Outcomes of Hyperopic LASIK Centered on the Visual Axis or Line of Sight

Omid Kermani, MD; Uwe Oberheide, PhD; Karl Schmiedt, MD; Georg Gerten, MD; Harkaran S. Bains

ABSTRACT

PURPOSE: To report refractive outcomes of hyperopic LASIK with automated centration on the visual axis compared with centration on the line of sight (LOS).

METHODS: The NIDEK Advanced Vision Excimer Laser platform (NAVEX) was used to treat 181 hyperopic eyes with centration on the LOS (LOS group) and 64 hyperopic eyes with centration on the visual axis (visual axis group). The coordinates of the visual axis were digitally transferred to the excimer laser system based on the positional relationship between the LOS and the coaxially sighted corneal light reflex. All eyes were treated with a 6.5-mm optical zone and 9.0-mm transition zone. Three-month postoperative outcomes were retrospectively analyzed.

RESULTS: The preoperative manifest refraction spherical equivalent (MRSE) was +2.57±1.26 diopters (D) (range: 0.13 to 5.63 D) in the visual axis group and +2.46±1.32 D (range: 0.38 to 5.63 D) in the LOS group. The postoperative MRSE was +0.29±0.70 D (range: −1.00 to 1.75 D) in the visual axis group and +0.19±0.57 D (range: −0.75 to 1.75 D) in the LOS group. Postoperatively, 81% (38/47) of eyes in the visual axis group and 64% (74/116) of eyes in the LOS group were ±0.50 D. In the visual axis group, 91% (44/52) of eyes and 92% (102/109) of eyes in the LOS group maintained best spectacle-corrected visual acuity within one line compared with preoperatively.

CONCLUSIONS: Initial experience with hyperopic LASIK centered on the visual axis indicated safe and predictable outcomes. [*J Refract Surg*. 2009;25:Sxxx-Sxxx.]

Ablation centration strategies for the treatment of patients undergoing excimer laser treatment remains controversial. Two alternate landmarks have been proposed; the line of sight (LOS) and the visual axis.[1,2]

Centration is being increasingly debated due to the introduction of wavefront-guided[3] treatments, topography-guided treatments,[4] and refined ablation algorithms that treat hyperopic refractive error successfully.[5] Custom ablation requires meticulous centration to reduce rather than induce aberrations.[6] Centration of hyperopic ablations is important due to the smaller effective optical zones achieved and the greater prevalence of angle kappa in hyperopia compared with myopia.[5,7] The risk of decentrations is greater in hyperopic treatments due to these factors. Centration on the LOS does not account for the shift in pupil center with differing pupil size.[8] Alternately, surgeon "sighting" of the visual axis approximated by the coaxially sighted corneal light reflex can vary.[9] In addition, the coaxially sighted corneal light reflex obtained from corneal topography may not provide an accurate location of the visual axis.[10]

Recent studies have reported safety and efficacy with hyperopic ablations centered on the visual axis using the coaxially sighted corneal reflex.[9,11] To date, there are no published comparative studies of hyperopic LASIK centered on the LOS or the visual axis. Currently, only the NIDEK Advanced Vision Excimer Laser platform (NAVEX; NIDEK Co Ltd, Gamagori, Japan) offers a closed loop of visual axis identification, computation of centration landmarks coordinates with regard to the LOS, shot data recalculation, and eyetracker centration to a surgeon-desired offset distance. In this study, we report our experience of hyperopic LASIK centered on the LOS or visual axis (defined as midway between the photopic LOS and coaxially sighted corneal reflex [50% P.Dist]).

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The authors have a proprietary interest in the material presented herein. Dr Kermani and Mr Bains are clinical consultants to NIDEK Co Ltd, Gamagori, Japan.

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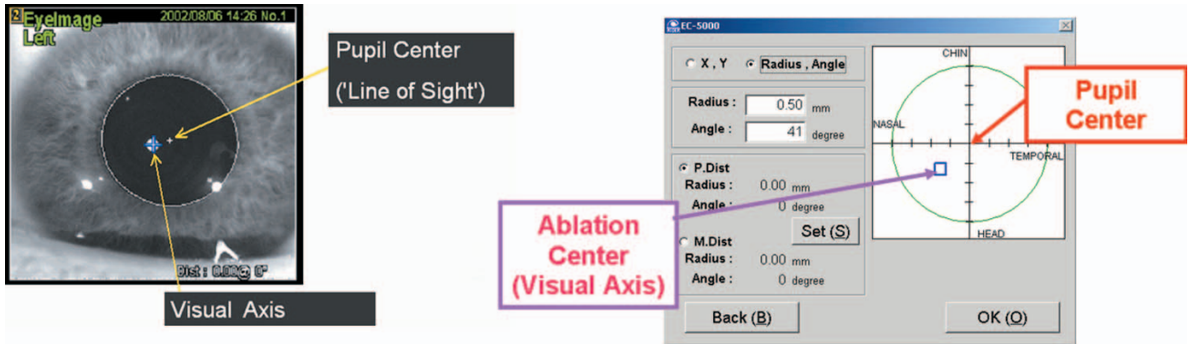

Figure 1. A) Centering landmarks identified during the OPD-Scan (NIDEK Co Ltd) measurement. The coaxially sighted corneal light reflex is considered an accurate estimation of the visual axis and the pupil center denotes the line of sight. **B)** Screen capture of the automated data import of the position of the visual axis in relation to the photopic line of sight (P.Dist). The distance and angle can be changed based on surgeon preference.

PATIENTS AND METHODS

Refractive outcomes of 245 eyes of patients who underwent hyperopic LASIK were retrospectively analyzed. One hundred eighty-one eyes (99 women; 93 right eyes) underwent treatment with centration on the LOS (LOS group) between 2003 and 2004and our initial cohort of 64 eyes (28 women; 33 right eyes) that underwent treatment with centration on the visual axis (visual axis group) between 2006 and 2007. Patients in the LOS group underwent LASIK with the NIDEK MK-2000 keratome (NIDEK Co Ltd) that created a nasal-hinged flap using either an 8.5- or 9.5-mm ring with 130/160-µm head. All eyes in the visual axis group underwent flap creation using the IntraLase (Advanced Medical Optics, Irvine, Calif) laser keratome with a superior-hinged flap with a preset flap thickness of 110 µm. All eyes underwent laser ablation using the NAVEX with a 6.5-mm optical zone and a 9.0-mm transition zone. The CX excimer laser (NIDEK Co Ltd) software version 1.24 and eyetracker software version 5.28 were used for all treatments. The NAVEX platform has been described previously.[3,4]

Preoperatively, all patients underwent an ophthalmic evaluation that included corneal topography, wavefront aberrometry (6-mm pupil; sixth Zernike order), autorefraction, autokeratometry, and pupillometry, all performed using the OPD-Scan (NIDEK Co Ltd); uncorrected visual acuity (UCVA) (decimal notation); best spectacle-corrected visual acuity (BSCVA); manifest and cycloplegic refractions (pushing plus method); strabismus examination; slit-lamp microscopy of the anterior segment and cornea; ultrasound corneal pachymetry; and dilated funduscopy. Tear-film testing (Schirmer I and II, break-up time) was performed in all patients. At 3 months postoperatively, patients underwent the same evaluations with the exception of the cycloplegic refraction, strabismus examination, dilated funduscopy, and tear-film testing.

Preoperatively, the OPD-Scan identifies and digitally marks the position of the mesopic and photopic LOS relative to the coaxially sighted corneal light reflex, which is close to, but not exactly, the "Visual Axis" (Fig 1). The difference between the central corneal reflex and the mesopic or photopic pupil center is computed and given as "Mdist" and "Pdist" values, respectively. The positional data can be transferred via the OPD-Scan into the Final Fit software (NIDEK Co Ltd) during preparation of the shot data for laser ablation.[12] During treatment simulation, the center of the ablation can be positioned at either the LOS or visual axis or at any point between using a Cartesian coordinate system.[12] The centering procedure is entirely automated, and data are transferred to a 200-Hz infrared eyetracker and does not rely on surgeon estimation of landmarks during surgery.

All surgeries were performed by two surgeons (O.K., G.G.), using the same surgical technique that has been described previously.[5] Based on our previous experience,[5,12] we elected to center the laser ablation midway between the photopic LOS and the visual axis (50% P.Dist option entered into Final Fit). Three-month postoperative refractive outcomes, visual acuity, and ocular higher order root-mean-square (RMS) values are reported.

RESULTS

In the visual axis group, the preoperative manifest refraction spherical equivalent (MRSE) was +2.57±1.26 diopters (D) (range: 0.13 to 5.63 D), mean spherical hyperopia was +3.27±1.48 D (range: 0.75 to 7.75 D), and mean cylinder was −1.40±1.25 D (range: −4.50 to 0.00 D). Preoperatively, the mean MRSE was +2.46±1.32 D (range: −0.38 to 5.63 D),

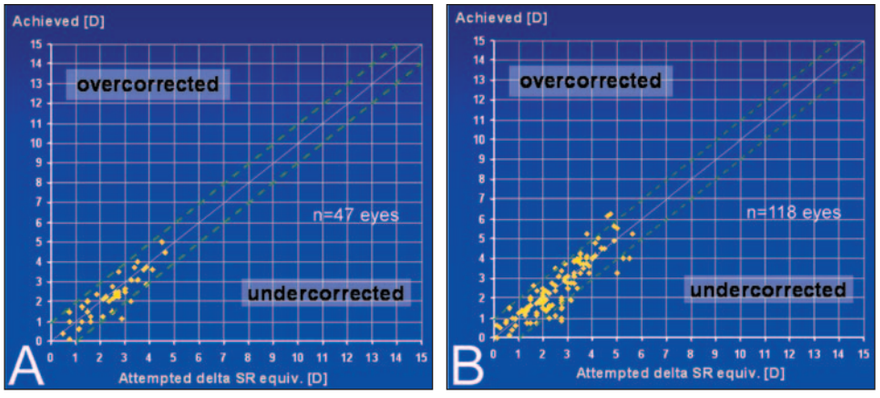

Figure 2. Attempted vs achieved manifest refraction spherical equivalent (SR equiv) of eyes that underwent hyperopic LASIK centered on the **A)** visual axis or **B)** line of sight.

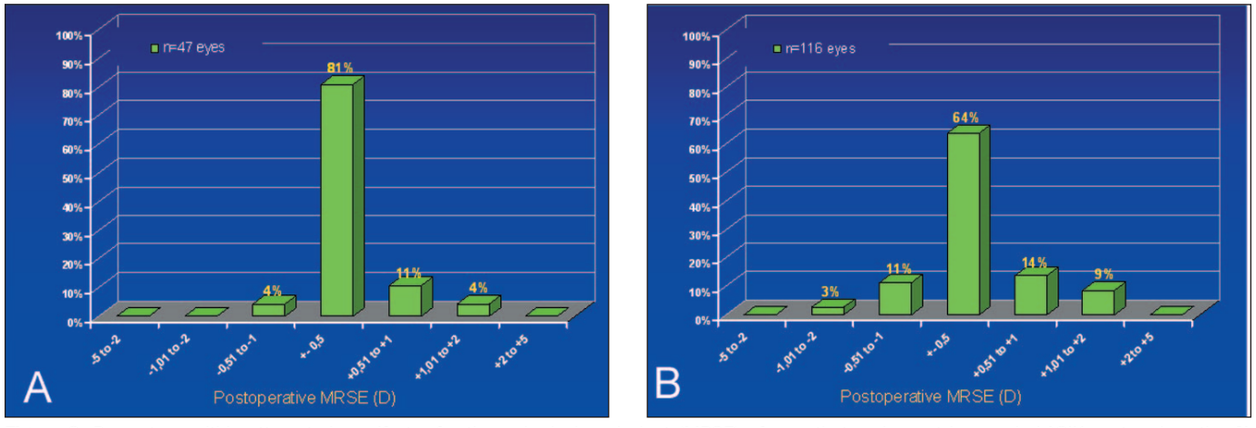

Figure 3. Percentage within attempted manifest refraction spherical equivalent (MRSE) of eyes that underwent hyperopic LASIK centered on the **A)** visual axis or **B)** line of sight.

mean spherical hyperopia was +3.03±1.35 D (range: 0.25 to 5.75 D), and mean cylinder was −1.14±0.95 D (range: −4.50 to 0.00 D) in the LOS group.

Fifty-two eyes in the visual axis group and 118 eyes in LOS group were available for 3-month follow-up. In the visual axis group, the mean postoperative MRSE was +0.19±0.57 D (range: −0.75 to 1.75 D), mean sphere was +0.50±0.68 D (range: −0.50 to 2.25 D), and mean cylinder was −0.62±0.54 D (range: −2.25 to 0.00 D). The mean postoperative MRSE was +0.01±0.65 D (range: −1.50 to 1.88 D), mean sphere was +0.26±0.69 D (range: −1.50 to 2.50 D), and mean cylinder was −0.51±0.45 D (range: −2.50 to 0.00 D) in the LOS group.

Figure 2 plots the attempted versus achieved MRSE for both groups. Postoperatively, 38 (81%) eyes in the visual axis group and 74 (64%) eyes in the LOS group were within 0.50 D of the intended MRSE (Fig 3). Clinically significant loss or gain of lines was considered a change of 2 lines or greater. There was no clinically significant change in 44 (91%) eyes, whereas 5 (10%) eyes lost 2 lines of BSCVA and 3 (6%) eyes gained 2 or more lines of BSCVA in the visual axis group (Fig 4). In the LOS group, 102 (92%) eyes maintained BSCVA, whereas 6 (6%) eyes lost 2 or more lines of BSCVA and 3 (3%) eyes gained 2 lines of BSCVA (Fig 4). In the visual axis group, 30 (73%) eyes had 0.8 or better UCVA and 9 (22%) eyes had 1.3 or better UCVA postoperatively (Fig 5). In the LOS group, 85 (73%) eyes had 0.8 or better UCVA, and 14 (12%) eyes had 1.3 or better UCVA postoperatively (Fig 5). Higher order RMS did not increase in the visual axis group postoperatively compared with the LOS group (Fig 6). The modulation transfer function (MTF) decreased in both groups postoperatively (Fig 6).

DISCUSSION

The refractive outcomes of hyperopic LASIK centered on the visual axis in this preliminary cohort of eyes were shown to be safe and effective. There was minimal loss of clinically significant BSCVA 3 months postoperatively (see Fig 4), and the majority of eyes were within 0.50 D of the intended MRSE (see Fig 3). Compared with that for the control group (LOS group), the UCVA was similar postoperatively. In this study, we found minimal differences between the visual axis group and LOS group. Due to the significant difference

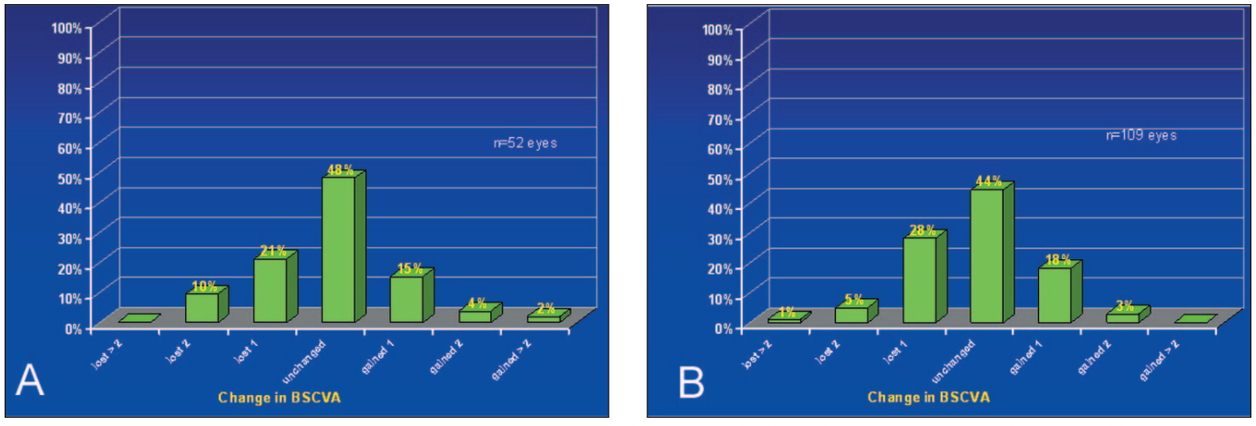

Figure 4. Three-month postoperative change in best spectacle-corrected visual acuity (BSCVA) of eyes that underwent hyperopic LASIK centered on the **A)** visual axis or **B)** line of sight.

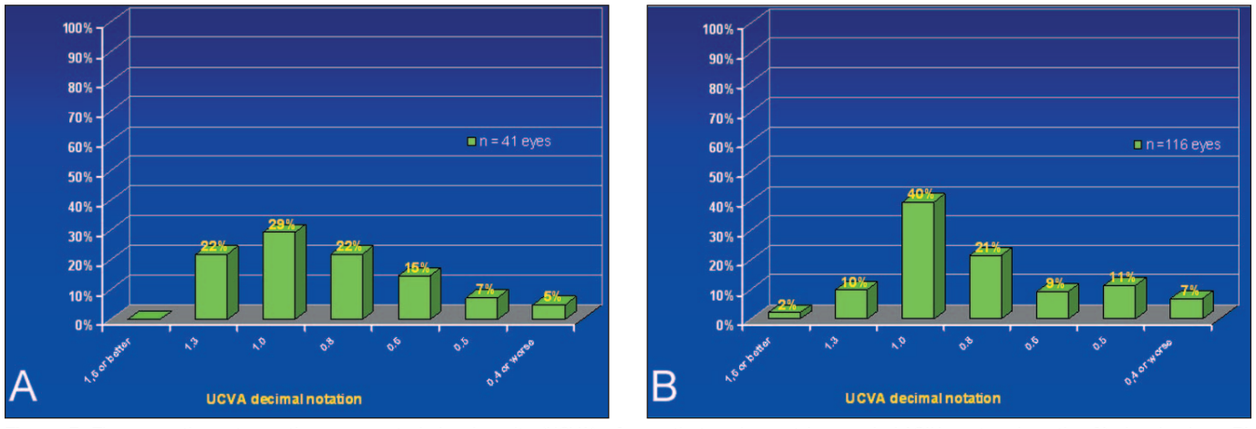

Figure 5. Three-month postoperative uncorrected visual acuity (UCVA) of eyes that underwent hyperopic LASIK centered on the **A)** visual axis or **B)** line of sight.

in the number of eyes analyzed between groups, our findings need to be interpreted with caution. The outcomes presented here represent our initial experience of centering toward the visual axis (50%P-Dist) in a controlled, predictable manner as opposed to subjective surgeon sighting.

The greater difference of the position of the visual axis in hyperopia compared with myopia (Fig 7), coupled with the introduction of wavefront-guided hyperopic treatments, makes ablation centration a critical issue. A sample of candidates from our refractive surgery center clearly shows a difference in the visual axes in myopia compared with hyperopia (see Fig 7). All hyperopic eyes under study had visual axes displaced from the LOS with a mean distribution of 0.26 mm @ 364° in right eyes and 0.24 mm @ 174° in left eyes at 50% P.Dist (Fig 8). The mean total offset in the hyperopic population was as high as 0.50 mm (data not shown). Based on these and other documented differences,[7] centering on the LOS for hyperopic ablations may risk symptoms associated with decentered ablations likely inducing coma. Due to the ambiguous position of LOS under different illumination, which cannot be addressed properly during surgery, we believe centering on the LOS poses greater risk of decentered ablations.[2,12] Symptoms such as monocular diplopia, ghosting, and glare may become worse due to the change in retinal irradiance between the image and blur circle and the reduction of the Stiles–Crawford effect due to this lack of compensation for the change in LOS.[13]

Due to our limited previous experience with centration on the visual axis, we used a conservative approach of treating halfway between the visual axis and the LOS (50% P.Dist). Whether treatments closer to the visual axis provide greater benefit will be addressed with more experience. A unique aspect of the OPD-Scan is that it measures corneal topography, pupil size, and pupil shape. This allows direct measurement rather than estimation (as with stand-alone

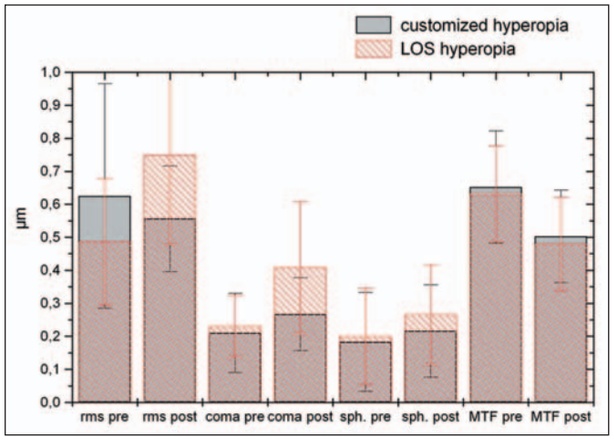

Figure 6. Root-mean-square (RMS) values and modulation transfer function (MTF) preoperatively and 3 months postoperatively of eyes that underwent hyperopic LASIK centered on the visual axis (customized hyperopia; n = 52 eyes) or the line of sight (LOS hyperopia; n = 109).

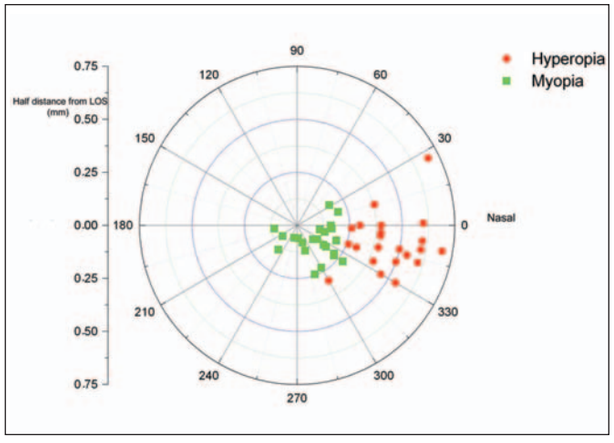

Figure 7. Distribution of the visual axis in 25 myopic eyes and 22 hyperopic eyes from refractive surgery candidates. LOS = line of sight

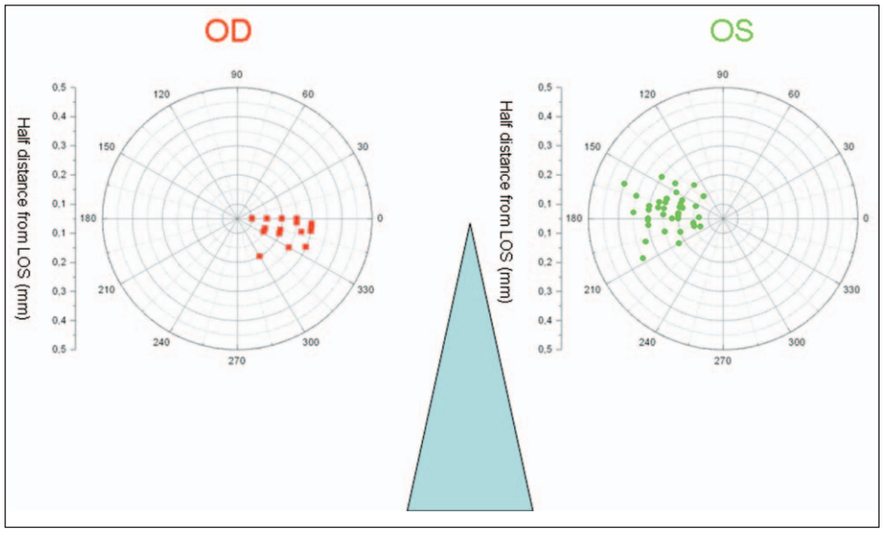

Figure 8. Distribution of the visual axis in relation to the line of sight (LOS) of 33 right eyes and 31 left eyes of a cohort of hyperopic refractive surgery candidates. Depicted is 50% P.Dist (half-offset distance from center of entrance pupil, LOS). Data represent actual shot file data for customized alignment in this study.

corneal topographers) of the difference between the coaxially sighted corneal light reflex (closest landmark to visual axis) and the differing LOS (defined by the pupil centers). Whether this is a relatively accurate measurement of the visual axis must be confirmed with a comparative study to a synoptophore. Statistically significantly higher angle kappa values from corneal topography compared with a synoptophore have been reported recently.[12] For example, in hyperopia the differences ranged from 1.25° to 2.43°. Our results confirm our previous observations and other studies that report better centration using the corneal reference compared with the LOS.[5,9,11,12,14]

An additional advantage of using this automated alignment system is that it mitigates surgeon-induced error[9] in estimating the position of the visual axis. Furthermore, the position of the visual axis is harder to visually estimate once the corneal flap is reflected to expose the underlying stroma.[5] The transfer of the positional coordinates to the eyetracker and excimer laser system ensures that the ablation remains centered on the visual axis regardless of the optical quality of the cornea during treatment.

Decentered ablations can result in the induction of coma aberrations.[9] We found a relatively low induction of coma in the visual axis group postoperatively (see Fig 6). The total ocular higher order aberrations decreased postoperatively in the visual axis group but not in the LOS group (see Fig 6). This finding may indicate that better centration and better visual quality are achieved by centering on the visual axis. Studies with a larger sample are required to determine whether this is this case.

Hyperopic LASIK centered on the visual axis is safe and predictable, with little induction of higher order aberrations. Treatment on the visual axis may result in better centration. Additional studies are required to validate our preliminary experience with this technique.

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AUTHOR QUERIES

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Please define line of sight and visual axis at first mention in the introductory paragraph.

The following was changed. Okay as edited?

Original: One hundred eighty-one eyes (99 women; 93 right eyes) underwent treatment with centration on the LOS (LOS group) in 2003/2004 and our initial cohort of 64 eyes (28 women; 33 right eyes) that underwent treatment with centration on the visual axis (visual axis group) in 2006/2007.

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