Changes in Corneal Astigmatism and High Order Aberrations After Clear Corneal Tunnel Phacoemulsification Guided by Corneal Topography

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ABSTRACT

PURPOSE: To study changes in corneal astigmatism and high order aberrations after clear corneal tunnel phacoemulsification guided by corneal topography.

METHODS: All patients were randomly assigned to the test group or the control group. Corneal topography-guided clear corneal tunnel phacoemulsification followed by intraocular lens (IOL) implantation was performed on 22 eyes of 16 patients in the test group and conventional temporal corneal tunnel phacoemulsification and IOL implantation were performed on 22 eyes of 21 patients in the control group. The corneal astigmatism and high order aberrations were measured using the NIDEK OPD-Scan aberrometer and topographer preoperatively and up to 3 months after surgery. The corneal astigmatism and sixth order root-mean-square (RMS) for corneal coma, trefoil, spherical, secondary coma, and secondary spherical aberrations at 4-mm pupil diameters were compared.

RESULTS: Fifteen (69%) eyes in the test group and 8 (36%) eyes in the control group achieved 20/25 uncorrected visual acuity 3 months after surgery, which was statistically significant (P<.05). The best spectacle-corrected visual acuity was 20/20 in 14 (63%) eyes in the test group and 10 (45%) eyes in the control group. The mean surgically induced astigmatism in the test group was 0.58±0.39 diopters (D) compared with 0.73±0.41 D in the control group. The change in corneal astigmatism from preoperative to 3 months after surgery was −0.17±0.32 D for the test group and 0.10±0.41 D for the control group, which was statistically significant (P<.05). The RMS value of trefoil aberrations increased, and all other aberrations decreased at 3 months after surgery in the test group. The RMS values of all corneal high order aberrations increased in the control group, with the increase in trefoil being statistically significant. The comparison of surgically induced high order aberrations between the two groups showed that corneal coma, trefoil, and secondary coma were significantly different.

CONCLUSIONS: Clear corneal tunnel phacoemulsification and IOL implantation guided by corneal topography can yield better visual acuity by reducing the pre-existing astigmatism and inducing less corneal aberrations than conventional temporal corneal tunnel phacoemulsification. [J Refract Surg. 2006;22:S1083-S1088.]

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Olson and Crandall\(^9\) and Oshika and Tsuboi\(^16\) found that an incision <2.0 mm had no impact on corneal curvature. The bimanual technique is not yet widely available, especially in developing countries.

To correct pre-existing astigmatism and minimize surgically induced astigmatism, we adopted 2.6-mm clear corneal tunnel phacoemulsification and IOL implantation guided by corneal topography with the incision placed at the steepest corneal meridian. The goal was to evaluate the changes in corneal astigmatism and high order aberrations after surgery compared with those achieved in traditional surgery with the incision placed temporally. The outcomes of the study may assist the surgeon in selecting the optimal surgical plan for individual cataract patients.

**PATIENTS AND METHODS**

**Patient Population**

A total of 37 patients (44 eyes) between the ages of 54 and 82 years (mean age: 65.05 ± 9.53 years) were randomly assigned to either the test group or the control group. Each case was numbered and those with odd numbers were assigned to the test group and those with even numbers to the control group. A 2.6-mm clear corneal tunnel phacoemulsification/IOL implantation guided by corneal topography was performed on 22 eyes of 16 patients in the test group, and conventional temporal corneal tunnel phacoemulsification with IOL implantation was performed in 22 eyes of 21 patients in the control group. Selection criteria included good general health, absence of corneal pathology during slit-lamp microscopy examination, no previous corneal or scleral surgery, absence of severe retinal pathology that could affect the infrared ray reflection from the macula during ocular wavefront aberration measurement, and no complications during or after surgery.\(^2,7\) An explanation of the study was given to all patients and informed consent obtained.

**Examination**

Clinical examinations were conducted preoperatively and at 1 week, 2 weeks, 1 month, and 3 months after surgery. Clinical examination included best spectacle-corrected visual acuity (BSCVA) and uncorrected visual acuity (UCVA), manifest and cycloplegic refractions, intraocular pressure, and anterior and posterior segment evaluation. The corneal astigmatism and high order aberrations were measured using the NIDEK OPD-Scan aberrometer/topographer (NIDEK Co Ltd, Gamagori, Japan), which uses skiascopy-based ocular aberrometry using 1440 infrared points and plaido disk corneal topography.\(^7\) The OPD-Station software (NIDEK Co Ltd) was used to isolate corneal aberration out to the sixth order.

**Surgical Technique**

All surgeries were performed under topical anesthesia by the same surgeon (L.Y.). Conventional temporal corneal tunnel phacoemulsification and IOL implantation were performed on the patients in the control group. A 2.6×2.0- to 2.5-mm temporal clear corneal tunnel incision was used. A 0.6-mm wide paracentesis was carried out for the insertion of the chopper. Subsequently, Duovisc (Alcon Laboratories, Ft Worth, Tex) was used to maintain the anterior chamber, and a continuous curvilinear capsulorrhesis and hydrodissection were performed. Endocapsular phacoemulsification of the nucleus with Phacochop or “stop-and-chop” techniques and cortical aspiration were performed using an Infinite or Legacy phacoemulsifier (Alcon Laboratories). The anterior chamber and the capsular bag were refilled with Duovisc. A foldable IOL was inserted into the capsular bag using an injector cartridge system. The residual viscoelastic material was removed using an irrigation/aspiration handpiece. Balanced salt solution was injected through the paracentesis to maintain the anterior chamber. At the end of surgery, the wound was checked and found to be watertight. All surgeries were completed without sutures. Postoperatively, all patients were treated with topical 0.1% Tobradex (Alcon Laboratories) and 0.1% Pranoprofen (Sumika Finechem, Osaka, Japan) three times a day for 1 month. All patients in the test group underwent the same surgical procedure as those in the control group with the exception that incisions were placed on the steepest corneal meridian, which were determined using the OPD-Scan axial corneal topography.

**Statistical Analysis**

The mean corneal astigmatism, the surgically induced astigmatism, and the root-mean-square (RMS) of corneal coma, trefoil, spherical aberration, secondary coma, and secondary spherical aberration for a 4-mm pupil diameter before and after surgery were compared. The surgically induced astigmatism was calculated and standardized using Jaffe’s vector analysis. The statistics were performed using the STATA 8.0 (Stata Corp, College Station, Tex) statistical software. The chi-square test, t test, Scheffe test, nonparametric Wilcoxon signed-rank test, Mann-Whitney test, and Kruskal-Wallis test were used to analyze the variables studied. A P value <.05 was considered statistically significant.
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**RESULTS**

At 3 months after surgery, 15 (68%) eyes in the test group and 8 (36%) eyes in the control group achieved UCVA ≥20/25. This difference in postoperative UCVA was statistically significant (P<.05). Fourteen (64%) eyes achieved BSCVA ≥20/20 postoperatively in the test group, and 10 (45%) eyes achieved BSCVA ≥20/20 postoperatively in the control group. This difference in postoperative BSCVA was not statistically significant (P>.05).

Figure 1A shows the mean values of corneal astigmatism in both groups preoperatively and at 1 week, 2 weeks, 1 month, and 3 months after surgery. No statistically significant difference was noted between the mean value of corneal astigmatism at 1 week and 2 weeks, 1 month, and 3 months after surgery. *P>.05. B) The change in corneal astigmatism induced by cataract surgery 3 months postoperatively. The test group versus the control group, P<.05.

![Figure 1](image1.png)

**Figure 1. A** The mean values of corneal astigmatism in two groups preoperatively and 1 week, 2 weeks, 1 month, and 3 months after surgery. No statistically significant difference was noted between the mean value of corneal astigmatism at 1 week and 2 weeks, 1 month, and 3 months after surgery. *P>.05. **B** The change in corneal astigmatism induced by cataract surgery 3 months postoperatively. The test group versus the control group, P<.05.

![Figure 2](image2.png)

**Figure 2. A** The amount of surgically induced corneal astigmatism at 1 week, 2 weeks, 1 month, and 3 months postoperatively in the test and control groups. No statistically significant difference was noted between the mean values of surgically induced corneal astigmatism at each time point. *P>.05. **B** Surgically induced corneal astigmatism 3 months postoperatively in the test group versus control group (*P>.05). Surgically induced corneal astigmatism was analyzed using the vector method described by Jaffe.

The change of corneal high order aberrations for 4-mm pupil diameters in the test and control groups are shown in Figures 3 and 4, respectively. Trefoil increased at 3 months postoperatively in the test group. Coma, spherical, secondary coma, and secondary spherical aberrations decreased 3 months postoperatively in the test group (see Fig 3). None of the changes in corneal higher order aberrations were statistically significant (see Fig 3). All of the corneal high order aberrations in the control group increased 3 months postoperatively (see Fig 4). The only statistically significant change in individual aberrations from pre- to postoperatively in the control group was trefoil (P<0.05) (see Fig 4).

![Figure 5](image5.png)

**Figure 5** demonstrates a typical example of the induced changes in corneal third order aberrations pre- and postoperatively.

The mean values of surgically induced corneal astigmatism at 1 week, 2 weeks, 1 month, and 3 months after surgery in the test and control groups are shown in Figure 2A. The mean surgically induced astigmatism at 3 months postoperatively was 0.58±0.39 D for the test group and 0.73±0.41 D for the control group. This difference was not statistically significant (P>.05) (Fig 2B).

The change of corneal high order aberrations for 4-mm pupil diameters in the test and control groups are shown in Figures 3 and 4, respectively. Trefoil increased at 3 months postoperatively in the test group. Coma, spherical, secondary coma, and secondary spherical aberrations decreased 3 months postoperatively in the test group (see Fig 3). None of the changes in corneal higher order aberrations were statistically significant (see Fig 3). All of the corneal high order aberrations in the control group increased 3 months postoperatively (see Fig 4). The only statistically significant change in individual aberrations from pre- to postoperatively in the control group was trefoil (P<0.05) (see Fig 4).

Figure 5 demonstrates a typical example of the induced changes in corneal third order aberrations pre- and postoperatively.
and postoperatively in the test group. At 3 months after surgery, a trefoil pattern dominates the third order aberrations, and coma is diminished (see Fig 5). Figure 6 demonstrates a typical example of the induced changes in corneal third order aberrations pre- and postoperatively in the control group. At 3 months after surgery, coma and trefoil dominate the third order aberrations and direction of the trefoil pattern has reversed (see Fig 6).

The comparison of surgically induced corneal higher aberrations between the two groups at 3 months after surgery show that corneal coma, trefoil, and secondary coma were statistically significantly different \( (P<.05) \), whereas the spherical and secondary spherical aberrations were not significantly different \( (P>.05) \) (Fig 7).

**DISCUSSION**

The optical quality of the pseudophakic eye is determined by the combination of corneal and internal aberrations generated by the IOL and those induced by surgery. Spherical aberration is determined by the corneal asphericity. In this study, corneal astigmatism and high order aberrations were evaluated as a...
measure of change in the cornea after cataract surgery.

A statistically significantly greater number of patients in the test group read 20/25 with correction than in the control group (P<.05). Greater astigmatic correction occurred in the test group shown by the statistically significant change in corneal astigmatism from pre- to postoperatively (P<.05). Based on these data, we believe that a 2.6-mm clear corneal tunnel phacoemulsification and IOL implantation guided by corneal topography can correct astigmatism as low as 0.25 D, resulting in better postoperative visual acuity. For higher preoperative astigmatism, a clear corneal incision placed at the steepest meridian may be beneficial.10 Although not statistically significant, there were slight differences between groups with respect to surgically induced astigmatism at 1 week, 2 weeks, 1 month, and 3 months postoperatively. However, from 2 weeks to 3 months postoperatively, the corneal astigmatism showed little change, indicating that the 2.6-mm clear corneal tunnel incision was fully stable by 2 weeks postoperatively. This finding is similar to that reported by Masket and Tenn.18

The quality of the retinal image is primarily limited by the aberrations of the eye.4 The total ocular aberrations include corneal aberrations and internal aberrations. One study reported that the average retinal image quality of pseudophakic patients was worse than that in healthy younger subjects because of an increase in aberrations postoperatively.19 The lower the aberrations, the better the optical quality. Many studies show cataract surgery with IOL implantation can increase corneal aberrations2,17,20 and internal aberrations.21-25 However, Marcos et al2 found that corneal spherical aberration decreased after the surgery. This study reports a similar result.

The present investigators elected to study aberrations for a 4-mm pupil diameter, because pseudophakic eyes rarely dilate to 6 mm without dilating drops.7 This investigation found no statistically significant change in any of the higher order aberrations postoperatively. This was likely due to the size and location of the incision. Another reason might be the small number of patients; thus sampling error cannot be fully excluded.

In the control group, a statistically significant increase was noted in trefoil postoperatively versus preoperatively (P<.05). The comparison of surgically induced higher order aberrations between the two groups shows that corneal coma, trefoil, and secondary coma were significantly different. These changes indicated that 2.6-mm clear corneal tunnel phacoemulsification and IOL implantation guided by topography produced less corneal high order aberration and resulted in better corneal optical quality.

Clear corneal tunnel phacoemulsification and IOL

Figure 6. A typical example of changes in third order corneal higher order aberrations for a 4-mm pupil diameter of an eye before and after surgery in the control group. A) Coma and trefoil aberrations before surgery. B) Aberrations 3 months after surgery. C) Difference map showing surgically induced third order aberrations.

Figure 7. Surgically induced high order aberrations at 3 months after surgery for the test group versus the control group (*P>.05; #P<.05).
implantation guided by corneal topography induce less astigmatism and less corneal higher order aberrations compared with temporally placed incisions, both of which can lead to better recovery of visual acuity after surgery.

REFERENCES