ARTICLE

Comparison of refractive and keratometric astigmatism after microincision cataract surgery

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Purpose: To measure the correlation between refractive and keratometric astigmatism after microincision cataract surgery (MICS).

Setting: Takayanagi Clinic, Kushiro, Hokkaido, Japan.

Design: Retrospective case series.

Methods: This study evaluated patients having phacoemulsification and intraocular lens implantation through a 2.0 mm temporal clear corneal incision. Refractive astigmatism and keratometric astigmatism were described by Jackson cross-cylinder with-the-rule (J0) and oblique (J45) components and compared using linear regression analysis.

Results: The study comprised 90 eyes of 54 patients. The mean postoperative refractive J0 was −0.29 diopter (D) ± 0.46 (SD), and the mean postoperative refractive J45 was −0.09 ± 0.24 D. The multivariate model for the J0 component was postoperative J0 = 0.75 × keratometric J0 + 0.21 × preoperative J0 − 0.23 (R^2 = 0.85, P < .001). The coefficient of determination of the multivariate model was higher than that of the univariate model (R^2 = 0.82). The regression equation for the J45 component was postoperative J45 = 0.85 × keratometric J45 − 0.03 (R^2 = 0.70, P < .001).

Conclusion: Refractive astigmatism and keratometric astigmatism after MICS were strongly correlated.

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It is widely accepted that there is a linear statistical relationship between refractive astigmatism and keratometric astigmatism. Javal first postulated this relationship in 1890.[1] Subsequently, several authors have revised and improved the Javal rule.[2,3]

The traditional thinking about pseudophakic eyes is that postoperative keratometry (K) values alone determine the postoperative refractive astigmatism because any difference between the preoperative K reading and refractive astigmatism reflects lenticular astigmatism, which is eliminated by cataract surgery. Toric intraocular lens (IOL) guidelines state, "To avoid any potential influence of lenticular astigmatism, the keratometric reading, rather than the refraction, should guide the selection of the toric power and axis."[4] However, some studies show that not all differences in astigmatism are the result of lenticular astigmatism. To indicate that there are astigmatic elements beyond the corneal surface, Holladay et al.[5] and Alpins[6] used the terms *intraocular astigmatism* and *ocular residual astigmatism* (ORA), respectively. Accordingly, refractive astigmatism might contain independent information about the cornea that is not reflected in routine K measurements.

The many advances in cataract surgery technology have reduced the incision size to 2.0 mm or smaller. Cataract surgery through these incisions is called microincision cataract surgery (MICS). Microincision cataract surgery induces significantly less corneal astigmatism and corneal shape changes than cataract surgery using larger incisions.[7] Thus, MICS is the most suitable cataract surgery technique to evaluate postoperative astigmatism.

The purpose of our study was to measure the correlation between refractive astigmatism and keratometric astigmatism after MICS to test the accepted hypothesis that refractive astigmatism in the pseudophakic eye is virtually identical to keratometric astigmatism. To our knowledge, this study is the first to determine the correlation after MICS.

PATIENTS AND METHODS

This study was performed in accordance with the tenets of the Declaration of Helsinki and was approved by the clinic's institutional review board, which decided that written informed consent from the patients was not required because of the retrospective nature of the study. Data were collected retrospectively from patients who had phacoemulsification and implantation of an IOL (Acrysof IQ SN60WF, Alcon Laboratories, Inc.) between October 2015 and September 2016 at Takayanagi Clinic, Kushiro,

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Hokkaido, Japan. The exclusion criteria were irregular corneal astigmatism, congenital eye abnormality, glaucoma, uveitis, previous corneal or retinal disease, previous ocular surgery, a history of eye trauma, and perioperative or postoperative complications.

All patients had a preoperative evaluation including refraction, visual acuity, and slitlamp and dilated funduscopic examinations. Keratometry measurements were performed with a keratometer (ARK-530A, Nidek Co., Ltd.). Preoperative IOL calculations were performed on the basis of IOLMaster biometry (Carl Zeiss Meditec AG) and the keratometry measurements. The IOL powers were calculated by the SRK/T formula.[8]

The same surgeon (A.K.) performed all cataract surgeries using topical anesthesia of lidocaine hydrochloride 4.0%. Coaxial micro-incision phacoemulsification was performed through a 2.0 mm temporal clear corneal incision on the horizontal meridian. A side-port incision created with the left hand in a forearm position comfortable for a right-handed surgeon. Next, the IOL was inserted into the capsular bag through an unenlarged incision using an incision-assisted technique. The ophthalmic viscosurgical device was removed, and all incisions were hydrated to aid closure of the incision. No eye required sutures.

Postoperative examinations and follow-ups were performed at 1 day, 1 week, 1 month, and 2 months. The postoperative refraction and visual acuity were measured at 2 months. The cumulative mean visual acuities were calculated using the logarithm of the minimum angle of resolution method. Refractive astigmatism was expressed as a negative value. Measurements were taken objectively with the use of keratometry. Subjective refractions were performed using a phoropter at a nominal vertex distance of 13.75 mm when the corneal vertex was located at the large mark on the calibration scale. The results were converted to the corneal plane using the method described by Holladay et al.[5] Total corneal astigmatism was calculated on the basis of the K reading and assuming an effective corneal refractive index of 1.3375. Corneal astigmatism was calculated based on the simultaneous K reading as the difference between the maximum corneal power and minimum corneal power, with the cylinder axis set at the corneal meridian with minimum power.

All preoperative, postoperative, and expected refractions were converted to the power vector components described by Thibos and Horner.[9] In this system, refractions are considered to be the sum of the following 3 components: the spherical equivalent; a Jackson cross-cylinder oriented at 180 degrees (J0), which quantifies with-the-rule (WTR) and against-the-rule (ATR) astigmatism; and a Jackson cross-cylinder oriented at 45 degrees (J45), which quantifies oblique astigmatism. Before the data were converted into power vector components and to ensure a consistent coordinate system, the angle of the axis of astigmatism in the left eye was converted using the following formula: transformed angle = 180 – angle.

The relationship between preoperative and postoperative keratometric astigmatism and subjective refractive astigmatism was assessed using multivariate linear regression analysis. Nonsignificant variables were removed by the stepwise method. Ekuseru-Toukei software (2010, Social Survey Research Information Co., Ltd.) was used to perform the statistical analyses. A P value less than 0.05 was considered to indicate statistical significance.

RESULTS

The study evaluated 90 eyes of 54 patients. The mean age of the 26 men and 28 women was 73.5 years ± 7.4 (SD) (range 56 to 86 years). Of the 90 eyes, 47 were right eyes and 43 were left eyes. The mean axial length was 24.22 ± 1.20 mm (range 21.77 to 28.75 mm), and the mean IOL power was 19.5 ± 2.9 diopters (D) (range 8.0 to 26.5 D).

No patient had a perioperative complication. Table 1 shows the refractive and keratometric outcomes. Table 2 shows the results of J0 and J45 components. Table 3 shows the predictors of postoperative refractive astigmatism from the multivariate regression analysis.

The mean preoperative and postoperative refractive J0 reflected a small amount of ATR astigmatism. The mean J0 and J45 values other than the preoperative refractive astigmatism J0 values were close to 0. For the J0 components, there was interpatient variability (standard deviation [SD] from 0.46 to 0.48). There was less oblique astigmatism in both K and the refraction values, as indicated by the smaller mean and SD values for J45.

On the multivariate regression analysis of postoperative refractive J0, both postoperative keratometry and preoperative refraction were significant independent predictors of postoperative refractive WTR astigmatism ($R^2 = 0.85$, $P < .001$):

$$\text{Postoperative J0} = 0.75 \times \text{keratometric J0} + 0.21 \times \text{preoperative J0} - 0.23$$

The coefficient of determination of multivariate model was higher than that of univariate model ($R^2 = 0.82$).

The multivariate regression analysis of postoperative refractive J45 was ($R^2 = 0.72$, $P < .001$) was as follows:

$$\text{Postoperative J45} = 0.82 \times \text{keratometric J45} + 0.08 \times \text{keratometric J0} - 0.03$$

The final term, reflecting the relationship between J0 and J45 keratometric astigmatism postoperatively, was expected. Preoperative refractive J45 was not selected by the stepwise method as the significant independent predictor of postoperative refractive oblique astigmatism. Postoperative keratometric J0 had significant statistical strength but an unclear physiologic basis. The multivariate model based on oblique

Table 1. Refractive and keratometric outcomes.

Parameter	Mean ± SD Preoperative	Mean ± SD Postoperative
CDVA (logMAR)	0.25 ± 0.21	−0.02 ± 0.07
Sphere (D)	−0.22 ± 2.25	0.15 ± 0.85
Subjective cylinder (D)	−0.98 ± 0.79	−0.97 ± 0.69
Keratometric cylinder (D)	−0.84 ± 0.69	−0.86 ± 0.63
Minimum keratometry (D)	43.66 ± 1.34	43.63 ± 1.39
Maximum keratometry (D)	44.50 ± 1.30	44.49 ± 1.30

CDVA = corrected distance visual acuity; logMAR = logarithm of the minimum angle of resolution

Table 2. Results of J0 and J45 components.

Parameter	Mean ± SD J0 Component	Mean ± SD J45 Component
Preoperative		
Refractive astigmatism (D)	−0.34 ± 0.47	0.06 ± 0.23
Keratometric astigmatism (D)	0.09 ± 0.48	−0.07 ± 0.22
Postoperative		
Refractive astigmatism (D)	−0.29 ± 0.46	−0.09 ± 0.24
Keratometric astigmatism (D)	0.02 ± 0.47	−0.08 ± 0.23

J0 = Jackson cross-cylinder oriented at 180 degrees; J45 = Jackson cross-cylinder oriented at 45 degrees