OUTCOMES OF MYOPIC LASIK WITH AND WITHOUT NIDEK ACTIVE TORSION ERROR CORRECTION

Jan Venter, MD

From Optical Express, London, United Kingdom.

The author has no financial or proprietary interest in the materials presented herein.

Correspondence: Jan Venter, MD, Optical Express, 22 Harley St, London, United Kingdom, W1G 9AP. Tel: 44 0207 580 1200; Fax: 44 0207 580 1201; E-mail: drjanventer@gmail.com

Received: September 22, 2007; Accepted: November 20, 2008

Posted online: January 15, 2009

ABSTRACT

PURPOSE: To compare refractive outcomes and higher order aberrations of eyes that underwent LASIK for myopia with astigmatism with or without active cyclotorsion error correction.

METHODS: This was a contralateral eye study of 48 eyes of 24 patients who underwent LASIK using the NIDEK Advanced Vision Excimer laser platform (NAVEX), treating one eye with active cyclotorsion error correction (TEC eyes) and the fellow eye without active cyclotorsion error correction (without TEC eyes). Postoperatively, the refractive outcomes, including postoperative astigmatism and higher order aberrations were compared between groups using the t test. A P value <.05 was considered statistically significant. Three-month postoperative outcomes are presented.

RESULTS: Preoperative manifest refraction spherical equivalent was −3.59±1.60 diopters (D) (range: −1.25 to −6.75 D) for the TEC group and −3.82±1.89 D (range: −1.38 to −8.63 D) for the without TEC group. No statistically significant differences were noted in postoperative visual acuity between groups (P>.05). The TEC eyes had statistically significant lower postoperative cylinder (0.28±0.27 D [range: 0 to −0.75 D] for the TEC group vs 0.49±0.30 D [range: 0 to −1.00 D] for the without TEC group; P=.02). A mean decrease in root-mean-square (RMS) of higher order aberration was noted in the TEC eyes, and a mean increase was noted in RMS of higher order aberration for the without TEC eyes at both 5- and 6-mm pupil diameters. The TEC eyes had statistically significantly lower RMS of higher order aberration (P<.01).

CONCLUSIONS: Active torsion error correction with the NIDEK NAVEX platform statistically significantly increases the predictability of astigmatism correction and reduces the induction of higher order aberrations of eyes undergoing LASIK. [J Refract Surg. 2009;25:985-990.]

doi:10.3928/1081597X-20091016-03

Ocular cyclotorsion during laser refractive surgery can result in diminution of the postoperative optical quality of the eye. This reduction in optical quality can be caused by induction of astigmatism and/or higher order aberrations due to the incorrect placement of the laser ablation. Theoretical analyses estimate that even a 5° torsional misalignment can decrease retinal image quality and laser delivery must account for cyclotorsion to an accuracy within 3°. The greatest magnitude of cyclotorsion occurs between the upright and supine positions and under monocular conditions in the majority of patients. One study reported that >30% of eyes undergoing LASIK experienced at least a 5° cyclotorsional error during surgery. Currently, most excimer laser platforms do not have an active torsion error correction that compensates for cyclotorsion.

To date, no peer-reviewed studies compare eyes treated with or without active cyclotorsion error correction on astigmatism or higher order aberrations after LASIK. In this study, the refractive outcomes and wavefront aberrations of patients who underwent LASIK with active cyclotorsion error correction in one eye and without cyclotorsion error correction in the other eye are compared.

PATIENTS AND METHODS

In this contralateral eye study design, 48 eyes of 24 patients underwent wavefront-guided LASIK using the NIDEK Advanced Vision Excimer laser platform (NAVEX; NIDEK Co Ltd, Gamagori, Japan) with or without active cyclotorsion error correction (TEC) to compare the refractive outcomes, including the induction of astigmatism and higher order aberra-
tion postoperatively. NAVEX consists of the OPD-Scan wavefront sensor and corneal topographer, the CX III excimer laser, MK-2000 keratome, and Final Fit ablation planning software (all NIDEK Co Ltd).

Mean patient age was 38±9 years (range: 25 to 61 years). Mean preoperative manifest spherical equivalent refraction was −3.71±1.76 diopters (D) (range: −1.25 to −8.63 D). Mean preoperative sphere was −3.28±1.72 D (range: −0.75 to −8.00 D), and mean preoperative cylinder was −0.86±0.83 D (range: −3.00 to 0.00 D).

All patients underwent a baseline ophthalmic examination and postoperative follow-up at 1 week, 1 month, and 3 months that included measurement of distance uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), manifest and cycloplegic refractions (performed by an optometrist), slit-lamp examination, corneal topography and aberometry using the OPD-Scan, corneal pachymetry, keratometry, and a dilated fundus examination. Postoperatively, a dilated fundus examination and cycloplegic refraction were only conducted if clinically warranted; all other measurements were the same as the preoperative examinations. All wavefront measurements were performed for a 6-mm pupil plotted to the 8th Zernike order. Wavefront measurements were cropped to 5 mm using the OPD Station software (NIDEK Co Ltd). Written informed consent was obtained from all patients. This study followed the tenets of the Declaration of Helsinki.

**Torsion Error Correction Module**

The torsion error correction (TEC) module allows for treatment of the cornea on the basis of the preoperative axis. Prior to and during laser ablation, the iris landmarks acquired preoperatively using the OPD-Scan are compared to the iris landmarks while the patient is supine. Torsion error correction actively compensates for cyclorotational movements via a feedback loop to the excimer laser, enabling a change in the position of the ablation. Torsion error correction actively corrects any cyclotorsional movements occurring during treatment. The surgeon can preset the TEC to a maximum allowable error (ie, ±1°). When this rotational tolerance is exceeded during treatment, the ablation is interrupted automatically. The surgeon then represses the foot pedal, the TEC system immediately corrects the torsion error, and laser ablation continues. The magnitude of cyclotorsional error is visible on the monitor at all times.

**Statistical Analysis**

Refractive outcomes and changes in higher order aberrations were analyzed using STATISTICA software (Statsoft, Tulsa, Okla) using the t test for statistical significance. A P value <.05 was considered statistically significant.

**RESULTS**

Three-month data were analyzed in this study. For the eyes treated with TEC (TEC eyes), the mean preoperative manifest spherical equivalent refraction was −3.59±1.60 D (range: −1.25 to −6.75 D), mean preoperative sphere was −3.16±1.60 D (range: −0.75 to −6.50 D), and mean preoperative cylinder was −0.88±0.80 D (range: −0.25 to −3.00 D). For the eyes treated without TEC (without TEC eyes), the mean preoperative manifest spherical equivalent refraction was −3.82±1.89 D (range: −1.38 to −8.63 D), mean preoperative sphere was −3.40±1.82 D (range: −1.00 to −8.00 D), and
mean preoperative cylinder was $-0.85\pm0.84$ D (range: 0 to $-2.75$ D). No statistically significant differences were noted in the preoperative sphere, cylinder, and manifest spherical equivalent refraction between the TEC eyes and the without TEC eyes ($P>.05$).

The mean postoperative manifest spherical equivalent refraction was $0.04\pm0.39$ D (range: $+1.00$ to $-1.25$ D). Mean postoperative sphere was $0.23\pm0.37$ D (range: $-0.75$ to $+1.00$ D) (Fig 1). No statistically significant difference was noted in postoperative sphere between groups ($P>.05$) (see Fig 1). Mean postoperative cylinder was $-0.39\pm0.31$ D (range: 0 to $-1.00$ D) (Fig 2). Mean refractive cylinder was $0.28\pm0.27$ D (range: 0 to $-0.75$ D) for the TEC group and $0.49\pm0.30$ D (range: 0 to $-1.00$ D) for the without TEC group. A statistically significant difference was noted in postoperative cylinder between groups ($P=.02$) (see Fig 2). Vector analyses for both groups are shown in Figure 3.

Mean postoperative UCVA was 0.05 (logMAR) in the TEC eyes and 0.08 (logMAR) in the without TEC eyes. There was no statistically significant difference in postoperative UCVA between groups ($P>.05$). Mean postoperative BSCVA was $-0.01$ (logMAR) in the TEC eyes and 0 (logMAR) in the without TEC eyes. There was no statistically significant difference in postoperative BSCVA between groups ($P>.05$).

The mean root-mean-square (RMS) values for higher order aberrations, spherical aberrations, and coma are shown in Tables 1 and 2. There was a mean decrease in RMS of higher order aberrations in the TEC eyes and a mean increase for the without TEC eyes at both 5- and 6-mm pupil diameters (Fig 4, Tables 1 and 2).
A statistically significant difference was noted in the change in the RMS of higher order aberrations from preoperatively to postoperatively between groups for both 5-mm ($P<.01$) and 6-mm pupil diameters ($P<.01$). There were no statistically significant differences in the changes in coma from pre- to postoperative between groups ($P>.05$) (Fig 5, Tables 1 and 2).

A mean increase in RMS of spherical aberration occurred in the without TEC eyes and no change in spherical aberration in TEC eyes at both 5- and 6-mm pupil diameters (Fig 6, Tables 1 and 2). There were

**Figure 4.** Change in root-mean-square of higher order aberrations ($\mu$m) of 48 eyes of 24 patients who underwent contralateral LASIK treatment with or without active cyclotorsion correction using NAVEX. A statistically significant difference was noted between eyes treated with active cyclotorsion correction (red) or eyes treated without active cyclotorsion correction (blue) at 5-mm ($P<.01$) and 6-mm ($P<.01$) measurement diameters. All measurements were performed from the 3rd to 8th Zernike order. Ave = mean

**TABLE 1**

Higher Order Aberrations for a 5-mm Pupil Diameter of 48 Eyes of 24 Patients Who Underwent Contralateral LASIK Treatment With or Without Active Cyclotorsion Correction Using NAVEX

<table>
<thead>
<tr>
<th>Mean ± Standard Deviation ($\mu$m)</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOA Coma SA</td>
<td>With TEC</td>
<td>Without TEC</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>0.245±0.104</td>
<td>0.106±0.041</td>
<td>0.052±0.039</td>
</tr>
<tr>
<td>0.248±0.073</td>
<td>0.075±0.030</td>
<td>0.055±0.035</td>
</tr>
<tr>
<td>0.191±0.068</td>
<td>0.100±0.045</td>
<td>0.054±0.050</td>
</tr>
<tr>
<td>0.284±0.106</td>
<td>0.116±0.060</td>
<td>0.094±0.107</td>
</tr>
</tbody>
</table>

HOA = higher order aberration, SA = spherical aberration, TEC = cyclotorsion error correction

Note. All wavefront measurements were performed for a 6-mm pupil plotted to the 6th Zernike order. Wavefront measurements were cropped to 5 mm using the OPD-Scan software.

**TABLE 2**

<table>
<thead>
<tr>
<th>Mean ± Standard Deviation ($\mu$m)</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOA Coma SA</td>
<td>With TEC</td>
<td>Without TEC</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>0.371±0.126</td>
<td>0.181±0.075</td>
<td>0.122±0.110</td>
</tr>
<tr>
<td>0.385±0.114</td>
<td>0.148±0.071</td>
<td>0.122±0.102</td>
</tr>
<tr>
<td>0.340±0.133</td>
<td>0.187±0.100</td>
<td>0.132±0.118</td>
</tr>
<tr>
<td>0.466±0.159</td>
<td>0.209±0.134</td>
<td>0.164±0.100</td>
</tr>
</tbody>
</table>

HOA = higher order aberration, SA = spherical aberration, TEC = cyclotorsion error correction

Note. All wavefront measurements were measured to the 6th Zernike order.
no statistically significant differences in the changes in spherical aberration from pre- to postoperative between groups ($P > .05$).

**DISCUSSION**

This contralateral eye study of LASIK using active cyclotorsion correction found refractive outcomes, primarily cylinder, and higher order aberrations differed statistically significantly, favoring the eyes treated with active cyclotorsion correction. However, sphere, manifest refraction spherical equivalent, and individual higher order aberration did not differ between groups.

Kermani\(^5\) found that cyclotorsion increases when going from the binocular sitting position to the monococular supine position with a clinically significant change in axis in a third of patients and reported changes in approximately 10% of eyes. A change of up to 16° in axis due to cyclotorsion has been reported.\(^2\) Compensation of cyclotorsion is necessary for spherocylindrical treatment, as a misaligned ablation can induce astigmatism postoperatively. For the treatment of higher order aberrations, active compensation for cyclotorsion is fundamental to avoid the induction of aberrations. Residual astigmatism and induced higher order aberrations have been shown to reduce retinal image quality.\(^2\) The effect of a displaced ablation is different for each aberration.\(^2\) If the cyclotorsion is clinically significant (eg, >3° to >5°) greater aberrations will be generated.\(^9\)

The statistically significant reduction in cylinder in the TEC eyes is likely a result of active cyclotorsion correction, as uncorrected torsional movement during ablation will likely result in greater residual or induced astigmatism postoperatively. The amount of induced astigmatism is due to both the magnitude and frequency of cyclotorsional movements during the ablation. For example, a sustained tort of 10° during ablation is likely to result in greater induced astigmatism or higher order aberration than a fleeting tort of 10°.

Rotationally symmetrical aberrations such as spher-
ic aberration are less likely to be affected by cyclotorsion than asymmetric aberrations such as coma. This is likely the reason we did not find a significant difference in postoperative spherical aberration between groups. Although we did not find a significant difference in coma, significant difference was found in the induced higher order aberrations between groups. Hence, this difference was likely due to the induction of other asymmetric aberrations such as trefoil and secondary astigmatism in the without TEC eyes. However, these aberrations were not measured and cannot be conclusively proven to be the case. The induction of aberrations postoperatively is due to cyclotorsion movement rather than lateral decentrations as an active 200-Hz eye-tracker was used during treatments for both groups. To reach the goal of diffraction limited vision using wavefront ablations, the preoperative reference system and delivery of the ablation requires extreme precision. Active eye tracking combined with active cyclotorsion correction rules out two of the major hurdles to achieve this goal.

Further study with a larger sample and the use of contrast sensitivity and subjective questionnaire may provide more insight into the benefit of cyclotorsion error correction. In summary, we found that using the NAVEX platform with active torsion error correction statistically significantly increases the predictability of astigmatism correction and higher order aberration correction during laser vision correction.

REFERENCES


