ARTICLE

Differences in the corneal biomechanical effects of surface ablation compared with laser in situ keratomileusis using a microkeratome or femtosecond laser

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PURPOSE: To compare the effects of different flap creation techniques on the biomechanical properties of the cornea in patients having myopic laser refractive surgery.

SETTING: UCLA Laser Refractive Center of the Jules Stein Eye Institute, Los Angeles, California, USA.

METHODS: In this retrospective case series, eyes that had myopic laser refractive surgery were categorized according to the type of flap creation: mechanical microkeratome (MK) LASIK (n = 32), femtosecond laser (FSL) LASIK (n = 32), or no flap creation (PRK) (n = 33). The preoperative central corneal thickness, intraoperative flap thickness, and planned ablation depth (AD),and the preoperative and postoperative manifest refraction spherical equivalent, corneal hysteresis (CH), and corneal resistance factor (CRF) were recorded.

RESULTS: The mean change in CH (ΔCH) was 2.2 mm Hg, 1.9 mm Hg, and 2.3 mm Hg in the MK, FSL, and PRK groups, respectively. There were no significant differences in AD, ΔCH, or ΔCRF between the 3 groups. The correlation between AD and ΔCH was significant in all 3 groups. The correlation was strongest in the FSL group ($r = 0.82$, $P<.0001$) and weaker in the PRK group ($r = 0.47$, $P = .006$) and MK group ($r = 0.46$, $P = .008$).

CONCLUSIONS: The biomechanical measures of CH and CRF decreased similarly after PRK and LASIK using laser or mechanical flap creation. However, LASIK using femtosecond laser flap creation caused a significantly more predictable change in corneal biomechanics, which correlated strongly with AD, than the change with PRK and LASIK with microkeratome flap creation.

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The biomechanical properties of the cornea affect the predictability and stability of refractive surgery outcomes. Differences in biomechanical strength and structure may explain differential achieved corrections in 2 patients with otherwise identical demographics and attempted corrections treated by the same surgeon at the same location on the same day. Keratectasia, defined as progressive corneal steepening resulting in loss of uncorrected and best corrected visual acuity, occurs after laser in situ keratomileusis (LASIK)[1,2] and photorefractive keratectomy (PRK),[3–6] even in the absence of known risk factors. There is little question that abnormal and/or significantly altered corneal biomechanics plays a critical role in the development of this most serious post-refractive surgery complication. An effective means of quantifying the biomechanical state of a cornea before refractive surgery would be a welcome addition to the diagnostic tools currently available and may help reduce the incidence of keratectasia by improving refractive surgery screening.

Femtosecond laser and mechanical microkeratome systems have different mechanisms of action to create corneal flaps for LASIK surgery. The mechanical microkeratome uses an oscillating blade for sharp dissection as the blade passes across the cornea in a rotational or translational approach. The femtosecond laser creates a corneal resection plane by delivering laser pulses at a predetermined depth in the cornea. These pulses physically define the cleavage plane through photodisruption, producing thousands of microscopic expanding bubbles of carbon dioxide gas and water, which separate the corneal lamellae. Blunt dissection is then used to complete the tissue

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separation.[7,8] Many studies show compromises to corneal tensile strength and biomechanics after flap creation (J.L. Alio, MD, D. Ortiz, MD, D. Piñero, MD, "Flap Biomechanics with the Femtosecond and Mechanical Microkeratomes," presented at the XXIII Congress of the European Society of Cataract & Refractive Surgeons, Lisbon, Portugal, September 2005).[9–12]

There is growing evidence that there are differences in the wound-healing response and biomechanical effects on the cornea depending on whether a flap is created by a microkeratome or femtosecond laser or no flap is created (ie, PRK).[10,13,14] Having a greater understanding of the differential effects of the method of flap creation and ablation have on postoperative corneal biomechanics may be useful for the refractive surgeon in assessing the risk for potential patients.

To date, we are unaware of any published in vivo comparative case series evaluating changes in the biomechanical measurements of the cornea after all 3 surgical methods (ie, surface ablation or flap creation by mechanical microkeratome or flap creation by femtosecond laser). In this study, we examined the changes in the corneal biomechanical parameters, corneal hysteresis (CH) and corneal resistance factor (CRF), in myopic patients before and after laser refractive surgery with surface ablation or LASIK using flaps created with a mechanical microkeratome or a femtosecond laser. We then evaluated the correlation between these parameters and the amount of tissue ablated in each group.

PATIENTS AND METHODS

All files of patients who had laser refractive surgery at the UCLA Laser Refractive Center of the Jules Stein Eye Institute from January to June 2006 were reviewed. All patients had a rigorous preoperative assessment and were determined to be suitable candidates for myopic laser refractive surgery. Patients were excluded from the study if they did not have all requisite preoperative parameters measured or did not have at least 1 month follow-up with all parameters recorded. Age was recorded for all patients.

For each eye, manifest refraction spherical equivalent (MRSE) was measured before and after surgery. The preoperative central corneal thickness (CCT) measured by ultrasound, the planned ablation depth (AD), and the intraoperative flap thickness (FT) measured by subtraction ultrasound pachymetry were also recorded. Three groups of patients were selected depending on the flap creation method: those who had LASIK using a mechanical microkeratome for flap creation (MK group), those who had LASIK using a femtosecond laser for flap creation (FSL group), and those who had PRK (PRK group). To eliminate possible bias due to different ADs between the 3 groups, eyes in the PRK and FSL groups were selected for inclusion such that their AD matched as closely as possible to 1 eye in the MK group.

The Ocular Response Analyzer (ORA, Reichert Instruments) was used to measure in vivo biomechanical properties of the cornea. The ORA was originally developed to generate a corneal-compensated intraocular pressure reading independent of corneal thickness. In doing so, the ORA quantifies 2 biomechanical parameters: CH and CRF. During the measurement procedure, a rapid air impulse is used to applanate the cornea. Using an electrooptical system, 2 applanation pressure measurements are recorded. The first measurement occurs when the cornea is flattened and moving inward and the other as the cornea flattens and is moving outward after moving through a concavity at maximum applanation. This process takes approximately 20 milliseconds. Due to its viscoelastic properties, the cornea resists the dynamic air puff differentially on the inward and outward applanation events, resulting in 2 different pressure values. Corneal hysteresis is defined as the difference between these 2 pressure values. Corneal hysteresis is thought to correlate with the amount of viscous dampening inherent to the cornea. The CH measurement also provides a basis for an additional parameter, the CRF. This measure appears to be an indicator of the overall mechanical resistance of the corneal tissue, including both viscous and elastic components, and is derived from specific combinations of the inward and outward applanation values using proprietary algorithms.[15] Preoperative and postoperative CH and CRF measurements were obtained in all eyes. All ORA measurements were taken at least twice and averaged for the statistical analysis. All ORA waveforms of patients included in the study showed adequate amplitude and shape. To minimize differences in postoperative healing and the possible effects on biomechanics, all postoperative data were collected as close to 10 to 12 weeks after surgery as possible.

A weighted biomechanical index (WBI) was calculated by the following formula: $(AD + FT)/CCT$. For the purposes of this index, FT for the PRK group was chosen to be 50 μm, a nominal thickness of the corneal epithelium. This parameter attempts to weight both biomechanical-altering events, ablation of stroma and flap creation, by the preoperative CCT.

Each eye had custom LASIK or custom PRK for myopic astigmatism using the LadarVision 4000 platform with CustomCornea (Alcon Laboratories). All eyes had ablations using an optical zone diameter of 6.5 mm with a 1.25 mm

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Fei Yu, PhD, statistician at the Clinical Research Center, Jules Stein Eye Institute, performed all the statistical analyses.

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