ABSTRACT

PURPOSE: To report the ocular and corneal higher order aberrations of a pilot trial of optimized prolate ablations for the treatment of myopia.

METHODS: In this prospective study, patients were treated using optimized prolate ablation or conventional ablation. Five patients underwent bilateral optimized prolate ablation treatment, and nine patients were randomized to receive optimized prolate ablation (OPA group) in one eye and conventional ablation (control group) in the other eye. The mean preoperative manifest refraction spherical equivalent was \(-4.13 \pm 1.17\) diopters (D) (range: \(-8.00\) to \(-1.50\) D), with a mean cylinder of \(-0.42 \pm 0.32\) D (range: \(-1.00\) to 0.00 D). Predictability, contrast sensitivity, and corneal and ocular aberrations were analyzed out to 6 months postoperatively.

RESULTS: Postoperative predictability was similar between the two groups. There was an increase in mesopic contrast sensitivity in the OPA group, and the OPA group had higher mesopic contrast sensitivity postoperatively. At 6 months postoperatively, the root-mean-square (RMS) of the total ocular higher order aberrations was 0.47 \(\mu\)m for the OPA group and 0.75 \(\mu\)m for the control group. Ocular spherical aberration was 0.04 \(\mu\)m for the OPA group and 0.22 \(\mu\)m for the control group. Six-month postoperative RMS of corneal spherical aberration was 0.25 \(\mu\)m for the OPA group and 0.46 \(\mu\)m for the control group.

CONCLUSIONS: The preliminary outcomes in this study indicate that optimized prolate ablation-treated eyes had less induction of higher order aberration and spherical aberrations postoperatively. Better contrast sensitivity was noted in eyes that underwent optimized prolate ablation treatment compared with preoperatively. [J Refract Surg. 2009;25:S136-S141.]

PATIENTS AND METHODS

In this prospective study, 14 patients with myopia with pupil sizes of 6.00 mm or larger were grouped into 5 patients who underwent bilateral optimized prolate ablation LASIK (OPA group) and 9 LASIK patients whose eyes were randomized to receive optimized prolate ablation in 1 eye (OPA group) and conventional ablation in the contralateral eye (control group).

All eyes underwent LASIK using the IntraLase (Advanced Medical Optics Inc, Santa Ana, Calif) keratome targeting 110-\(\mu\)m flap thickness and the NIDEK Advanced Vision Excimer laser platform (NAVEX; NIDEK Co Ltd, Gamagori, Japan). A 200-Hz infrared eyetracker and a torsion error detection module were used to deliver the ablation to the prescribed corneal location. The optimized prolate ablation al-

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algorithm and pre- and postoperative protocol have been described previously. The optical zone selected for the optimized prolate ablation treatments was centered on the vertex normal (visual axis) and covered the entire mesopic pupil diameter measured by the NIDEK OPD-Scan (NIDEK Co Ltd). All transition zones for optimized prolate ablation treatments were 1.50 mm larger than the programmed optical zone. Zero postoperative spherical aberration was targeted for all eyes in the OPA group. For the conventional ablations, the largest optical zone/transition zone combination with a similar ablation depth as the contralateral optimized prolate ablation eye was always selected. All treatments in the control group were centered on the pupil (line of sight). All eyes of all patients were targeted for emmetropia.

Postoperatively, patients were assessed at 1 day, 1 week, and 1, 3, and 6 months. Ocular and corneal higher order aberrations, spherical aberrations, and coma were determined using the OPD-Station software (NIDEK Co Ltd) for a 6-mm pupil plotted to the sixth Zernike order. Predictability and mesopic contrast sensitivity were evaluated 6 months postoperatively. Mesopic contrast sensitivity was tested with best correction using the CSV-1000 (Vector Vision Inc, Greenville, Ohio).

**RESULTS**

Preoperatively, the mean age of the entire cohort of patients was 27 years (range: 20 to 41 years), the mean manifest refraction spherical equivalent (MRSE) was \(-4.13 \pm 1.17\) diopters (D) (range: \(-8.00\) to \(-1.50\) D), and the mean cylinder was \(-0.42 \pm 0.32\) D (range: \(-1.00\) to \(-0.00\) D). At 6 months postoperatively, 25 (89.5%) eyes were available for follow-up. Predictability is plotted in Figure 1. All eyes in the OPA group and 7 (78%) of the 9 eyes in the control group were within 1.00 D of the intended MRSE. Mesopic contrast sensitivity is plotted in Figure 2. No difference was noted in the control group compared with preoperatively. In the OPA group, the contrast sensitivity increased at 12 cycles per degree (cpd) compared with preoperatively. A greater difference in postoperative contrast sensitivity changes was noted in the OPA group.

At 6 months postoperatively, ocular higher order root-mean-square (RMS) was 0.75 µm for the control group and 0.47 µm for the OPA group (Fig 3). There was no change in ocular spherical aberration in the OPA group from pre- to postoperatively (Fig 4). At 6 months postoperatively, there was an increase in ocular spherical aberration in the control group (see Fig 4). The ocular spherical aberration was lower in the OPA group.
Figure 3. Ocular higher order aberration root-mean-square (RMS) (µm) for 28 eyes that underwent optimized prolate ablations (OPA) or conventional (Conv) LASIK. All measurements were performed for a 6-mm pupil to the sixth Zernike order.

Figure 4. Ocular spherical aberration for 28 eyes that underwent optimized prolate ablations (darker color) or conventional (lighter color) LASIK. All measurements were performed for a 6-mm pupil to the sixth Zernike order.

Figure 5. Corneal spherical aberration for 28 eyes that underwent optimized prolate ablations (OPA) or conventional (Conv) LASIK. All measurements were performed for a 6-mm pupil to the sixth Zernike order.
at all postoperative visits compared with the control group (see Fig 4). In the OPA group, corneal spherical aberration increased 0.03 µm from preoperatively to 6 months postoperatively (Fig 5). Over the same period, there was a 0.23-µm increase in corneal spherical aberration in the control group (see Fig 5). Coma increased by 0.14 µm in the control group and decreased in the OPA group (Fig 6). Corneal coma increased from 0.23 µm preoperatively to 0.38 µm 6 months postoperatively in the control group and from 0.20 µm to 0.24 µm 6 months postoperatively in the OPA group (Fig 7). There was lower induction of ocular coma and corneal coma in the OPA group (see Figs 6 and 7). Preoperatively, there was greater scatter in ocular coma in the OPA group; 6 months postoperatively, there was greater scatter in the control group (Fig 8).

A representative case example of postoperative corneal topography is shown in Figure 9. The preoperative manifest refraction was $-4.25 - 0.25 \times 180^\circ$ in the right eye and $-4.50 - 0.25 \times 175^\circ$ in the left eye. The patient underwent conventional ablation in the right eye and optimized prolate ablation in the left eye. Six months postoperatively, the effective optical zone is larger in the optimized prolate ablation-treated left eye, and the conventionally treated right eye is oblate (see Fig 9).

**DISCUSSION**

Optimized prolate ablations differ from other aspheric treatment in three ways. First, they treat the ocular spherical aberration specific to the eye; second, they treat the corneal irregularities (higher order aberrations); and third, the optical zones are centered on the “visual axis” (vertex normal) that incorporates the entire mesopic pupil. This unique strategy is possible due to the OPD-Scan, which can measure and separate corneal aberrations from the internal aberrations and marks the line of sight (pupil center) and “visual axis.”
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The potential advantages of the optimized prolate ablation architecture are the patient-specific compensation for the radial loss of energy, the treatment of pre-existing spherical aberrations and corneal aberrations that may degrade visual quality, and ablation centration that extends beyond the scotopic pupil diameter to circumvent dysphotopsias such as halo and glare. Theoretically, no additional spherical aberration should be induced using optimized prolate ablation.

This was the case in our study, in which we considered the ocular and corneal spherical aberrations induced by optimized prolate ablation to be clinically insignificant. In the conventionally treated eyes, we found significant induction of spherical aberration and higher order aberrations that increased over time, which may be the byproduct of epithelial healing (see Figs 4 and 5).

In this study, we elected to center optimized prolate ablation treatments midway between the center of the entrance pupil and the vertex normal. This offset is calculated by the OPD-Station software and is transferred to the excimer laser computer with the shot data file. The conventional laser ablation was centered on the pupil center. This may explain, at least partly, the approximately two-fold increase in coma in the control eyes. Induction of coma has been linked to decentration.9 Because the same surgeon (M.A.E.) performed all surgeries, it is unlikely that a systematic decentration occurred in the control eyes only. The mild increases in higher order aberrations, coma, and spheric-
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Optical aberrations may well have contributed to the better visual quality measured by contrast sensitivity in the optimized prolate ablation-treated eyes.

In this pilot study, all optimized prolate ablation-treated corneas were prolate postoperatively (data not shown). Applying more ablation to the midperiphery maintains the physiologic prolate shape, which reduces the effect of aberrations significantly compared with oblate corneas.10

A larger sample size with a contralateral study design is required to validate the outcomes presented herein. In the present study, it was found that higher order aberrations such as spherical aberration and coma remain unchanged and there was an increase in visual quality compared with preoperatively using optimized prolate ablations.

REFERENCES


