Comparison of Corneal Thickness with Online Optical Coherence Pachymetry and Ultrasound Pachymeter

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Abstract: Purpose*:* To evaluate the accuracy of the intraoperative online optical coherence pachymetry (OCP) during LASIK surgery and assess its value during laser ablation. Setting: International Eye Hospital, Cairo, Egypt Methods: A prospective comparative study of 78 patients (156 eyes) with mild to moderate myopic/myopic astigmatic refractive error who underwent LASIK with Schwind Amaris Excimer Laser system equipped with optical coherence pachymetry (OCP). Preoperative, pre- and post- ablation stromal beds were measured with ultrasound pachymetry and optical coherence pachymetry. Only the Moria M2 microkeratome was used, and the flap thickness and actual ablation depth were calculated. Results: The preoperative measurements taken with the non-contact OCP were significantly lower than that with the contact ultrasound pachymeter, while there was a good correlation between them in the pre- ablation stromal bed and post- ablation stromal bed thicknesses. The calculated ablation depth by both techniques also matched the assumed maximum ablation depth calculated preoperatively with Schwind-CAM software.Conclusion: Intraoperative online optical coherence pachymetry may be considered a useful tool to assess the flap thickness and the residual stromal bed during LASIK surgery.

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1. Introduction

Corneal thickness is the major limiting factor in all tissue ablating corneal treatment procedures. Ablations deeper than planned may lead to over-corrections and inadequate residual corneal thickness which increases the risk of postoperative keratectasia **(1-4).** It is especially important in laser in situ keratomileusis (LASIK) as the flap may lead to mechanical instability of the cornea **(5).** Adding to the difficulty and unpredictability is the fact that the cut depth of conventional microkeratomes is variable for each individual patient, therefore it is almost impossible to reliably maintain a defined minimum of untreated cornea in each individual case **(6–9).** Therefore, intraoperative measurements of corneal thickness appear to be desirable for the safe assessment of corneal thickness during LASIK.

Until recently, there was no possibility to measure corneal thickness during refractive corneal surgery. This has changed with the integration of optical coherence tomography (OCT) into excimer laser systems. With this new device, very fine structures in the eye can be detected through an interferometric principle. The significant advantages of online pachymetry are the high resolution in micrometer range, no requirement of contact with the cornea and the continuous measurement of corneal thickness during the surgical procedure. **(10)**

Several instruments are available to measure the central corneal thickness (CCT) with varying degrees of accuracy. Ultrasound (US) pachymetry is commonly used because it is easy to use and relatively inexpensive, and has been considered the gold standard for CCT measurement. Disadvantages of US pachymetry include the need to anesthetize the cornea, cornea–probe contact, corneal indentation and the possible compression effect during measurement leading to corneal surface disturbance (which can interfere with other evaluations such as topography and wavefront acquisition). There is also the risk for corneal epithelial damage and transmission of infection. **(11)** In addition, measurements can vary as a result of probe misalignment or decentration, and the probe may not be perpendicularly aligned accurately positioned because of a lack of fixation and gaze control. Other disadvantages include the estimation of the thickness of a single point with each contact, and changes in the speed of sound in corneal tissues with different degrees of hydration**(12)** No correlation has been shown between compression and applied force.**(13-15)** Therefore the reproducibility of US pachymetry measurements is largely dependent on examiner experience; inter-examiner reproducibility is lower than intra-examiner repeatability, even when measurements are performed in normal corneas by expert examiners.

The purpose of this study was to evaluate the role of online optical coherence pachymetry in improving safety during LASIK procedures. The goals were to compare the results taken by acoustic and interferometric pachymetry, thus establish the reliability and applicability of the online OCP device in routine clinical practice.

2. Patients and Methods

One hundred and fifty six eyes of 78 patients with mild to moderate myopic/myopic astigmatic refractive error were inducted to this study. All eyes had a best corrected distance visual acuity of 20/20. There were no age or sex restrictions.

Surgical Technique and Measurement

Preoperative US pachymetry was performed first. The device used was the Sonogage Corneo-Gage Plus, Sonogage Inc. The ultrasound velocity was set at 1640 m/sec. After topical anesthetic drops (proparacaine 0.5%) were instilled, the US probe was placed directly in the center of the eye, creating a 90-degree angle. The final US pachymetry value was obtained from 1 measurement by 1 technician. The US pachymetry device takes multiple, rapid, and sequential readings during a single applanation of the probe. This gives a mean US pachymetry reading with a standard deviation (SD). The reading was accepted when the SD was less than 2.0 to 3.0 mm.

The patients were prepared to undergo LASIK with Schwind Amaris Excimer Laser system equipped with optical coherence pachymetry (OCP). All the procedures were performed by one surgeon at the International Eye Hospital in Cairo, Egypt. Only patients having same-day bilateral LASIK using the Moria M2 microkeratome to create superiorly hinged flaps were included. The right eye was always treated first. The head size used was 130µ. The same suction ring and stop (following the Moria M2 nomogram), microkeratome blade head size (130 µm) were used in all eyes. However, to ensure consistency and avoid the variance in flap thickness when using the same blade for both eyes of each patient, each eye was treated with a new blade (i.e. first cut).

The online OCP was activated in all cases after insertion of the lid speculum and with first alignment of the eye with the excimer laser system. It was continuously active until the end of the procedure. The flap was always centered on the visual axis and opened immediately under the excimer laser microscope. At defined time points during the procedure, measurements by both the online OCP and followed by the US pachymeter were taken and recorded as follows: (1) with first alignment of the eye (preoperative); (2) after the flap was created and lifted; (3) at the end of ablation; (4) at the end of the procedure after the flap was repositioned. Flap thickness was defined as the difference between measurements 1 and 2. Residual stromal bed was defined as the difference between measurements 2 and 3.

3. Results

The results show that all the measurements taken by the US were higher than the OCP. The preoperative pachymetry measurements showed a mean difference of 26.4µ. The flap thickness was higher with US, with a mean difference of 20.0µ. The preablation pachymetry showed a mean difference of 10.1 microns, the actual ablation depth presented a mean difference of 0.35µ, and the postoperative pachymetry showed a mean difference of 9.6µ. The correlation coefficient between online OCP and U/S measurements was 0.92 (*P*<0.001); with a mean difference of 15.125 ± 6.9 µm.

The mean postoperative refraction was SE of -0.5 ± 0.18 D; range from 0 to 1.25 D.

None of the eyes needed intraoperative alteration of the planned ablation parameters; a 300 µm residual stromal bed limit was not exceeded in any of the cases.

Table 1: Corneal pachymetry measurements with US and OCP; preoperative, pre-ablation and post-ablation LASIK

All measurements in µm	U/S		OCP	
	Mean ± Standard Deviation	Range	Mean ± Standard Deviation	Range
Preoperative pachymetry	551.7 ± 32.3	500 to 599	525.3 ± 32.1	483 to 575
Planned flap thickness	160			
Actual flap thickness	135.9 ± 23.5	119 to 157	120.9 ± 23.7	92 to 138
Pre-ablation pachymetry	453.6 ± 46.2	383 to 518	443.5 ± 41.9	385 to 505
Planned ablation depth	65.4 19.5 (42 to 90)			
Actual ablation depth	65.6 ± 27.7	46 to 111	65.25 ± 21.1	43 to 94
Post-ablation pachymetry	388.6 ± 53	323 to 482	379.2 ± 54.4	322 to 480

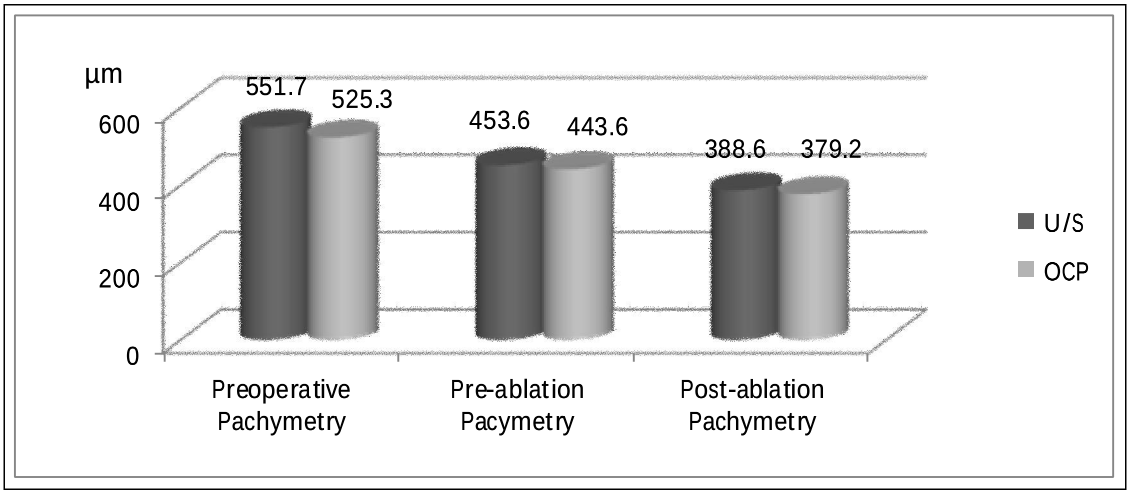

Figure 1: Mean of different measurements with U/S and OCP

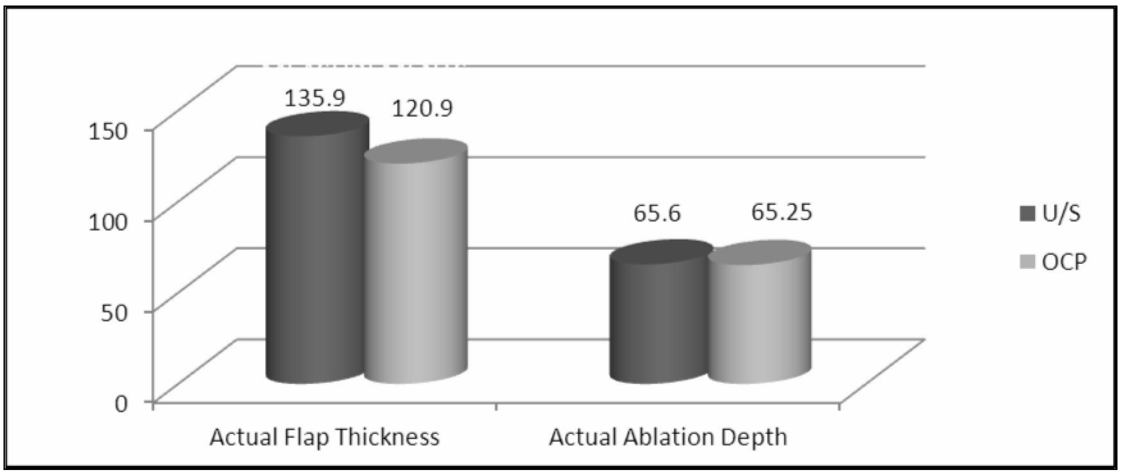

Figure 2: Mean of different measurements with U/S and OCP

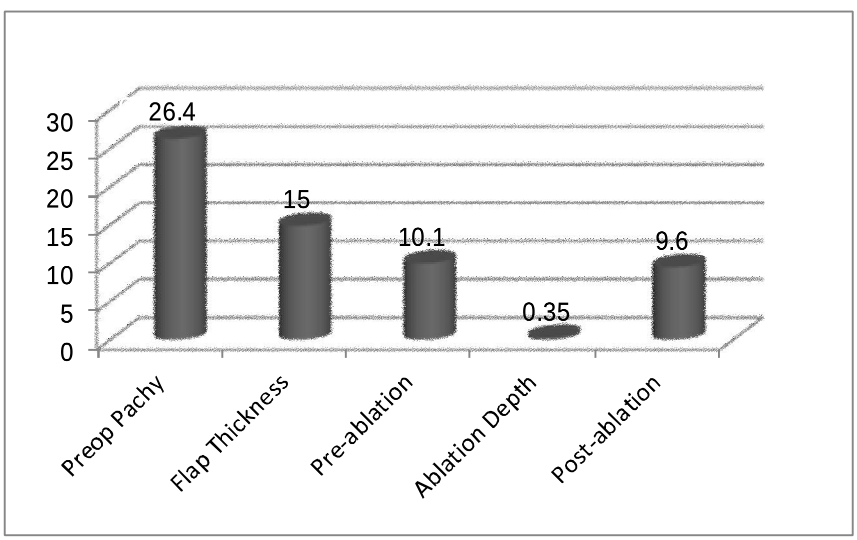

Figure 3: Mean difference between OCP and US measurements during the different stages of the procedure

4. Discussion

Accurate assessment of corneal thickness is important to minimize the risk for serious post-LASIK complications, such as keratectasia. Knowing the corneal thickness allows the surgeon to compute the depth of residual corneal tissue and determine the safety limit of a procedure. (16, 17) Given the amount of uncertainty in determining corneal thickness, considerably more tissue would have to be left unablated to ensure safety. This is especially important when treating eyes with higher myopic refractive errors with proportionally larger ablation depths, and during enhancement procedures. Furthermore, highly accurate corneal thickness measurements are critical in ensuring the accuracy and safety of enhancement procedures. (18,19) Although US pachymetry has been the standard for CCT measurement because of its established reliability, the high speed and noncontact approach of online optical coherence pachymetry make this method a promising alternative.

This study found that preoperative online OCP data (with the system-integrated 5% correction factor) were consistent with the ultrasound measurements. This is in accordance with the results in other studies, (20-25) which found slightly thicker corneal thickness measurements with the ultrasound than with slit lamp-mounted OCP or other intraoperative OCP measurements (without the use of a correction factor). Several reasons for this have been suggested; these include tilting of the ultrasound probe, averaging mode, and edema from local anesthesia (26) Since ultrasound is still considered the gold standard, this common denominator has been agreed on for practical purposes, as all different pachymetry techniques lead to slightly different results and it is up to now uncertain which device measures closest to the actual value. (27).

In our study, additional factors influencing the reliability of the pachymetry measurements must be considered. First, preoperative pachymetry measurements with ultrasound and online OCP were recorded after local anesthesia was applied.

Second, the measurement location of the online OCP was always on the visual axis, whereas the location of the ultrasound pachymetry was the center of the cornea. Despite these considerations, which are a problem in any study on this subject, both measuring techniques were consistent, including the gold standard (ie, ultrasound pachymetry).

Although several studies propose the use of ultrasound for intraoperative pachymetry, there are several limitations to this technology. These include the requirement of intraoperative contact with the stromal bed, possible incitement of inflammation, the problem of resolution and reproducibility of measurement, location, and the need for a certain amount of fluid in the tissue bed for proper coupling, which may interfere with laser ablation. (7,28,29)

The major drawback of online OCP in clinical use is that a fixed refractive optical group index of 1.3684 is used throughout the procedure. Experimental studies with corneas have shown that the optical index is different in the epithelium, Bowman membrane, and the anterior and posterior stroma. In addition, hydration changes in human and bovine corneas have been documented before and after LASIK. (5)

Online OCP is an excellent scientific tool, but further studies are needed to determine the implications of thinner central corneal thickness measured with online OCP as well as to resolve the systematic differences in measurements by these pachymetric technologies.

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