ABSTRACT

PURPOSE: To investigate the predictability and accuracy of active cyclotorsion compensation during LASIK for myopia with astigmatism.

METHODS: Fifty-two eyes of 26 patients were divided into two groups; one group (30 eyes) underwent primary LASIK with torsion error correction (TEC [TEC group]) and 22 eyes underwent LASIK without TEC (control group). The NIDEK EC-5000 CX III excimer laser was used for all treatments. All eyes were targeted for emmetropia. Manifest refraction spherical equivalent (MRSE), refractive outcomes, and dispersion and predictability of manifest refractive cylinder were compared between the TEC and control groups. A $P < 0.01$ was considered statistically significant. All outcomes are reported at 3 months postoperatively.

RESULTS: Statistically significantly lower cylinder dispersion and mean manifest refractive cylinder postoperatively were demonstrated in the TEC group ($P < 0.01$). Final refractive cylinder for the TEC group was $-0.21 \pm 0.16$ diopters (D) (range: $-0.62$ to $0.00$ D) and $-0.56 \pm 0.34$ D (range: $-1.25$ to $0.00$ D) for the control group. No statistically significant differences in mean MRSE or safety (defined as a loss of 2 or more lines of best spectacle-corrected visual acuity) was noted between groups.

CONCLUSIONS: LASIK with active cyclotorsion error correction increases the accuracy of cylinder correction. [J Refract Surg. 2007;23:S1041-S1045.]

LASIK and photorefractive keratectomy for myopia without astigmatism are considered effective procedures. Postoperative measurement has historically focused on high contrast Snellen visual acuity. Increasingly, however, there is a shift toward considering the quality of vision postoperatively. Visual acuity and quality are considered accurate indicators of patient satisfaction. A variety of factors can affect the quality of vision postoperatively, including lateral or torsional decentrations. Although the incorporation of eye trackers in most laser platforms has addressed the issue of lateral decentration, active compensation for cyclotorsion during ablation remains largely unaddressed. Cyclotorsion affects the accuracy of cylindrical correction as well as the quality of vision.

This study of LASIK for myopia and myopic astigmatism compared the effectiveness and safety of eyes treated with and without active cyclotorsion compensation using the torsion error correction (TEC) function of the NIDEK EC-5000 CX III excimer laser (NIDEK Co Ltd, Gamagori, Japan).

PATIENTS AND METHODS

This prospective, non-randomized clinical trial evaluated LASIK for the correction of myopia with or without astigmatism. Thirty eyes of 15 patients underwent primary LASIK with TEC (TEC group), and 22 eyes of 11 patients underwent LASIK without TEC (control group). Patients in the TEC group were selected from consecutive LASIK candidates with $\geq 1.00$ diopters (D) manifest refractive astigmatism. Patients in the control group were selected from consecutive LASIK candidates undergoing surgery during the same time period with $\geq 0.50$ D manifest re-
fractive astigmatism. Patients with stable myopia or myopic astigmatism who met the requirements for primary LASIK were included in the study. All eyes were targeted for emmetropia.

Preoperatively, all patients underwent a comprehensive ophthalmic evaluation including measurement of uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), manifest refraction, corneal topography and wavefront aberrometry using the OPD-Scan (NIDEK Co Ltd), ultrasound corneal pachymetry, Goldmann tonometry, slit-lamp microscopy, and dilated fundus examination. All preoperative examinations, with the exception of dilated funduscopy (unless warranted), were repeated at 1 week and 1 and 3 months postoperatively. Postoperative data are presented for 3 months.

**Surgery**

The LASIK procedure has been previously described. All ablations were centered using the line of sight option built into the laser tracker software. All eyes were targeted for emmetropia and no retreatments were performed until termination of the study. The customized aspheric treatment zone algorithm (CATz) was used for all patients.

**Device Description**

The NIDEK EC-5000 CX III excimer laser consists of an argon fluoride (ArF) excimer laser beam delivery system; a diode-aiming laser; optical viewing system including a microscope, fixation light, and illumination lamps; mechanical systems used for positioning, focusing, and gas handling; and the microprocessor.
controllers. The manufacturer incorporated an active TEC module, which 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 iridal 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. An active 200 Hz infrared eye tracking unit was used to compensate for lateral movements of the eye. Eye images were continually obtained using infrared light. The image of the camera was transferred with an image rate of 200 Hz via a video signal to the eye tracking unit, where it was digitized. The digitized image was processed to obtain the position of the eye for each video image. The center of the pupil was determined for each image in pixel coordinates with a sampling rate of 200 Hz. The user was also able to visualize the identified pupil position by overlaying a crosshair onto the video output image, showing the real-time changes in the size of the pupil. The eye position data are used to control the scanner position of the laser, and validity flags are used to control the laser ablation.

**Statistical Analysis**

In this study, the MRSE, refractive outcomes, vector analysis, and dispersion and predictability of manifest refractive cylinder were compared between the TEC and control groups. The F test and Welsh’s t test were used to determine the difference between the TEC and control groups. A P value <.01 was considered statistically significant.

**Dispersion**

When data values in a sample are not all the same, the variation between values is called dispersion. A large dispersion means the values are widely scattered; when dispersion is small, they are tightly clustered. The width of diagrams, such as box plots used in this study, is greater for samples with more dispersion and vice versa. Although several measures of dispersion can be used, the most common is standard deviation. These measures indicate the degree of which the individual observations of a data set are dispersed or “spread out” around their mean.

**Results**

All eyes were available for follow-up at 3 months postoperatively.

Preoperatively, there were no statistically significant differences in mean MRSE, mean sphere, mean cylinder, and the associated standard deviation between groups (P >.01, F test) (Table 1).
Active Cyclotorsion Error Correction During LASIK/Bharti & Bains

POSTOPERATIVE OUTCOMES

Dispersion and Predictability of Manifest Refractive Cylinder. Dispersion of manifest refractive cylinder in the TEC group was statistically significantly lower than the control group ($P=.003$, F test) (Fig 1; Table 2). Postoperative mean manifest cylinder in the TEC group was also statistically significantly lower than the control group ($P<.001$, Welch’s $t$ test) (Table 3).

Predictability of Manifest Refraction Spherical Equivalent. Ninety percent of eyes (n=27) in the TEC group and 64% of eyes (n=14) in the control group were within 0.50 D of the intended MRSE. All 30 eyes (100%) in the TEC group and 19 eyes (86%) in the control group were within 1.00 D of the intended MRSE. The mean MRSE was $0.11\pm0.16$ D (range: $-0.31$ to $0.43$ D) for the TEC group and $-0.23\pm0.64$ D (range: $-2.06$ to $0.50$ D) for the control group. No statistically significant difference in mean MRSE between groups was noted ($P>.01$). A tighter grouping of points in the attempted versus achieved plot was noted; however, the difference was not statistically significant ($P>.01$) (Fig 2).

Visual Acuity and Safety. No statistically significant difference in UCVA between groups was noted ($P>.01$) (Fig 3). No eye lost two or more lines of BSCVA postoperatively in the TEC and the control groups ($P>.01$).

No eye experienced induced refractive astigmatism $>2.00$ D in either group ($P>.01$). No adverse events, including surgical complications, occurred for the duration of this study.

Vector Analysis. Vector analysis of cylinder changes from preoperative to 3 months postoperatively shows a statistically significant greater reduction of cylinder magnitude in the TEC group ($P<.01$) (Table 4; Fig 4). Statistically significantly lower mean axis error and standard deviation in the TEC group were noted ($P<.01$) (Table 4).

DISCUSSION

This study shows that LASIK for myopia using the NIDEK EC-5000 CX III equipped with active cyclotorsion error compensation was safe and efficacious. For example, 90% of patients (27 eyes) had UCVA of 20/20 or better postoperatively. Additionally, no eye experienced induced refractive astigmatism of $\geq2.00$ D.

Because intraoperative cyclotorsion is likely to induce astigmatism postoperatively, we elected to measure the dispersion and predictability of cylinder corrections postoperatively. Evaluation of MRSE only may have masked low, yet statistically significant, induced cylinder. In our opinion, directly measuring the effects on cylinder postoperatively provides a better approach. In this study, we found statistically significantly greater predictability and accuracy of cylinder correction in eyes treated with active TEC (TEC group) than those not treated with TEC (control group) ($P<.01$) (see Figs 1, 2, and 4; Tables 2-4).

Low to moderate amounts of cyclotorsion have been
reported in previous studies\textsuperscript{7-9,11}; the magnitude of which seems to increase under monocular conditions. Even four degrees of torsional misalignment can decrease cylinder correction by 14\%.\textsuperscript{12} Therefore, meticulous alignment and correct registration and compensation of cyclotorsion are essential for proper correction of astigmatism. As vision correction surgery advances to wavefront treatments, meticulous alignment will become even more critical as incorrect placement of the laser ablation will induce significant aberrations. The tolerances for rotational decentrations will be even more stringent as ablation patterns become more complex and specific to the individual. Theoretical investigations conclude that a rotation of more than two degrees could introduce significant postoperative aberrations.\textsuperscript{12,13} Therefore, accurate compensation using TEC will reduce the occurrence of induced astigmatism or higher order aberrations. The outcomes of this study support the use of TEC to enable accurate and predictable correction of cyclotorsion during surgery, thereby contributing to optimal visual outcomes and potentially decreased retreatment rates.

REFERENCES


