Original Article

Comparison of Intraoperative Ultrasound Pachymetry and Postoperative Optical Coherence Tomography of Anterior Segment in the Measurement of Flap Thickness in Eyes Receiving Laser in situ Keratomileusis

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Abstract

Purpose: To compare the measurement of flap thickness using intraoperative ultrasound pachymetry and postoperative visante anterior segment optical coherence tomography (Visante-OCT) in eyes receiving laser in situ keratomileusis (LASIK).

Methods: Seventeen patients (34 eyes) received LASIK using a Technolas-217Z100 laser and AMADEUS Ⅱ mechanical microkeratome (140 μm head). Flap thickness was assessed with an ultrasound pachymeter intraoperatively and a Visante - OCT postoperatively at 1 week and 1 month.

Results: The intraoperative mean flap thickness by ultrasound pachymetry was (124±13.9) μm (range: 96.5 to 160 μm), and mean flap thickness by Visante-OCT was (145±7.13) μm (range: 130 to 158 μm) and (143±5.32) μm (range: 132 to 155 μm) postoperatively at 1 week and 1 month respectively ($F=63.52$, $P<0.01$). Intraoperative subtraction pachymetry underestimated flap thickness compared with postoperative Visante-OCT ($P<0.01$). There was no significant difference between postoperative Visante-OCT measurements at 1 week and 1 month after LASIK ($P=0.16$). The 95% limit of agreement (LoA) of flap thickness between ultrasound Visante-OCT and pachymetry was −5.40 to 42.10 μm.

Conclusion: OCT overestimates flap thickness compared with intraoperative ultrasound pachymetry when using the AMADEUS Ⅱ mechanical microkeratome. (***Eye Science 2012; 27: 60-63***)

Keywords: cornea flap thickness; laser in situ keratomileusis; anterior segment optical coherence tomography; ultrasound pachymeter

LASIK is the most popular refractive surgery performed worldwide. One of the most important risk factors for keratectasia after LASIK is insufficient residual stromal bed thickness < 250 μm after LASIK[1]. Currently, LASIK surgeons are calculating the residual stromal bed by subtracting the expected flap thickness and ablation depth from the central corneal thickness (CCT) measured by an ultrasound pachymeter. The actual flap thickness can vary greatly from the intended setting in both systemic and random fashions[2]. Subtraction of stromal bed thickness from preoperative corneal thickness also equals the flap thickness. Another method to measure the flap and stromal bed thickness after LASIK is optical coherence tomography (OCT), which provides non-contact high-resolution corneal cross-sectional images[3] from which flap and stromal thicknesses can be measured.

Current research compared intraoperative subtraction pachymetry flap thickness measurement with postoperative Visante-OCT flap thickness measurement in eyes that had undergone LASIK.

Patients and methods

Patients and surgery

Inclusion criteria were −1.25 to −8.50 diopters (D) of spherical myopia, with up to −1.50 D of refractive astigmatism, and a stable refraction for 1 year. Participants were seeking LASIK treatment in Joint Shantou International Eye Center from August 2007 to September 2007. All eyes had a predicted postoperative residual stromal bed thickness of >250 μm. Preoperative evaluation included ultrasound pachymetry (IOPac, Heidelberg Engineering, Heidelberg, Germany), and corneal topography (Orbscan II;

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Bausch & Lomb, Rochester, NY, USA). The LASIK flap was created with AMADEUS II mechanical microkeratome (Advanced Medical Optics, Inc., Santa Ana, CA, USA), flap thickness was programmed to 140 μm. All flaps had a nasal hinge, head advance speeds were 3 mm/s, and oscillation rates were 11000 rpm. Ablation of the stromal bed was performed with a Technolas 217z100 excimer laser (Bausch & Lomb, Rochester, NY, USA).

Ultrasound pachymetry

CCT was measured before the microkeratome passed, and the residual stromal thickness was measured during surgery, before laser ablation. Three IOPac pachymetry readings were taken at each time and then averaged. The flap thickness was given by the subtraction method.

OCT Imaging

At one week and one month postoperatively, all eyes were evaluated with the Visante OCT (Carl Zeiss Meditec, Jena, Germany). The scan rate was 2000 axial scans/second. The axial resolution was 18 μm (in tissue), and the transverse resolution was 60 μm. The axial scan depth of 3 mm was used for high resolution scans. Three high-resolution corneal scans for each eye were performed along a 0° (including 180°) meridian, which was a horizontal line scan consisting of 512 axial scans. Both patterns were 8 mm long and centered on the vertex reflection. The "flap tool" function of the software was used to visualize and check the flap interface, as determined by the observer. During analysis of the best scanned image of three scans, three measurement points were manually located on the central zone of the cornea (< 2 mm in diameter). Three readings of flap thickness were taken each time, and then averaged.

Statistical analysis

Statistical analysis was performed using SPSS version 17.0 for Windows (SPSS Inc., Chicago, Illinois) and MedCalc for windows (version 10 MedCalc Inc., Mariakerke, Belgium). At each of the measurement points of the individual flaps, the mean and standard deviations were calculated. The OCT measurements were compared with ultrasound measurements by One-way analysis of variance (ANOVA) and by Pearson correlation. Agreement of the two methods was analyzed by Bland-Altman plots. Statistical significance level was set at 0.05 for all tests.

Results

This study included 34 eyes of 17 patients (8 men and 9 women) with a mean age of (22.58±4.49)years (range: 18 to 35 years). Mean preoperative spherical equivalent refraction was (−5.18±1.98)D (range: −1.00 to −8.25D), mean sphere was (−4.95±1.99) D(range: −0.75 to −8.25 D), and mean cylinder was (−0.50±0.37) D (range: 0.00 to −1.50 D).

Intraoperative CCT was (535.94±24.63) μm (range: 487 to 579 μm). The intraoperative mean flap thickness by ultrasound pachymeter was (123.80±13.86) μm (range: 96.50 to 160.00 μm). It was easy to identify the flap interface up to one month (Figure 1). Flap thickness by Visante-OCT was (144.54±7.13)μm (range: 130.00 to 158.33 μm) and (143.21±5.32) μm (range: 131.67 to 154.67 μm) at one week and one month postoperatively (F=130.90, P < 0.01). Intraoperative subtraction pachymetry consistently underestimated flap thickness compared with postoperative Visante-OCT (P<0.01). There was no significant difference in postoperative Visante-OCT measurements between one week and one month after LASIK (P=0.16). The 95% LoA of flap thickness between Visante-OCT 1 month after LASIK and ultrasound pachymeter was (−5.40 to 42.10)μm (Figure 2).The average and the difference of flap thickness between Visante-OCT one month after LASIK and ultrasound pachymeter were correlated negatively (Pearson correlation, r=−0.83, P=0.00). The OCT measurements were correlated positively with ultrasound measurements at one month postoperatively (Pearson correlation, r=0.58, P=0.001).

Discussion

Currently, one common method used for assessing corneal flap thickness is subtracting the residual stromal bed thickness from the intraoperative corneal thickness, which has several limitations. First, there is a risk of contamination and hydration change when the ultrasound probe contacts the stromal bed. Additionally, there is an imprecision associated with the manual placement of the two measurements.

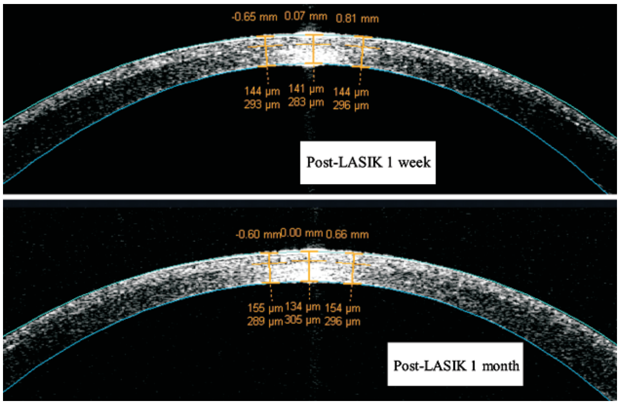

Figure 1 OCT flap profile scans at postoperative 1 week and 1 month

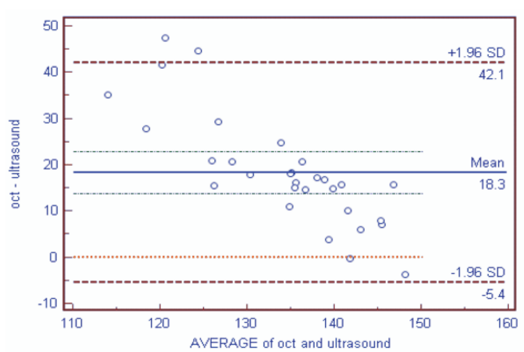

Figure 2 Bland–Altman plots comparing OCT 1 month after LASIK and ultrasound flap thickness measurements. Horizontal lines show mean and 95% limits of agreement

Therefore, the flap and stromal bed thicknesses may not be available when needed at a later time for repeated laser treatment enhancement planning or complication management. Another method of flap analysis, which is noncontact OCT, has the advantages of ease of use, ability to evaluate the flap morphology in a wide area, direct visualization of the flap-stroma interface, and precise measurement of the flap thickness. In the present study, we had no difficulty identifying the flap interface up to one month postoperative using OCT. No significant differences were noted in the achieved flap thickness between one week and one month postoperatively. The repeatability of flap was excellent for the profile (2–5 μm) and good for the map (5–7 μm) within the central 5 mm diameter area by CAS-OCT, which is similar to the prototype of Visante-OCT[4].

The intraoperative mean flap thickness by ultrasound pachymeter was (123.80±13.86) μm. This study showed that the AMADEUS Ⅱ fiap thickness measurements by ultrasound pachymeter is usually thinner than the manufacturer's label, confirming the results of other studies[5-6]. Using the same AMADEUS 140 microns cutting head and intraoperative pachymetry, Rocha found central flap thickness measured was (107.2±14) μm[5], and Lackerbauer reported the central flap thickness achieved (132.1±10.0) microns[6]. Jackson[7] found mean flap thicknesses for the 140-micron head was (153±18) μm. Factors that explained the variability of corneal flap thickness included microkeratome model, plate thickness, mean preoperative pachymetry, K min, surgery order, head serial number, blade lot number, and surgeon[8,9]. For AMADEUS II microkeratome, different head advance speeds and oscillation rates created corneal flap with different thicknesses. A slower head–advance speed causes a thicker fiap[6].

The 95% LoA of flap thickness between Visante-OCT and ultrasound pachymeter was –5.40 to 42.10 μm. There are a few factors that could explain this discrepancy.

First, the cornea undergoes a hydration shift as soon as the flap is cut because water as liquid lubrication goes into the flap-stroma interface in the process of cutting corneal flap, and the tensile strain borne by the flap is shifted to the posterior stromal bed. Water as liquid lubrication goes into corneal stromal bed when the ultrasound probe contacts the stromal bed. These factors cause an immediate increase in water content of the corneal bed. Corneal bed thickness measured by ultrasound pachymeter is greater than the actual value as it underestimates the thickness of the corneal flap. Moreover, the increases in the water content/thickness of the process have significant differences, and the manual placement of the two measurements by ultrasound pachymeter introduces a new variation. Thus, the above factors further lead to a larger standard deviation of measurements by ultrasound pachymeter than Visante-OCT.

Second, after the corneal flap is cut, biomechanics dictate that the corneal tissue under greater tensile strain (i.e., the stromal bed) will become thinner, whereas tissue under less tensile strain (i.e., the flap) will absorb water and become thicker[10-14].

Third, the epithelial hyperplasia after myopic

LASIK[15] could be a contributing factor. The second and third factors explain the thicker fiap measurements by OCT one week and one month after LASIK compared with intraoperative ultrasound measurement. Underestimation of the thickness of the corneal flap by ultrasound pachymeter leads to a negative correlation of the average and the difference of flap thickness between Visante-OCT one month after LASIK and ultrasound pachymeter. Whatever the mechanism may be, OCT users should be aware that a certain systematic difference exists between OCT and ultrasound flap thickness measurement in AMADEUS II microkeratomes.

In summary, Visante-OCT overestimated flap thickness compared with intraoperative ultrasound pachymeter. A certain discrepancy does not detract significantly from the value of OCT in determining whether there is sufficient stromal bed thickness to perform a LASIK enhancement. Routine use of OCT will improve the safety of LASIK procedures.

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