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Longitudinal Evaluation of Posterior Corneal Elevation after Laser Refractive Surgery Using Swept-Source Optical Coherence Tomography

Tommy C.Y. Chan, FRCS,[1,2] Dexter Liu, MBBS,[1] Marco Yu, PhD,[3] Vishal Jhanji, MD, FRCOphth[1,2,4]

Purpose: To investigate the change in posterior corneal elevation up to 1 year after myopic femtosecond-assisted LASIK and photorefractive keratectomy (PRK).

Design: Prospective, longitudinal, comparative study.

Participants: Patients undergoing femtosecond-assisted LASIK or PRK.

Methods: Corneal imaging was performed using swept-source optical coherence tomography at baseline and at each postoperative follow-up. A 2-way analysis of variance model with repeated measures and a linear mixed effect model were used to compare the differences in posterior corneal elevation between LASIK and PRK at different points after adjusting for the preoperative spherical equivalent (SEQ), central corneal thickness (CCT), thinnest corneal thickness (TCT), residual bed thickness (RST), and ablation depth (AD).

Main Outcome Measures: The changes in posterior corneal elevation 1 month, 3 months, 6 months, and 12 months after surgery.

Results: Ninety-eight eyes of 49 patients (mean age 35.2 $\pm$ 8.5 years) (62 LASIK, 36 PRK) were included. The mean change in posterior corneal elevation values after LASIK and PRK were 4.88$\pm$0.47 μm versus 3.67$\pm$0.48 μm (B-1), 2.42$\pm$0.56 μm versus 3.00$\pm$0.47 μm (B-3), 3.76$\pm$0.46 μm versus 2.76$\pm$0.46 μm (B-6), and 2.92$\pm$0.46 μm versus 2.72$\pm$0.46 μm (B-12), respectively. Significant differences in posterior corneal elevation after LASIK were found from month 1, to month 3, to month 6, to month 12 ($P \leq 0.001$), whereas posterior corneal elevation did not change significantly from month 3, to month 6, to month 12 ($P \geq 0.373$) after PRK. LASIK and PRK eyes showed significant differences at months 3 and 12 ($P \leq 0.023$). A similar pattern was observed for the changes in posterior corneal elevation after LASIK and PRK after adjusting for the effect of SEQ, CCT, TCT, RST, and AD. The adjusted forward displacements of the posterior corneal surface were statistically significant throughout the study period after both refractive surgeries ($P < 0.05$).

Conclusions: The findings of our study suggested that there was a mild but significant forward protrusion of the posterior cornea after femtosecond laser-assisted LASIK and PRK. The posterior cornea fluctuated during the first postoperative year after LASIK, whereas it stabilized as early as 3 months after PRK. *Ophthalmology 2015;■:1–6 © 2015 by the American Academy of Ophthalmology.*

Elevation of the posterior corneal surface after myopic correction with LASIK and photorefractive keratectomy (PRK) has been observed in several studies.[1–5] Such changes in the posterior cornea also have been suggested to indicate subclinical keratectasia after laser refractive surgery. Early studies investigated the cornea after PRK or LASIK using scanning-slit topography (Orbscan; Bausch & Lomb, Rochester, NY) and demonstrated a forward protrusion of posterior cornea.[1–5] However, the accuracy of these measurements remained uncertain because the posterior corneal surface is actually recreated through triangulation algorithms from the anterior cornea when using scanning-slit topography.[6] Later studies using Scheimpflug photography (Pentacam HR; Oculus, Germany) showed minimal or no changes in posterior corneal elevation through direct analysis of the posterior corneal surface.[7–9] Furthermore, comparison between the 2 imaging systems demonstrated a significant difference in postoperative changes in the posterior corneal surface after LASIK or PRK.[10–12] Swept-source optical coherence tomography (Casia SS-1000; Tomey, Nagoya, Japan) is a recently developed technology that enables high-speed and high-resolution imaging of the anterior segment, including the anterior as well as posterior corneal surface. This study aimed to investigate the changes in posterior corneal elevation longitudinally over 1 year after myopic femtosecond laser-assisted LASIK and PRK using swept-source optical coherence tomography.

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Methods

A total of 49 consecutive subjects (98 eyes) were recruited at the Refractive Surgery Clinic of the Chinese University of Hong Kong Eye Centre, Hong Kong, China. Detailed informed consent was obtained from all the patients. The Institutional Review Board of the hospital (Kowloon Central Cluster Ethics Committee, Hospital Authority) approved the conduct of the study. The study adhered to the tenets of the Declaration of Helsinki. Before surgery, all patients underwent a complete ophthalmic examination and had no ocular abnormality except myopia or myopic astigmatism with a corrected distance visual acuity of 20/20 or better in both eyes. Patients with suspicion of keratoconus on corneal topography (displacement of the corneal apex, decrease in thinnest-point pachymetry, asymmetric topographic pattern), cataract, ocular inflammation, and infection were excluded.

Surgical Procedures

Femtosecond Laser-Assisted LASIK. LASIK flaps were created using a 150-kHz femtosecond laser (IntraLase; Abbott Medical Optics, Chicago, IL). All flaps had a superior hinge. The intended thickness and flap diameter were 110 μm and 9.0 mm, respectively. Other settings included hinge angle, 55°; bed energy, 0.75 μJ; spot separation, 6 μm; line separation, 6 μm; side-cut energy, 1.1 μJ; pocket width, 200 μm; pocket start depth, 210 μm; and both pocket tangent and radian spot separation, 4 μm. Stromal ablation was performed with Allegretto Wave & Eye-Q 400-Hz laser (WaveLight Laser Technologie AG, Germany) using a 6.5-mm optical zone.

Photorefractive Keratectomy. Alcohol-assisted corneal epithelial removal was performed over a 9.0-mm optical zone centered over the pupil. Ethanol 20% in distilled water was dropped into a 9.0-mm well and kept in contact with the epithelium for 40 seconds and then absorbed with a dry cellulose sponge. The eye then was washed with balanced salt solution. A blunt spatula then was used to remove the loosened epithelium. Stromal ablation was performed with the Allegretto Wave & Eye-Q 400-Hz laser using a 6.5-mm optical zone. After the stromal ablation, a circular cellulose sponge soaked with mitomycin C 0.02% (0.2 mg/ml) was placed on the cornea for 30 to 45 seconds. Eyes requiring a deeper ablation had longer contact with the mitomycin C. A bandage contact lens was placed over the cornea at the end of the surgery.

After surgery, all patients received topical levofloxacin 0.5% 4 times daily for 1 week. Topical prednisolone acetate 1% was used 4 times daily for the first postoperative week and then tapered over 1 month. Preservative-free artificial tears were used for 3 months after surgery.

Postoperative Examination

All patients were examined on day 1, week 1, and months 1, 3, 6, and 12 after surgery. All patients were imaged with swept-source optical coherence tomography (Casia SS-1000) in both eyes before and at each postoperative follow-up (excluding day 1 and week 1). All measurements were obtained between 10 AM and 4 PM. Testing was conducted under dim room illumination. A single examiner carried out all investigations.

Swept-Source Optical Coherence Tomography

The SS-1000 uses a wavelength of 1310 nm with a speed of 30 000 axial scans per second. The axial and transverse resolution of the device is less than 10 μm and less than 30 μm, respectively. We used the Topo-Pachy-Map scan protocol comprising an evenly spaced 16 radial B-scans with total scan duration of 0.3 seconds to measure the corneal thickness and topography. The images obtained were without any lid artifacts. The topographic data of posterior corneal surfaces as well as corneal thickness and keratometry were obtained from the map. The diameter for calculating the best-fit sphere was fixed (8.0 mm) across all examinations. The changes in the posterior corneal elevation surface were determined by subtracting the preoperative elevation data from the postoperative elevation data (difference map). An ectatic change (forward protrusion of the posterior corneal surface) resulted in a positive number.

Statistical Analysis

Statistical analysis was performed using R 2.15.2 (R Foundation, Vienna, Austria). The change in posterior corneal elevation from baseline to month 1, baseline to month 3, baseline to month 6, and baseline to month 12 were compared using 1-way analysis of variance models with repeated measures after LASIK and PRK operations. The 2-way analysis of variance model with repeated measures was adopted to compare the differences in posterior corneal elevation after LASIK or PRK up to different time points (months 1, 3, 6, and 12). A linear mixed-effects model was used to evaluate the change in posterior corneal elevations from baseline to month 1, baseline to month 3, baseline to month 6, and baseline to month 12, and between LASIK and PRK after adjusting for spherical equivalent, central corneal thickness, thinnest corneal thickness, residual bed thickness, and ablation depth. Spherical equivalent, central corneal thickness, thinnest corneal thickness, residual bed thickness, and ablation depth before LASIK and PRK also were compared by 1-way analysis of variance model with repeated measures. A P value of less than 0.05 was considered statistically significant.

Results

Ninety-eight eyes of 49 patients (62 LASIK, 36 PRK) were included. The mean age of the patients was 35.2±8.5 years. Significant differences were observed in spherical equivalent refraction, central corneal thickness, thinnest corneal thickness, and ablation depth between patients in the LASIK and PRK groups ($P \leq 0.021$; Table 1).

The mean changes in posterior corneal elevation values after LASIK were 4.88±0.47 μm, 2.42±0.56 μm, 3.76±0.46 μm, and 2.92±0.46 μm for months 1, 3, 6, and 12, respectively (Fig 1). Significant differences in posterior corneal elevation were found from baseline to month 1, baseline to month 3, baseline to month 6, and baseline to month 12 ($P \leq 0.001$), except between months 3 and 12 ($P = 0.227$; Table 2). The mean changes in posterior corneal elevation values after PRK were 3.67±0.48 μm, 3.00±0.47 μm, 2.76±0.46 μm, and 2.72±0.46 μm for months 1, 3, 6, and 12, respectively (Fig 1). Significant differences in posterior corneal elevations were found between months 1 and 6 and between months 1 and 12 ($P \leq 0.006$), but not from baseline to month 3, baseline to month 6, or baseline to month 12 ($P \geq 0.373$; Table 3). The changes in posterior corneal elevation after LASIK and PRK were significantly different from each other at months 3 and 12 ($P \leq 0.023$). The forward displacements of the posterior corneal surface were statistically significant throughout the study period after both LASIK and PRK ($P < 0.05$).

A similar pattern was observed for the changes in posterior corneal elevation after LASIK and PRK after adjusting for the effect of spherical equivalent, central corneal thickness, thinnest corneal thickness, residual bed thickness, and ablation depth (Tables 4 and 5). Significant differences also were found in the