1.949	.054

STI = scleral tunnel incision, TCI = transparent corneal incision.

Table 4
The different effect of TCI and STI on cornea for age-related cataract patients.

	One month observation				Three months observation			
	TCI	STI	t	P	TCI	STI	t	P
Difference of flat K (D)	-0.25 ± 0.63	-0.01 ± 0.48	2.199	.033	-0.24 ± 0.57	-0.29 ± 1.06	-0.204	.839
Difference of steep K (D)	-0.25 ± 0.93	0.02 ± 0.43	1.695	.098	-0.44 ± 1.08	-0.12 ± 0.54	1.560	.128
Difference of axis of flat K (°)	19.29 ± 69.99	12.24 ± 56.11	-0.578	.566	4.57 ± 70.70	14.33 ± 60.78	0.715	.476
Difference of K average (D)	-0.25 ± 0.72	0.00 ± 0.39	2.089	.043	-0.34 ± 0.77	-0.20 ± 0.69	0.926	.357
Preoperative corneal SA (um)	0.31 ± 0.29*	0.41 ± 0.19	2.030	.048	0.32 ± 0.28†	0.36 ± 0.23	0.597	.552
Postoperative corneal SA (um)	0.42 ± 0.17*	0.44 ± 0.35	0.503	.616	0.43 ± 0.16†	0.39 ± 0.26	-0.713	.477
Difference of corneal SA (um)	0.11 ± 0.32	0.04 ± 0.33	-1.196	.233	0.10 ± 0.34	0.03 ± 0.21	-1.025	.312

STI = scleral tunnel incision, TCI = transparent corneal incision.

*Paired t test for pre- and postoperative corneal SA, t = 2.081, P = .044.

†Paired t test for pre- and postoperative corneal SA, t = 1.604, P = .120.

For the 3-month observation, there was no statistical significance in the difference of flat and steep K, axis of flat K and K average; however, TCI might induce a decreasing of steep K and K average, which relatively obvious than STI. As similar with the result of 1-month observation, even there no statistical significant difference, STI might make milder effect than TCI on CSA (0.03 ± 0.21 and 0.10 ± 0.34 um, respectively) (Table 4).

4. Discussion

Wave-front aberrations, especially SA, now are well-accepted as important factors on visual quality.^[12,13] Targeting plano postoperative refraction is not the only aim that refractive/ataract surgeons are looking for, furthermore adjustment of higher order aberrations and their effect on visual performance are well appreciated.^[14] Ocular SA is composed of CSA, which is usually positive, and intraocular SA, which mainly come from the lens and always neutralize CSA in young ages.^[15] Aspheric IOLs designed with 0 or negative SA can reduce or eliminate CSA after removal of the crystalline lenses.^[16] According to Dick, aspheric IOLs offer improved functional vision to patients, but

may need to be better targeted to accommodate the large range of CSA.^[17] Today, customized aspheric IOL implantations have been widely used, with CSA measured before surgery in many hospitals. However, cataract surgeons do not pay attention to the incision, which may have influence on the cornea, the main ocular SA source after the removal of crystalline lenses.

This study was intended to determine the change of CSA induced by TCI and STI, the 2 predominantly incision for cataract surgeries, and compare the difference of these 2 incision on CSA.

In a recent study, CSA of the fourth order ranged from -0.31 to 0.799 um.^[18] Wang et al,^[19] and Shimozone,^[20] also found individual variability in CSA, that ranged from + 0.069 to + 0.511 and -0.103 to + 0.497 um, respectively, with a mean value of 0.204 ± 0.10 um in Shimozone study. As another study reported corneal variable 0.148 ± 0.046 to 0.316 ± 0.021 um for the southern Chinese.^[21] In the current study, we found the preoperative CSA was 0.31 ± 0.29 to 0.41 ± 0.19 um, which is bigger than those previous studies, but kept consistent with a prior finding.^[22] Even still to be a dispute, more studies reported CSA increased with aging.^[22-28] That might be 1 of major reasons

for the difference between our study and the previous studies. Another major reason was CSA measurement performed with dilated pupils for our all patients. Other possible reasons included the difference of region, race, instruments, and so on.^[29,30]

One previous study reported the effect of TCI and STI on the ocular aberrations, a STI with unfoldable PMMA IOL implanted group had the least changes of ocular aberrations and a TCI with foldable IOL implanted group had the most, especially spherical and tetrafoil aberrations, with 6.0 mm pupils. And the difference would disappear with 3.5 mm pupils.^[31] Our study showed the differences of 1 and 3-month observations in TCI group, which was statistical significance for 1 month observation. It was not consistent with some previous studies, which reported CSA did not change significantly in 2.2 to 3.5 mm TCI.^[21,32–34] Moreover, there also had some studies reported the size of TCI could induce the differences of corneal aberrations, not included SA.^[35,36] As the increasing of the mean corneal radius at the vertex and the shape parameter would induced the increasing of CSA,^[37] the difference of pre- and postoperative CSA in our study might induced by the change of corneal curvature as Table 4. It might also due to the change of corneal astigmatism and asphericity.^[38,39] However, more powerful explanation is still need to be explored. Even without statistical significance, our study showed similar difference between TCI and STI groups both in 1 and 3-month observation. It might become from the destabilization of corneal structure and biomechanics as STI has minimal effect on the cornea compared with TCI. Because a 1.0 mm side clear corneal puncture was also made as a necessary operation step, CSA still had slightly increase of STI group both in 1 and 3-month observation.

As the diameter of pupil might disturb the measurement of SA, we unified the measurement with dilated pupil fully. It might be different with the physical condition for the postcataract patients. That is a limitation of our study. In the further study, we need to find a new way or a new method to measure SA under the physical condition with unified conditions.

In summary, the results of our study suggest that there is a trend of increased CSA in cataract operations with TCI, as while the STI has a minimal effect on the CSA. It indicates that cataract surgeons may take the effect of incision into account when choosing variable aspheric IOLs.

Author contributions

Xiaochun Li, Xiaoguang Cao and Xianru Hou wrote the main manuscript text, and Li Yuan and Yingying Yu provided the part of data, and Yongzhen Bao supervised the protocol. All authors reviewed the manuscript.

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