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Corneal Thickness Profile Changes After Femtosecond LASIK for Hyperopia

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Purpose: To compare changes in the corneal thickness profile before and 6 months after femtosecond laser in situ keratomileusis (LASIK) for hyperopia.
Methods: In a prospective noncomparative case series study, 24 eyes of 20 hyperopic patients undergoing femtosecond LASIK were examined preoperatively and 6 months postoperatively. Corneal profile was measured using Pentacam HR device. Paired *t* test was used to compare preoperative and postoperative values. Spearman correlation analysis was performed to evaluate the relationship between the central corneal thickness changes and attempted spherical equivalent refraction (SER).
Results: The mean uncorrected distance visual acuity significantly improved after surgery ($P<0.001$). Significant differences in central, midperipheral, ablative annular, and peripheral corneal thicknesses were observed from preoperatively to 6 months postoperatively (all $P<0.001$). There was no significant correlation between the changes in the central corneal thickness and attempted SER ($P=0.23$).
Conclusions: The corneal thicknesses across the whole ablation zone including central corneal thickness, significantly decrease postoperatively compared with preoperatively.

Key Words: Corneal thickness—Femtosecond LASIK—Hyperopia.

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Hyperopia is a common ophthalmic condition, which occurs in a number of people.[1–3] The surgical modalities for hyperopia include laser epithelial keratomileusis, laser in situ keratomileusis (LASIK), and femtosecond LASIK.[4–7] The laser procedures ablate a paracentral annulus of corneal tissue to steepen the central cornea and increase the corneal refractive power to obtain a clear image on the retina.

Numerous studies have been performed to evaluate the anterior ocular anatomical structures changes after myopic refractive surgeries.[8–21] For example, some previous studies demonstrated a forward shift of the posterior corneal surface after laser ablation, and this was believed to be caused by the decrease of corneal biomechanical strength postsurgically.[8–13,15,20] On the contrary, others reported no significant changes in the posterior corneal surface after refractive surgery.[14–17,19,21] Zhang et al.[18] found the displacement of posterior corneal surface after LASIK was time dependent and the displacement after epi-LASIK was region dependent. The corneal epithelial thickness[22–25] and stromal thickness[26] significantly increased after surgery, which may be a potential cause for myopic regression.

The pattern of the spatial distribution of ablation for hyperopic LASIK is different from that for myopic LASIK. However, to the best of our knowledge, few studies have evaluated the corneal structure changes after hyperopic surgery. Reinstein et al.[27] demonstrated thinner epithelium centrally and thicker epithelium paracentrally after LASIK for hyperopia using three-dimensional high-resolution ultrasound. de Ortueta et al.[28] showed no topographic regression between 3- and 36-month follow-up could be observed after hyperopic LASIK. We have previously reported that no change in anterior chamber dimensions was observed after femtosecond LASIK for hyperopia.[29] The purpose of this study was to compare the corneal thickness profile changes before and 6 months after femtosecond LASIK for hyperopia using the Pentacam HR device.

METHODS

Subjects

This study was a prospective noncomparative case series of 24 eyes of 20 hyperopic patients recruited at the Department of Ophthalmology and Vision Science of Fudan University Eye and ENT Hospital, Shanghai, China. The patients were recruited to the study before their treatment. A comprehensive ophthalmic examination was performed preoperatively to screen for ocular abnormalities and assess patient candidacy for refractive surgery. Exclusion criteria included unstable refraction for the preceding 2 years, keratoconus suspect, concurrent ocular pathologies, and systemic diseases deemed to impact surgical wound healing. All eyes showed a stable refraction with ≥3.00 D of spherical hyperopia and ≤1.50 D of refractive astigmatism (expressed in minus form) and were targeted for a plano refractive outcome.

The study was performed in accordance with the Declaration of Helsinki and was reviewed and approved by the Ethics Committee of Fudan University Eye and ENT Hospital. Written informed consent was obtained from all the subjects.

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TABLE 1. *Preoperative Patient Characteristics*

Parameters	Mean±SD (Range)
Age, yr	22.7±11.7 (11–63)
Spherical equivalent refraction, D	5.40±1.49 (2.63–8.63)
Attempted maximum ablation depth, μm	114.0±26.6 (71–163)
Axial length, mm	21.55±0.70 (20.46–22.83)

Surgical Procedures

The femtosecond LASIK procedure was considered standard-of-care at our institution for the included patients, based on their clinical symptoms. We prescribed, designed, and administered the femtosecond LASIK procedure for patients with the intention to study the efficacy and adverse effects of this procedure. The principle of the femtosecond LASIK procedure has been demonstrated in detail in the previous study.[29] Briefly, a flap was created using a VisuMax femtosecond laser (Carl Zeiss Meditec Inc., Oberkochen, Germany) with a repetition rate of 500 kHz and a pulse energy of 130 nJ. After the flap was lifted, the active Eye Tracker System was turned on, and laser ablation was performed using MEL 80 excimer laser (Carl Zeiss Meditec Inc.) by the same experienced surgeon (X.T.Z.). The optical zone was 6.50 mm in all cases, with a transition zone of 1 mm (total ablation zone of 8.5 mm). According to the treatment pattern for hyperopia and hyperopic astigmatism, paracentral and peripheral corneal tissue was removed with predetermined ablation, and the most central cornea was not ablated. A bandage contact lens was placed on the surgical eye for 1 day. Postoperatively, levofloxacin 0.5% (Santen Pharmaceutical Co., Ltd, Osaka, Japan) was applied four times daily in the first week, and fluorometholone 0.1% (Santen Pharmaceutical Co., Ltd) was used six times daily in the first postoperative 3 days and were gradually tapered every week to once a day. In addition, nonpreserved artificial tears (sodium carboxymethyl cellulose 0.5%; Allergan, Inc., Irvine, CA) were applied for 6 months.

Data Collection

In all cases, corneal thickness, central corneal true net power, and posterior corneal tangential curvature were measured using Pentacam HR device (Oculus Inc., Wetzlar, Germany) before and 6 months after femtosecond LASIK. Pentacam Scheimpflug imaging was performed with the patient seated using a chinrest and forehead strap. The patient was asked to keep both eyes open and to fixate on a blinking fixation target. All acquisitions were performed by a single experienced technician.

Midperipheral and peripheral corneal thicknesses were defined as 2 and 4 mm away from the corneal apex in the nasal and temporal quadrants, respectively. The ablative annulus (3.25 mm away from the corneal apex) was defined as the boundary of the attempted ablation optical zone (6.50 mm), where the ablation depth is supposed to be the most. The changes in corneal thickness were calculated as the differences between the preoperative and postoperative corneal thickness data.

Data Analysis

Statistical Package for the Social Sciences software (version 16.0; SPSS, Inc.) was used for statistical analysis. Paired *t* test was used to compare preoperative and postoperative values. Spearman correlation analysis was performed to evaluate the relationship between the central corneal thickness changes and attempted spherical equivalent refraction (SER). $P<0.05$ was considered statistically significant.

RESULTS

Twenty-four eyes, including 10 right eyes and 14 left eyes, were enrolled in this study. Preoperative data were summarized in Table 1, including age, SER, attempted maximum ablation depth, and axial length. Iatrogenic keratectasia was not clinically observed in the surgical eyes 6 months after femtosecond LASIK.

The mean postoperative uncorrected distance visual acuity (UDVA) of 0.66±0.30 significantly improved compared with

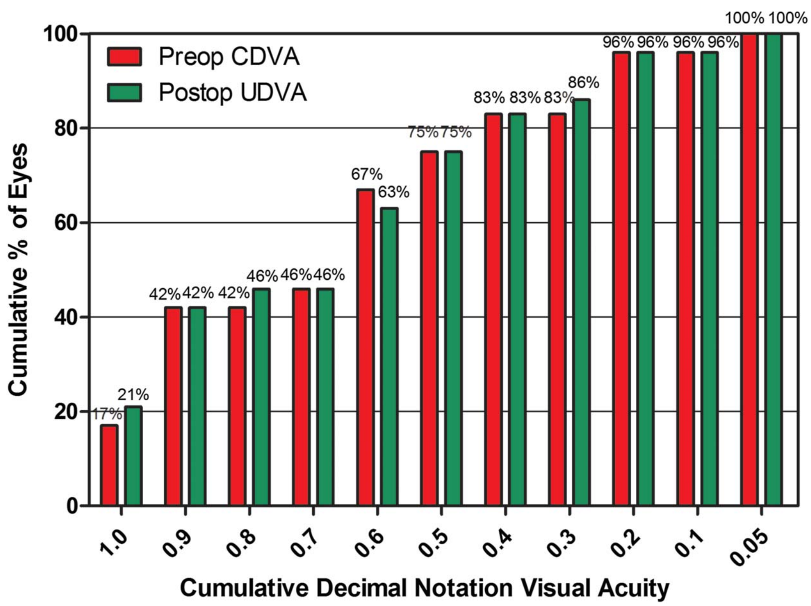

FIG. 1. Comparison of visual acuity between preoperatively and 6 month postoperatively. UDVA, uncorrected distance visual acuity; CDVA, corrected distance visual acuity. full color online

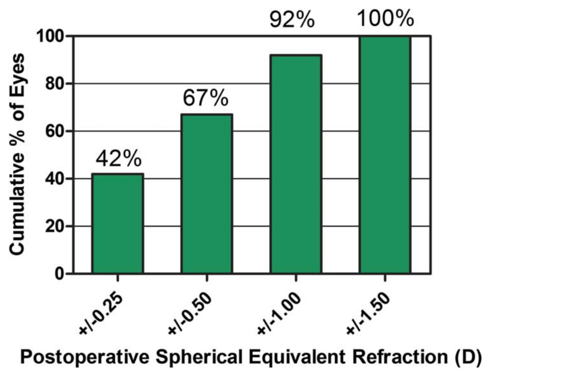

FIG. 2. Spherical equivalent refractive accuracy after hyperopic surgery. full color online

preoperative UDVA of 0.24±0.15 ($P<0.001$). The UDVA of 1.0 was obtained in 21% (5/24) of the treated eyes, and UDVA of 0.5 or better was obtained in 75% (18/24) of the treated eyes at 6 months postoperatively (Fig. 1). Corrected distance visual acuity (CDVA) was equal to or better than the preoperative CDVA in all the eyes at 6 months postoperatively. Furthermore, two eyes gained 1 line of CDVA. At the 6 month follow-up, mean SER was +0.44±0.42 D (range: −0.25 to +1.25 D). Forty-two percent of the treated eyes (10/24) fell within ±0.25 D, 67% (16/24) were within ±0.50 D, and 92% (22/24) were within ±1.00 D of the intended refractive target (Fig. 2).

Figure 3 showed corneal thicknesses as a function of horizontal eccentricity for the surgical eyes. Nasal cornea was thicker than temporal cornea at the same distance away from the corneal apex in normal eyes. Significant differences in central, midperipheral, ablative annular, and peripheral corneal thicknesses were observed from preoperatively to 6 months postoperatively (Fig. 3 and Table 2; all $P<0.001$). There was no significant difference between mean preoperative and postoperative posterior corneal curvature ($P=0.90$; 6.42±0.28 mm and 6.42±0.26 mm, respectively). Mean preoperative central corneal true net power was 41.3±2.0 D (range: 37.4–46.9 D), which increased postoperatively to 46.5±3.2 D (range: 41.3–57.4 D), and the difference was statistically significant ($P<0.001$).

Figure 4 demonstrated no significant correlation between the changes in the central corneal thickness and attempted SER ($P=0.23$). But the reduction in central corneal thickness increased with higher attempted SER.

TABLE 2. *Preoperative vs. Postoperative Changes in Corneal Thickness*

	Preoperative	Postoperative	Changes	P
Temporal periphery, μm	682.1±60.8	627.0±63.8	−55.1±30.2	<0.001
Temporal ablative annulus, μm	630.6±53.3	521.8±56.0	−108.9±25.9	<0.001
Temporal midperiphery, μm	577.3±39.8	536.3±44.1	−41.1±14.7	<0.001
Center, μm	562.3±33.9	548.2±35.3	−14.2±10.3	<0.001
Nasal midperiphery, μm	615.4±36.4	561.0±36.1	−54.5±16.6	<0.001
Nasal ablative annulus, μm	701.8±53.8	591.5±45.2	−110.3±31.9	<0.001
Nasal periphery, μm	762.8±44.7	682.1±57.6	−80.7±41.7	<0.001

Central corneal thickness was defined as the corneal apex. Midperipheral and peripheral corneal thicknesses were defined as 2 and 4 mm away from the corneal apex in the nasal and temporal quadrants, respectively. The ablative annulus was defined as 3.25 mm away from the corneal apex in the nasal and temporal quadrants, respectively.

DISCUSSION

In this study, significant changes in the corneal thicknesses at different horizontal locations and central corneal true net power were found after femtosecond LASIK for hyperopia. The refractive outcomes after hyperopic surgery were mainly concerned in the previous studies,[4,5,30–35] whereas few studies were conducted to focus on the corneal structural changes. To the best of our knowledge, this is the first study to comparatively analyze and report the corneal thickness profile changes after hyperopic LASIK using the Pentacam HR device.

Assessment of anterior ocular segment was an integral part of ophthalmic examination after surgery. Medeiros and his associates[36] found decreases in corneal hysteresis and corneal resistance factor after hyperopic LASIK. Zhou et al.[29] found anterior chamber profiles (including anterior chamber volume, anterior chamber angle, and central and peripheral anterior chamber depths) did not significantly change after femtosecond LASIK for hyperopia. There may be no forward or backward shift of posterior paracentral corneal surface under the normal intraocular pressure, although corneal biomechanical properties were changed after surgery.

In our study, the preoperative central corneal thickness of 565.5±32.1 μm was within reference range.[37] After surgery, the

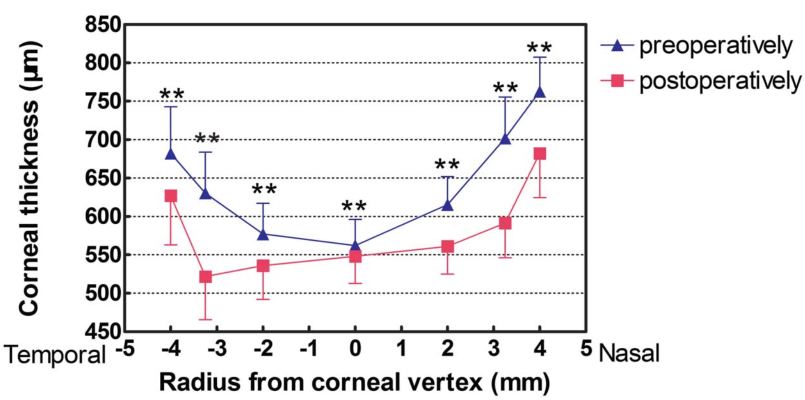

FIG. 3. Corneal thicknesses as a function of horizontal eccentricity for the surgical eyes. $**P<0.001$. full color online

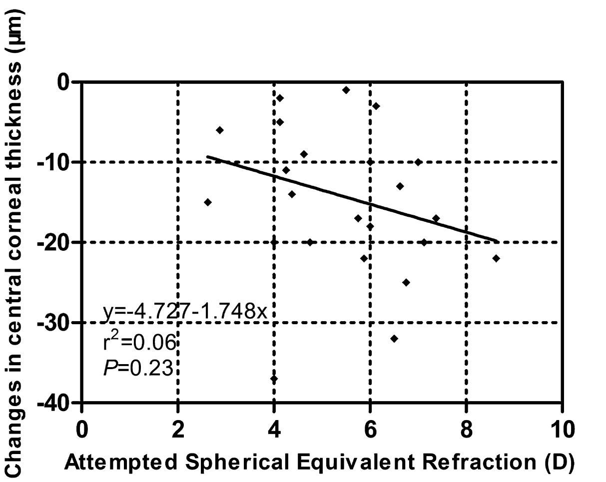

FIG. 4. Changes in the central corneal thickness versus attempted spherical equivalent refraction 6 months postoperatively.

corneal thickness significantly decreased across the whole ablation zone including the central corneal thickness (Fig. 3). However, the changes were not consistent with the predesigned scenario. The reduction in corneal midperipherical thickness (108.9 μm temporally and 110.3 μm nasally) in the ablative annulus was less than attempted maximum ablation depth (114.0 μm). This may be due to both explanations we propose in this report as follows: (1) a trend toward undercorrection in hyperopia (mean SER: +0.44 D at the postoperative 6 month) and (2) the result of the thickening of midperipherical cornea in the ablative zone after hyperopic surgery, which was related to postoperative regression.

The corneal thickness thinned in the central cornea after hyperopic surgery, where was supposed to be no laser ablation. Although the change in central corneal thickness was not significantly correlated with attempted SER, there was a trend that the reduction in central corneal thickness increased with higher attempted SER (Fig. 4). The higher the attempted SER, the longer the laser ablation. This may result in a larger probability that the central cornea could be ablated. The center corneal thinning was also indicative of decentration of laser ablation. Decentration of laser ablation could be due to amblyopia-related poor fixation, involuntary eye movement during a long treatment, and uneven laser energy delivery.[38,39] A larger angle kappa was also found in hyperopic eyes, which potentially enhanced the decentration effect.[38] Giaconi et al.[39] found mean decentration of the ablation zone was 0.3 mm after LASIK for hyperopes. However, Chan et al.[40] demonstrated the average decentration was 0.07 mm temporal after hyperopic LASIK. Although decentration not exceeding 0.5 mm was rarely visually significant,[41] the asymmetric corneal changes could induce an increase of irregular astigmatism and higher order aberrations after surgery.[42] In addition, epithelial remodeling with decrease in the center and increase in the periphery was expected to happen in the center and periphery after hyperoic LASIK treatment.[27]

There were two limitations in this study: a small sample in the study population and only two times of corneal thickness profile measurements at the preoperative timepoint and postoperative 6 month. Further studies with a larger sample are warranted to observe more meticulous corneal changes in different follow-up periods.

In conclusion, the corneal thicknesses across the whole ablation zone including central corneal thickness, significantly decrease postoperatively compared with preoperatively. This study provides important data for the understanding of the corneal thickness profile changes after hyperopic femosecond LASIK.

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