One-kilohertz Eye Tracker and Active Intraoperative Torsion Detection in the NIDEK CXIII and Quest Excimer Lasers

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ABSTRACT

PURPOSE: To describe recent technological additions to the NIDEK CXIII and Quest excimer lasers.

METHODS: A summary article with data from previous published studies outlining the benefits of newer technology.

RESULTS: The addition of a 1-kHz infrared eye tracker decreased the spread of laser spot placement from a mean of 228.79 µm without a tracker to 38.47 µm with the eye tracker. The addition of real-time torsion error correction produced a statistically significantly lower cylinder dispersion, mean manifest refractive cylinder, and error of angle postoperatively in eyes that underwent LASIK.


The field of excimer laser surgery continues to advance from treating solely refraction a decade ago to treating higher order aberrations of the cornea or the entire eye. Refined technological achievements have translated into significant improvements in the ability to detect and treat subtle aberrations specific to an individual and, in some cases, to treat specific aberrations without treating the refraction. However, this increase in precision demands new technology to ensure fidelity and accuracy of the treatment. The NIDEK CXIII and Quest excimer lasers (NIDEK Co Ltd, Gamagori, Japan) have kept pace by incorporating technology to meet this challenge. The newly designed Quest laser has incorporated from the design process onwards, whereas upgrades are required to incorporate these changes to the CXIII laser.

Fundamental to any refractive laser treatment platform is a robust aberrometer and corneal topographer. The OPD-Scan II (Optical Path Difference, NIDEK Co Ltd) has recently been upgraded for faster acquisition times and the ability to measure aberrations at near and far distances for planning presbyopic treatments. This instrument uses retinoscopy, which is time-based, in contrast to other aberrometers that use position-based techniques to plot the aberrations of the eye. The OPD-Scan II is a combined autorefractor, keratometer, topographer, aberrometer, and pupillometer, which allows alignment of this information along a single axis and the presentation of multiple types of data on one printout for the clinician.

The meticulous precision required for laser delivery now requires maintaining lateral and torsional centration throughout the ablation. The 1-kHz infrared eye tracker has been incorporated to address orthogonal movements. This eye tracker does not require pupil dilation and can track pupil sizes from 1.50

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Figure 1. Residual position error of eye movements A) without eye tracking, B) with 60-Hz eye tracking, C) with 200-Hz eye tracking, and D) with 1000-Hz (1-kHz) eye tracking. Solid circle represents 0.50 mm. Ave Dist denotes average distance from the center of data points. The data were measured with a high-speed video camera to determine the actual position of each point compared to the ideal position of each point. If an eye tracker is perfect, there is no spread of the points. These data plot the residual positioning error of different eye trackers. The group of points becomes increasingly tighter as the tracker speed increases.

Orthogonal centration is only one requirement for accurate laser delivery; the other is the ability to address rotational movements. This is facilitated by the incorporation of a torsion error detector module, online torsion error, and recently, the torsion error correction (TEC) function. The torsion error detector measures the difference in axis alignment based on iridal landmarks between the OPD-Scan II measurement and when the patient is supine at the beginning of surgery. The continuous online torsion error monitors the eye for cyclotorsion during the ablation. The TEC function actively compensates for cyclotorsion during laser ablation. Use of the torsion error detector and online torsion error monitor have shown better predictability of astigmatism treatments and lower induction of higher order aberrations.2 Theoretical studies estimate an accuracy <3° is required for precise treatment of higher order aberrations.3,4 Cyclotorsion can occur during surgery when the patient is supine and may increase under monocular conditions.5,6 A 4° torsional misalignment could theoretically result in a 14% undercorrection of astigmatism.3

With the increasing use of wavefront or custom ablations, the tolerances for misalignment become extremely stringent to ensure accurate placement of the ablation.3,4 Hence, active cyclotorsion compensation using TEC is increasingly becoming a requirement for refractive surgery.
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A prospective, bilateral, controlled clinical trial using the CXIII excimer laser for the correction of myopia with or without astigmatism was conducted by Bharti and Bains that compared the safety and effectiveness of the NIDEK active TEC system for LASIK. Fifty-two eyes of 26 patients were divided in 2 groups—30 eyes that underwent primary LASIK with TEC (TEC group) and 22 eyes that underwent LASIK without TEC (control group). 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 and 3-month postoperative results were reported. In this study, the scatter and predictability of manifest refractive cylinder were compared between the TEC and control groups. Postoperatively, eyes that underwent treatment using TEC had a statistically significantly lower scatter of manifest refractive cylinder than the control group (Fig 2) (P=.0028, F test).

Postoperative manifest cylinder in the TEC group was also statistically significantly lower than the control group as shown (Table) (P<.001, Welch’s t test). The results of this study indicated LASIK with active cyclotorsion error correction increases cylinder accuracy of the correction of astigmatism.

In conclusion, the ability to track and compensate for orthogonal and rotational eye movements allows for more accurate delivery of the laser ablation, which leads to better postoperative outcomes.

REFERENCES

TABLE

Vector Analysis of Cylinder Changes at 3 Months Postoperatively of 52 Eyes That Underwent Myopic LASIK With or Without Active Torsion Error Correction (TEC) During Laser Ablation

<table>
<thead>
<tr>
<th>Mean Cylinder±SD (D)</th>
<th>Postoperative Cylinder Reduction* (%)</th>
<th>Mean Axis Error±SD* (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
</tr>
<tr>
<td>TEC group (n=30)</td>
<td>-2.20±0.69</td>
<td>-0.21±0.16</td>
</tr>
<tr>
<td>Control group (n=22)</td>
<td>-1.02±0.59</td>
<td>-0.56±0.34</td>
</tr>
</tbody>
</table>

*P<.01
TEC group comprises eyes that underwent LASIK with active torsion error correction.
Control group comprises eyes that underwent LASIK without active torsion error correction.
Reprinted from Bharti and Bains.7

Figure 2. Manifest refractive cylinder 3 months postoperatively of 52 eyes that underwent myopic LASIK with or without active torsion error compensation (TEC) during laser ablation. Mean cylinder is indicated by the solid black line within the red box. The red box indicates the standard deviation, and the error bars indicate the 95% confidence intervals. Statistically significant differences were noted in the mean manifest cylinder and dispersion with TEC compared to without TEC (P<.01). (Reprinted from Bharti and Bains.)7