Customized Aspheric Treatment Zone Ablation to Treat Irregular Corneas After Corneal Refractive Surgery

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ABSTRACT

PURPOSE: To describe the retreatment of highly aber-rated corneas due to previous keratorefractive surgery using topography-guided aspheric treatments.

METHODS: Eight eyes (five patients) with reduced mesopic visual quality due to previous keratomileusis, excimer laser surgery, or radial keratotomy underwent retreatment with the customized aspheric treatment zone (CATz) algorithm with the CXIII excimer laser (NIDEK Co Ltd) to correct corneal wavefront aberrations. Before CATz treatments, all patients were satisfied with their preoperative photopic vision (all 20/30 or better uncorrected) yet were dissatisfied with their vision at night. All eyes had >20 µm (range: 20 to 33 µm) of corneal irregularity before CATz retreatment. All eyes had a flap cut or flap lift procedure for CATz retreatment.

RESULTS: One year after treatment with CATz, no eyes lost best spectacle-corrected visual acuity (BSCVA); all eyes had BSCVA of 20/30 or better. Mean modulation transfer function increased by 13% by the end of the first postoperative year. A 0.45-µm decrease was noted in coma 1 year postoperatively.

CONCLUSIONS: The CATz algorithm is effective in the treatment of severe corneal irregularities due to previous keratorefractive surgery.

keratorefractive surgery such as radial keratotomy, keratomileusis, and LASIK can reduce visual quality due to the induction of higher order aberrations. In some patients, good high contrast visual acuity does not preclude a reduction in postoperative visual quality. The cause of this decrease in visual quality in such cases is an irregular cornea postoperatively. In such cases, what would seem an adequate and sometimes excellent postoperative outcome is muted by a patient’s complaint of reduced visual quality at night. The treatment of such patients involves extensive postoperative counseling, pharmacologic intervention, contact lens therapy, and more recently, topography-guided retreatment. Topography-guided excimer laser treatment of symptomatic eyes seems to be the preferred surgical intervention due to the ability to measure highly aberrated corneas using corneal topography, the large measurement diameter, and greater number of data points compared to Hartmann-Shack aberrometry.

The current study describes the use of the customized aspheric treatment zone algorithm (CATz; NIDEK Co Ltd, Gamagori, Japan) to treat eyes with reduced visual quality due to previous keratorefractive surgery.

PATIENTS AND METHODS

In this retrospective study, eight eyes of five men were evaluated who had undergone previous keratorefractive surgery (eg, keratomileusis, radial keratotomy, LASIK, photorefractive keratectomy) and were retreated using the CATz algorithm with the NIDEK Advanced Excimer Laser System (NAVEX, NIDEK Co Ltd). The CATz algorithm and NAVEX have been described previously. Mean patient age was 34 years (range: 23 to 47 years). The mean manifest refraction spherical equivalent (MRSE) was −1.23±2.03 diopters (D) (range: −4.38 to
TREATMENT SIMULATION

Corneal topography, wavefront data, and pupillometry were acquired using the OPD-Scan II. Data were transferred to the Final Fit software (NIDEK Co Ltd) using a universal serial bus stick (USB). The treatment plans from Final Fit software were subsequently transferred to the CXIII excimer laser with a USB. Final Fit ablation planning software was used to plan and simulate treatments and generate shot data. Initial treatment planning with Final Fit software was for the reduction of corneal irregularity only. The refractive error was not treated in the first phase of treatment due to the extremely high levels of irregularity in all cases (>20 µm).

The treatments were simulated using a combination of treatment zones that encompassed the corneal irregularity detected by the OPD-Scan II and Final Fit software. Treatment simulations were planned with a final result of symmetric shape as described by Yoshida et al.4 In all cases, 100% of the treatment rate and the corneal wavefront mode were used for treatment of the irregularity component.

A flap lift or a new flap cut was performed in all cases. The eye underwent a povidone-iodine scrub followed by the instillation of one drop of topical anesthetic. A lid speculum was inserted to allow maximum globe exposure followed by instillation of two drops of topical anesthetic. A flap recut was performed using the Moria M2 microkeratome (Moria, Antony, France) with a larger flap diameter or deeper cut as required in each case. The primary LASIK technique has been described previously.7
Flap lift was performed under the laser microscope, and the flap margin was identified using a Sinskey hook (Medicon Ltd, Denmark). A Siebel IntraLase flap lifter and retreatment spatula (Rhein Medical Inc, Tampa, Fla) was inserted under the edge of the flap, pushed horizontally until the tip appeared from under the opposite side of the flap and then moved superiorly towards the hinge then inferiorly until the lower edge of the flap was freed. The laser delivery was aligned midway between the coaxially sighted corneal vertex and the pupil center (50% P-Dist value in Final Fit). This resulted in ablation centration closer to the visual axis not directly on the line of sight. Alignment was maintained by using a 200-Hz video-based eye tracker and patient fixation cooperation.

After laser ablation, the corneal bed was irrigated with balanced salt solution and the flap was reflected back onto the cornea, allowing it to adhere for 1 minute followed by instillation of one drop of topical nonsteroidal anti-inflammatory antibiotic and preservative-free artificial tears. Patients were discharged with instructions to instill topical antibiotic four times a day for 1 week and preservative-free artificial tears for 2 months or longer as required.

Mean UCVA, BSCVA, wavefront aberrations, and corneal topographies before and 6 months or later after CATz retreatment were recorded.

**RESULTS**

Visual acuity and refraction before and after CATz retreatment are presented in the Table. Best spectacle-corrected visual acuity before and after CATz retreatment is plotted in Figure 1. Postoperatively, 4 (50%) eyes were 20/20 or better and all eyes were 20/30 or bet-
Mean spherical aberration decreased by 0.45 µm postoperatively (Fig 2). Mean coma decreased by 0.45 µm (Fig 3). The ratio of higher order modulation transfer function (MTF) of the treated eyes to the MTF of emmetropes increased over time (Fig 4).

CASE REPORT

A patient who underwent LASIK overseas with a "tissue-saving" algorithm of a flying spot laser 1 year prior presented with complaints of severe starburst at night localized to the right eye. Records from the primary LASIK surgeon were not available and partial history was garnered from the patient. In the right eye, the refraction before primary LASIK was −10.00 −1.75 × 175. At presentation, UCVA in the right eye was 20/20 and BSCVA was 20/16 with 0 −0.25 × 20 (Case 3 in the Table). Slit-lamp microscopy was unremarkable, corneal thickness was 450 µm, and the dark adapted pupil diameter was 6.7 mm measured with the OPD-Scan II. Estimated effective optical zone on corneal topography before CATz retreatment was 4 mm. The OPD higher order map (OPD HO) shows an 8.00-D difference in refractive power across the pupil due to higher order aberrations of the eye (Fig 5). We elected to treat 24.50 µm of corneal irregularity with the corneal wavefront option of the Final Fit software. The refractive error was not treated.

One year after CATz retreatment, UCVA was 20/16, BSCVA remained unchanged at 20/16 with +0.50 D sphere. The effective optical zone increased considerably after retreatment (see Fig 5) and the refractive gradient caused by the higher order aberrations across the
pupil (OPD HO) decreased to 1.25 D (see Fig 5). The coma decreased from 2.13 μm before retreatment to 1.20 μm after retreatment. The MTF of the higher order curve increased from 36.3% to 60.8% (H/B ratio, see Fig 5). The patient reported resolution of symptoms.

**DISCUSSION**

In this study, the surgical treatment of patients with debilitating visual quality after previous refractive surgery was effective. There was an increase in mean higher order MTF over time indicating an increase in visual performance after CATz treatment (see Fig 4). This gain in visual performance was directly due to the treatment of higher order aberrations, as refractive error was not treated in this cohort of patients. All five patients were satisfied postoperatively.

In all cases, the primary goal was to regularize the corneal surface not the treatment of the refractive error. High magnitudes of higher order aberrations can lead to an inconclusive refraction. By making the corneal surface smooth and waiting for it to stabilize, a more conclusive refraction and a reduction of scotopic symptoms is possible. Some have advocated a one-step procedure in retreatment of eyes with significant aberration. However, one of these studies did not present the wavefront aberration data to determine the severity of the aberrations in the cornea. The other study reported that in highly aberrated eyes the outcomes were not as effective as retreatment of eyes with subtle aberrations. We agree with Yoshida et al that retreatment of eyes with severe corneal aberrations often requires a two-step procedure. This is primarily due to the unpredictability of the corneal wound healing in cases such as ours, eg, scar tissue due to previous surgery may not respond in the same fashion as nascent cornea.

There is a relative paucity of reports of the retreatment of extreme cases such as ours primarily due to two reasons: the incorporation of Hartmann-Shack aberrometers in some wavefront platforms that cannot accurately plot severe aberrations and the lack of ablational planning software that accurately simulates a treatment plan. Whole eye aberrometry-based retreatment would include the aberrations of the physiologic lens, which would result in needless tissue removal.

In the current study, we elected to use LASIK instead of photorefractive keratectomy (PRK) for all retreatments. Reports of PRK for the retreatment of severely aberrated corneas show regression that continues past 6 months. The elimination of Bowman’s layer results in an increased wound healing response, which may cause regression and haze. Although mitomycin C may mitigate haze formation after PRK, we believed the risk of regression in this group of patients with high expectations and good photopic visual acuity before retreatment was not acceptable. Severe haze could have resulted in diminution in photopic vision.

In summary, CATz for the retreatment of eyes that underwent previous keratorefractive surgery was effective with an objective increase in visual quality due to the specific and targeted reduction of higher order aberrations. This reduction of corneal irregularity led to greater patient satisfaction.

**AUTHOR CONTRIBUTIONS**

Study concept and design (A.E.D.); data collection (A.E.D.); interpretation and analysis of data (A.E.D., H.S.B.); drafting of the manuscript (A.E.D., H.S.B.); critical revision of the manuscript (A.E.D.); statistical expertise (A.E.D.); supervision (A.E.D.)

**REFERENCES**