Anterior Segment OCT Analysis of Thin IntraLase Femtosecond Flaps

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ABSTRACT

PURPOSE: Anterior segment optical coherence tomography (OCT) was used to analyze thin flaps created with the IntraLase femtosecond laser (IntraLase Corp).

METHODS: Twenty-five eyes of 25 patients had flaps created with the 60 kHz IntraLase femtosecond laser prior to excimer laser ablation. The desired flap thickness was 110 µm with a diameter of 8.5 mm for all eyes. At 1 month postoperatively, all eyes were evaluated with the Visante anterior segment OCT (Carl Zeiss Meditec). Four thickness measurements were obtained across the length of the flaps at the meridians of 45°, 90°, 135°, and 180°. Thus, 16 thickness measurements were analyzed for each flap.

RESULTS: Flaps were uniform (planar) with a mean thickness of 112±5 µm (range: 87 to 118 µm). Average standard deviation within the individual flaps was 4 µm (range: 1 to 8 µm).

CONCLUSIONS: The IntraLase femtosecond laser creates thin, uniform (planar) flaps with high predictability and reproducibility. [J Refract Surg. 2007;23:555-558.]

Previous studies have reported greater corneal biomechanical stability following PRK compared to traditional LASIK with a microkeratome.1,2 Thin flaps demonstrate biomechanical properties similar to those of PRK, but with the advantage of no pain or haze formation.2 These findings suggest that a thin flap, created with consistent thickness across the cornea, is the ideal choice for optimizing refractive and biomechanical outcomes. In this study, anterior segment optical coherence tomography (OCT) was used to analyze thin flaps created with the IntraLase femtosecond laser (IntraLase Corp, Irvine, Calif).

PATIENTS AND METHODS

In this Institutional Review Board-approved (Research Consultants Review Committee, Austin, Tex) prospective, contralateral study, 25 patients with myopia, with and without astigmatism, were randomized to undergo excimer laser ablation following thin flap creation with the 60 kHz IntraLase femtosecond laser in one eye and photorefractive keratectomy (PRK) in the fellow eye. (Results of this contralateral study will be reported separately.) A sub-study to evaluate the flaps by OCT was performed.

Standardized superior-hinged flap parameters were programmed for each procedure. The desired flap thickness was 110 µm. Our previous experience with the IntraLase femtosecond laser has shown that it must be programmed at 100 µm to obtain a flap thickness of 110 µm. Other laser parameters were 8.5-mm diameter, hinge angle of 50°, side cut angle of 75°, raster pattern energy of 1.30 µJ, pulse separation...
of 8 × 8 µm, and side cut energy of 2.00 µJ with the pocket enabled.

At 1-month postoperative follow-up, all eyes were evaluated with the Visante anterior segment OCT (Carl Zeiss Meditec, Jena, Germany) to image each flap. A technician performed all high-resolution corneal scans with 512 A-scans per line sampling and 0.25 seconds per line acquisition time (2048 scans per second). Because the Visante OCT can display a cross section of an image at any specified meridian, we chose to display the 45°, 90°, 135°, and 180° meridians for each flap. Using the software’s flap tool, the flap interface was visualized and marked by the examiner to measure flap and residual stromal bed thickness. Flap thickness was measured at four points for each cross section by one examiner who was masked to the attempted flap depth. Two points were ±3 to 4 mm from center, and two were ±1 to 2 mm from center. Thus, each flap’s thickness was measured at a total of 16 points (Fig 1).

**RESULTS**

All 16 measurements for each flap were analyzed. The flaps were planar in appearance with a mean thickness of 112±5 µm (range: 87 to 118 µm). Multivariate statistical analysis compared each data point to the mean 112 µm flap thickness; P values (P>.05) were not statistically significant. Therefore, the average flap was either uniform (planar) at 112 µm or varied insignificantly from the average (112 µm).

The 16 measurements per flap were analyzed for each eye individually, and the average standard deviation within the individual flaps was 4 µm (range: 1 to 8 µm). This also demonstrates that flaps were uniform (planar).

**DISCUSSION**

The high-speed, noncontact Visante OCT has high axial resolution to acquire cross sectional imaging of the cornea and anterior segment. Its ease of use, ability to image a wide area of cornea, and capacity to image the flap interface for multiple, direct measurements of flap thickness in four meridians is useful for analyzing flap dimensions. In addition, direct measurements of residual stromal thickness obtained with the OCT are helpful when considering LASIK enhancement procedures. Li et al reported that repeatability of OCT corneal thickness measurements was 2 µm. They also found that high-speed OCT is equivalent to ultrasound for central corneal thickness measurements before and after LASIK.

Automated computer algorithms have been developed for an OCT prototype similar to the Visante OCT for identification of the anterior and posterior corneal boundaries and flap interface thickness. Comparisons with ultrasound measurements have validated the algorithms’ accuracy for corneal and flap thickness. The Visante OCT currently requires the examiner to make...
flap measurements manually, which may be more subjective than an automated measurement. A study that compares automated measurement algorithms to manual measurements would help answer this question.

Our study shows that the 60 kHz IntraLase femtosecond laser produces uniform (planar) flaps that are both highly predictable and reproducible. The level of reproducibility demonstrated a mean flap thickness of 112 µm when a flap thickness of 110±5 µm was attempted. In this study, standard deviation equals the tolerance of thickness of the glass applanation plate used by the laser as the reference for the depth of laser beam placement during flap creation (personal communication with IntraLase Corp). The faster 60 kHz laser appears to have improved precision when our results are compared to a previous report with contact ultrasonic pachymetry that had a standard deviation of 12 µm using the 10 kHz femtosecond laser.

The importance of corneal biomechanics in refractive surgery outcomes has become apparent with recent publications. The corneal stroma consists of lamellae (organized collagen fibers), which run from limbus to limbus. Traditional LASIK, using a mechanical microkeratome, creates a flap approximately 160 µm thick, which severs a significant number of collagen fibers compared to PRK. The loss of lamellar integrity following LASIK results in compromised corneal biomechanical integrity due to minimal biomechanical loading distributed throughout the flap. Hence, there is no contribution from the flap to the biomechanical stability of the cornea.

Cohesive tensile strength studies demonstrate that Bowman’s layer is the strongest structural component of the cornea followed by the anterior third of the corneal stroma. In fact, the peripheral anterior third of the corneal stroma is stronger than the paracentral and central anterior third. These findings are supported by morphologic studies that demonstrate more collagen lamellar interweaving and collagen lamellae orientations that were transverse to the anterior surface of the cornea. These studies suggest that a thin, uniform flap would leave more of the strong anterior stroma untouched, which should provide greater corneal biomechanical strength than the thicker traditional LASIK flap that severs more of these strong anterior fibers.

The biomechanical considerations previously described suggest less stability with traditional microkeratome-LASIK compared to PRK. In vitro research with electronic speckle pattern and shearing interferometry by Marshall demonstrated greater corneal biomechanical stability with thin flaps created in the compact anterior corneal stroma just beneath Bowman’s layer compared to thicker flaps. Based on these findings, we can hypothesize that a cornea with a thin, uniform flap would have biomechanical stability more similar to that of PRK than traditional LASIK, but with the added benefit of no pain or corneal haze as with traditional LASIK. In addition, we speculate that flaps made deep to this level (traditional LASIK), in the weaker posterior cornea where the lamellae lie more parallel and less compact, create weaker corneal biomechanics.

The IntraLase femtosecond laser keratome also allows precise control over the diameter of the flap with standard deviation from 0.12 to 0.26 mm. In our study, we programmed a desired flap diameter of 8.5 mm. This is smaller than flaps created with mechanical microkeratomes, which are typically greater than 9.0 mm. These small-diameter flaps cut less of the strong peripheral corneal fibers and may further add to biomechanical strength compared to larger flaps.

Figure 2. Artemis UBM (Ultralink LLC, St Petersburg, Fla) image of a microkeratome-created flap demonstrating a meniscus shape. (Photo courtesy of Richard Foulkes, MD)
(J.L. Alio, MD written communication March 2, 2007). Analysis of flap dimensions in our study demonstrate that the 60 kHz femtosecond laser flaps have uniform thickness with a planar shape. The high predictability and reproducibility of the flaps created in this study indicate that using the 60 Khz femtosecond laser is an excellent technique for creating thin, uniform flaps. The femtosecond laser technique is likely safer than using microkeratomes to create thin flaps due to the increased risk of flap buttonholes when thin flaps are attempted with mechanical microkeratomes.

Thin, uniform flaps appear to benefit from the strengths of both LASIK (no haze or pain) and PRK (biomechanical stability) procedures. Drs Daniel S. Durrie and Stephen Slade have suggested that the name “Sub-Bowman’s Keratomileusis (SBK)” be used for excimer laser procedures performed with a uniform, thinner flap that is custom-designed for the individual patient.17-19 This study, using anterior segment OCT, demonstrates that the IntraLase 60 kHz femtosecond laser creates thin, uniform (planar) flaps with high predictability and reproducibility.

REFERENCES

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