Automated Visual Axis Alignment for Refractive Excimer Laser Ablation

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ABSTRACT

PURPOSE: To describe the use of new laser alignment and delivery software in the NIDEK Advanced Vision Excimer laser platform (NAVEX) that allows centration based on surgeon specification.

METHODS: Descriptive article with a case report.

RESULTS: The software allows specification via numeric entry of the exact placement of the laser tapered to the position of the visual axis or the line of sight.

CONCLUSIONS: The ability to specify the exact location of the laser ablation based on pupil position is fundamental in patients undergoing custom ablation and those with eccentric fixation. A conservative treatment strategy is recommended for initial experience with this alignment software. [*J Refract Surg.* 2006;22:S1089-S1092.]

In refractive excimer laser ablation (LASIK or surface ablation) of hyperopia and myopia, it should be the surgeon who determines which axis to choose for centration—the line of sight, the visual axis, or any point between these two landmarks. The correct alignment of the individually applied laser profile plays a fundamental role in the quality of refractive excimer laser ablation. Even minor lateral misalignments can impair the effect of the treatment.[1-3]

The line of sight is defined by the fixation point at one end and the center of the entrance pupil at the other.[4] The center of the entrance pupil is, in theory, a well-defined point. However, in practical terms, it is variable in position. For example, the entrance pupil center is known to change in position as the pupil size changes.[5] This is one of the reasons why aberrometry is best performed under mesopic conditions. Although the line of sight varies with different illumination conditions, the intercept of the visual axis on the cornea usually does not change its position. The visual axis is defined as the line between the fixation point and the fovea.[4] Clinically, it is difficult to locate the visual axis. However, centering the ablation zone along the intercept of the visual axis on the cornea is thought to ensure an equidistant area of refracted light to be projected around the fovea, minimizing the risk of degradation of vision. Hence, Pande and Hillman[6] recommended the visual axis as the reference axis for centration in corneal refractive procedures. In cases with significant eccentric fixation, it has been proposed, for safety reasons, to center the ablation zone half way between the center of the pupil (line of sight) and the visual axis.[7] The reason for this is the difficulty in determining the exact location of the visual axis once the flap had been reflected to expose stroma. Usually, with the flap in place, the adjustment of the first and second Purkinje images provides a good estimation of the location of the visual axis.

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Figure 1. OPD-Scan video image of the eye, depicting the quality of the Placido images and denoting both the central corneal light reflex (blue cross) and the line of sight (purple cross).

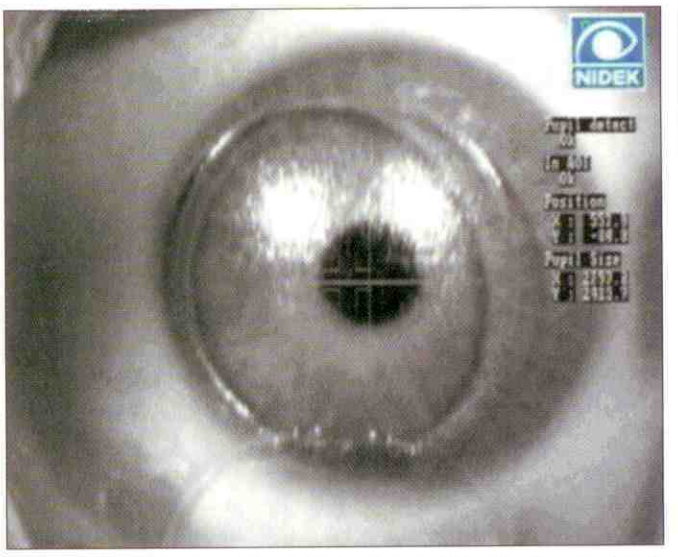

Figure 2. During treatment the center purple cross denotes the actual position of the ablation center, which is in line with the eccentric visual axis in this example. The green cross shows the actual torsional alignment (−1°). Note that the flap with a superior hinge was intentionally centered on the eccentric pupil using a femtosecond surgical laser (IntraLase, Irvine, Calif).

New excimer laser software by NIDEK Co Ltd (Gamagori, Japan) (version 5.27 on CXII or earlier, 8.10 on CXIII models) now allows the automated alignment of the ablation zone on the visual axis during surgery. During the preoperative workup, the OPD-Scan (NIDEK Co Ltd) first identifies and then digitally marks the position of the mesopic and photopic line of sight relative to the coaxial corneal light reflex, which is close to, but not exactly the "visual axis" (Fig 1). The differences between this central corneal reflex and the mesopic or photopic pupil center are computed and given as "MDist" and "PDist" values, respectively. The data are then transferred with all of the other information measured by OPD-Scan into the Final Fit software for preparation of the actual shot data.

For custom ablations, which include multipoint spot ablation (customized aspheric treatment zone and optical path difference customized ablation treatment), the surgeon must determine the centration strategy during the shot file preparation. Selecting the "LOS-Shot Data" function "off" keeps the irregularity ablation (spot ablation) component centered on the corneal reflex (close to the visual axis). With the "LOS-Shot Data" option "on" it will shift the irregularity ablation (spot ablation) component to the pupil center. This option is used in case the surgeon decides to keep the centration for sphere and cylinder on the eye tracker's default position, the pupil center. However, when the surgeon decides to center the sphere and cylinder treatment on the visual axis, MDist/PDist coordinates are used for precise alignment of the ablation zone (Fig 2). With this new software, the surgeon can choose the exact landmark for alignment by entering numerical values into the laser software rather than manually shifting the ablation center with the joystick. Future Final Fit software versions will fully automate this step by processing and transferring the MDist/PDist information automatically with the Final Fit laser shot file. This will likely help improve custom ablation outcomes.

CASE EXAMPLE

A hyperopic patient with differing MDist and PDist values and an OPD-Scan refraction of +4.28 −1.75 × 148 with a best spectacle-corrected visual acuity (BSCVA) of 20/20, was treated with NAVEX. Figure 1 shows the eye image with differing values of the line of sight and the corneal light reflex. Figure 2 shows that the intraoperative alignment of the laser is designated in a position close to the central corneal reflex and not on the line of sight. The preoperative OPD-Scan map is shown in Figure 3. In this case, the full PDist value of 0.6 mm was entered into the software for laser alignment and delivery (Fig 4). Figure 4A shows that the eye tracker was correctly tracking the predetermined region of the pupil. Figure 4B shows the laser delivery was being delivered to the same region. Postoperatively, the corneal topography shows a mild decentration relative to the area of the central corneal reflex. This is due to the fact that we used 100% PDist as the center offset value

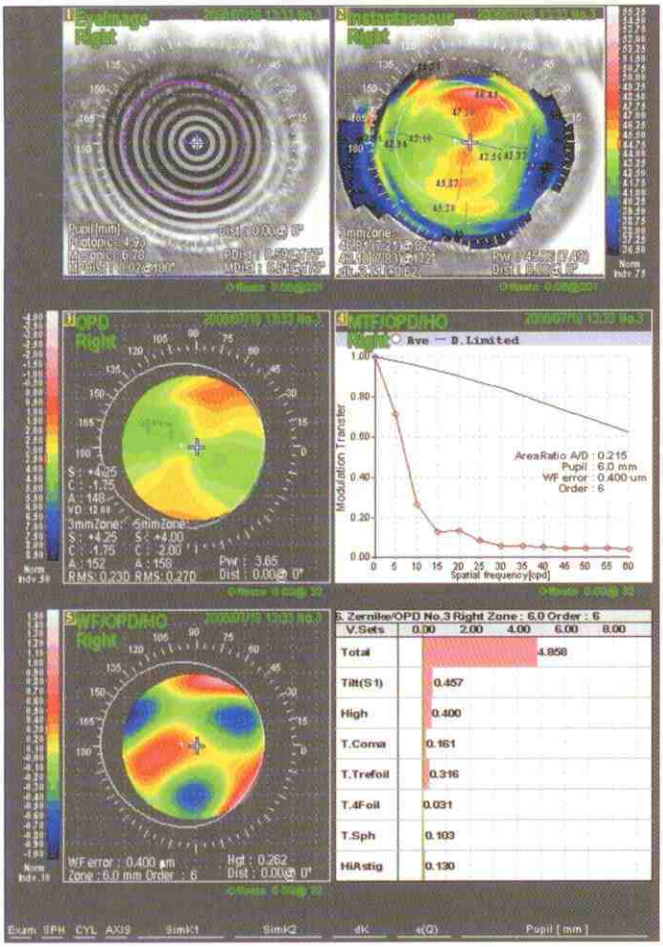

Figure 3. Preoperative diagnostic evaluation using the OPD-Scan. Top left shows the eye image for quality control and iris registration; top right shows instantaneous corneal topography; middle left shows spatially resolved refraction (aberrometry for 6.0 mm) in diopters; middle right shows the modulation transfer function (MTF) with the red line plotting the patient's eye and the blue line plotting the limit of MTF; bottom left shows the higher order (higher order without tilt, sphere, and cylinder) map; bottom right shows a selection of Zernike coefficients.

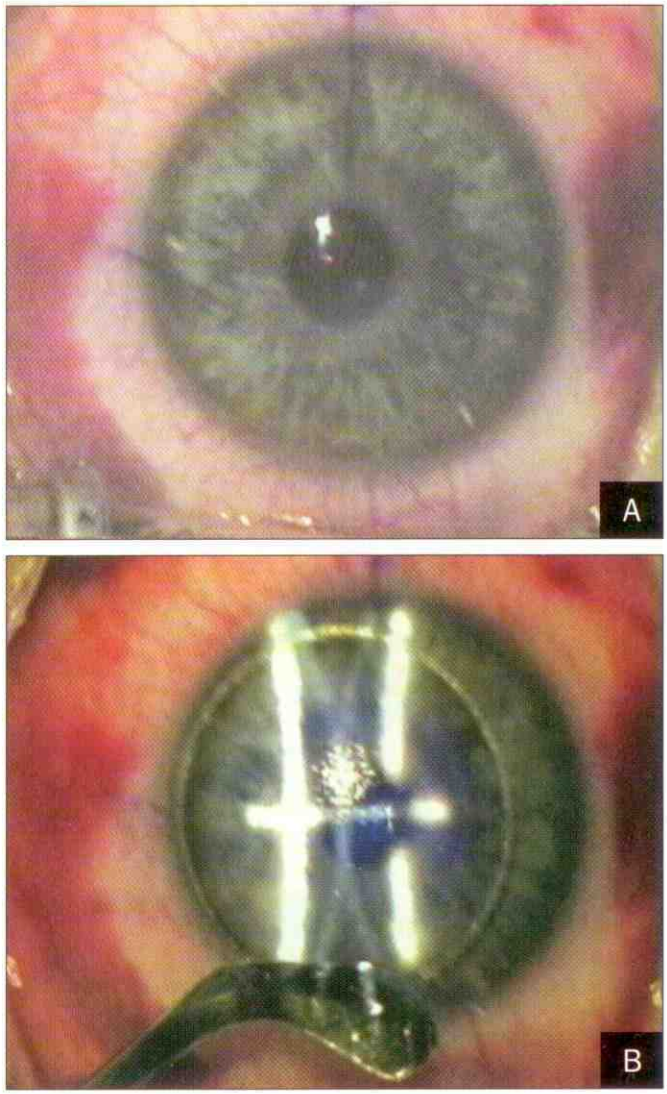

Figure 4. A) Alignment of the laser aiming diode in relation to the pupil. **B)** Laser alignment and delivery to a region of the cornea specified by the NAVEX software. (Note both images show the surgeon's view and are rotated 180° relative to the OPD-Scan images.)

in this case (Fig 5). Subjectively, the patient is asymptomatic postoperatively and uncorrected visual acuity and BSCVA are 20/20.

DISCUSSION

Based on the initial experience with this feature of the NAVEX software, only 50% of the PDist value and an incremental refinement of this value are recommended. The PDist value of the OPD-Scan represents the difference between pupil center and central corneal light reflex and is not the actual location of the visual axis, which may be only 50% to 80% of this value. The location of the intercept of the visual axis on the cornea might change with the change of corneal refraction due to laser ablation (J. Holladay, MD, personal communication, 2006).

Additionally, the change in the line of sight in differing light conditions presents a challenge that has not yet been fully addressed. For example, a change in retinal irradiance between the image and blur circle, and the breakdown of the Stiles-Crawford effect may be accentuated with an alignment strategy that does not account for change in line of sight in differing light conditions.[8]

The alignment of the laser ablation may also have to be specified in each patient taking into account his/her occupation, hobbies, and visual demands in daily life. A truck driver, for example, who does most of his driving at night will likely be more satisfied with the ablation centered on the mesopic pupil center rather

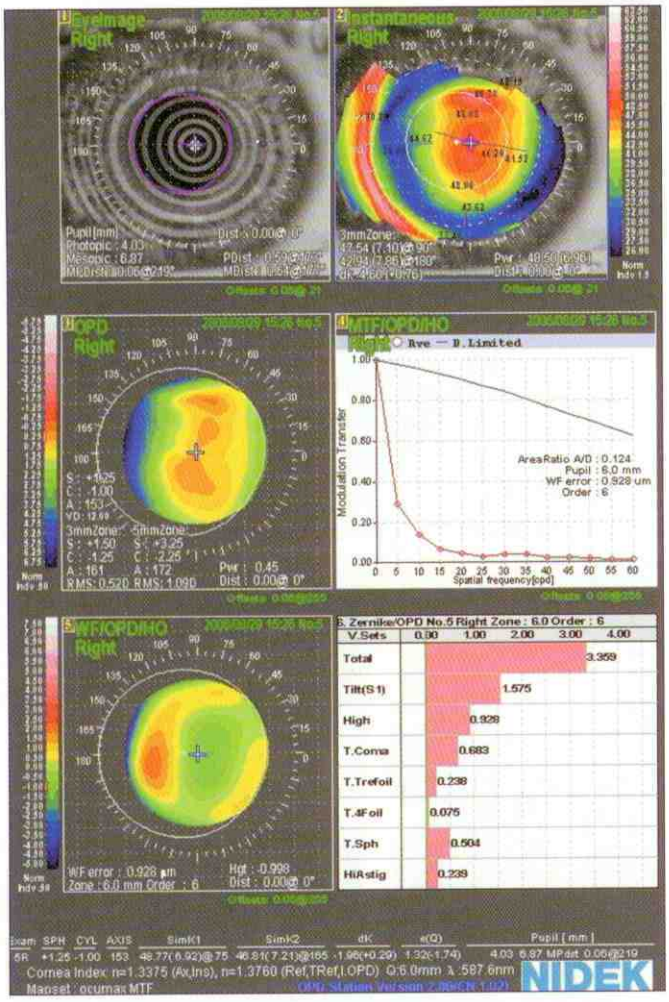

Figure 5. Postoperative diagnostic evaluation using the OPD-Scan. Top left shows the eye image for quality control and iris registration; top right shows instantaneous corneal topography; middle left shows spatially resolved refraction (aberrometry for 6.0 mm) in diopters; middle right shows the modulation transfer function (MTF) with the red line plotting the patient's eye and the blue line plotting the limit of MTF; bottom left shows the higher order (higher order without tilt, sphere, and cylinder) map; bottom right shows a selection of Zernike coefficients.

than the photopic pupil center. The ability to specify the exact center of laser ablation in relation to the pupil will be of fundamental importance for patients who have eccentric fixation such as some hyperopes, patients with significant shift in the line of sight in differing light conditions, and patients undergoing custom ablations. Software now incorporated into the NIDEK NAVEX platform represents a much more accurate method of laser alignment and delivery compared to manual centration over the visual axis.

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