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ORIGINAL ARTICLE

Comparison of central corneal thickness measurements using Pentacam and ultrasonic pachymetry in post-LASIK eyes for myopia

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PURPOSE. *To compare central corneal thickness (CCT) measurements obtained using the Pentacam Scheimpflug system with those obtained using DGH ultrasound pachymetry (UP) in post–laser in situ keratomileusis (LASIK) eyes for myopia.*
METHODS. *In a prospective study, measurement agreement was assessed in 143 eyes of 72 post-LASIK patients using both the Pentacam and UP at the Eye Consultants Center in Riyadh, Saudi Arabia.*
RESULTS. *The mean CCT was 522±42.2 µm with the Oculus Pentacam and 516.2±40.6 µm with UP. The Bland-Altman plot showed that the mean ± SD for the differences between the 2 devices was 5.8±13.6 µm, with 95% confidence interval limits ranging from –20.9 µm to 32.6 µm. A test of statistical significance indicated that the mean differences of 5.8±13.6 µm differed significantly from zero ($p<0.001$; Wilcoxon signed-rank test), thus indicating that the Pentacam measurements tended to overestimate CCT compared with UP. Analysis of regression showed a high correlation between the values obtained with both devices ($r=0.947$, $p<0.001$).*
CONCLUSIONS. *In post-LASIK myopic eyes, although a high correlation has been shown between Pentacam and UP measurements, Pentacam tends to overestimate CCT compared to UP. Pentacam probably cannot be used interchangeably with UP in post-LASIK eyes for myopia. (Eur J Ophthalmol 2010; 20: 852-7)*

KEY WORDS. *Corneal thickness, Laser in situ keratomileusis, Pachymetry, Pentacam, Ultrasound*

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INTRODUCTION

Attaining accurate central corneal thickness (CCT) measurements is important in the preoperative and postoperative management of corneal surgical procedures such as laser in situ keratomileusis (LASIK), a popular approach for the correction of refractive errors. Accuracy of measurements is particularly important in patients who have undergone previous LASIK with suboptimal outcomes and are being considered for an enhancement procedure. As postrefractive patients age, they are also more likely to experience glaucoma, cataracts, and degenerative corneal conditions. Therefore, having an accurate CCT measurement concerns not only surgeons who perform keratorefractive surgery but also any ophthalmologist who monitors and treats glaucoma, cataracts, and corneal disease states.

Ocular ultrasound, which has been used over the last 30 years, is still recognized as the most commonly used method of accessing and quantifying ocular structures (1). Ultrasound pachymetry (UP) is an efficient and accurate way to measure corneal thickness and is considered the current gold standard (2). Its advantages include ease of

use, portability, and low cost. However, concerns about the possibility of patient discomfort, epithelial damage, and infection with this contact method exist. In addition, errors caused by indentation of the cornea have been reported (3).

The Oculus Pentacam is a fast, noncontact method of measuring corneal thickness, which uses a rotating Scheimpflug camera that provides a 3-dimensional scanning of the anterior segment of the eye (4). From the images acquired, information regarding the anterior and posterior corneal topography, corneal pachymetry, anterior chamber depth, angle, and lens density can be evaluated. Because of video monitor control, precise positioning of the instrument's camera system is assisted by magnification, thus avoiding measurement bias caused by incorrect centration.

The Pentacam has been widely used for topographic pachymetry in virgin corneas (5-11); it has been compared to UP, giving a thicker (5, 9-11), thinner (6-9), or similar central CT (6-8, 10). To our knowledge, few reports compared these modalities in post-LASIK corneas (12-14). In this study, we compared the accuracy of CCT measurements using the Oculus Pentacam and UP in myopic patients who underwent LASIK in a relatively large sample of patients.

PATIENTS AND METHODS

The Oculus Pentacam (Oculus Inc., Wetzlar, Germany) and DGH-1000 ultrasonic pachymetry (DGH Technology Inc., San Diego, CA) were used to measure CCT in a total of 143 post-LASIK myopic eyes of 72 patients who presented 6 weeks or more postoperatively at the Eye Consultants Center in Riyadh, Saudi Arabia. None of the patients had ocular diseases other than the corrected refractive error. We excluded from the study any patient with intraoperative or postoperative complications. All subjects were volunteers and had provided informed consent.

LASIK procedures were performed by a single surgeon (K.M.J.). The corneal flaps were created using a gas turbine microkeratome (Moria, Antony, France). Laser photoablation was performed using a Nidek EC-5000 Excimer Laser Corneal Surgery System (Nidek, Gamagori, Aichi, Japan).

When the Oculus Pentacam is used, the patient is seated with his or her chin on a chin rest and forehead against the forehead strap and is asked to stare straight ahead at a fixation target. The operator visualizes a real-time image of the patient's eye on a computer screen, with the machine marking the pupillary edge and the corneal apex. The operator can manually focus and align the image. Arrows are displayed on the screen to guide the operator's alignment of the instrument in the horizontal, vertical, and anteroposterior axes. To reduce operator-dependent variables, the Pentacam's automatic release mode was used. In this mode, the instrument automatically determines when correct focus and alignment with the corneal apex have been achieved and then performs a scan in less than 2 seconds. The rotating camera captures up to 50 slit images of the anterior segment while minute eye movements are captured by the second camera and are corrected simultaneously. Each slit image consists of 500 true elevation points.

The anterior surface of the cornea is calculated using mathematical software with no optical distortion, and, according to the manufacturer, the tear film has no effect on measurements. Single-point pachymetric measurements of the entire cornea are calculated from the front and back surfaces using ray tracing, with the calculation taking into account optical distortions. Because the center of the cornea is measured repeatedly during the rotational imaging process (in each of the images), a very precise determination of CCT measurement can be achieved. Single CCT measurement for each cornea using Pentacam was taken. All measurements were taken by a single observer.

UP was determined using an A-scan ultrasonic pachymeter (DGH Technology, Inc.), which was precalibrated for all measurements. The ultrasonic velocity was set at 1,640 m/s. Topical anesthesia with benoxinate hydrochloride 0.4% (Novesin 0.4%) was used. CCT was measured with patients seated upright. A hand-held probe was aligned as perpendicular as possible on the central cornea. Five readings were obtained and averaged. The Pentacam readings were taken first to avoid any potential disturbance caused by the corneal contact involved in UP. All measurements were taken between 4:00 PM and 9:00 PM and were done by a single observer who was blinded to the Pentacam results, which were taken by another observer.

The distributions of ultrasound and Pentacam measurements for CCT were compared using histograms. The differences between measurements of both methods were investigated by Wilcoxon signed rank test. The correlation between the measurements obtained using the 2 methods was investigated by computing the Pearson correlation coefficient. The Bland-Altman graph was used to study the agreement between the 2 devices in the studied va-

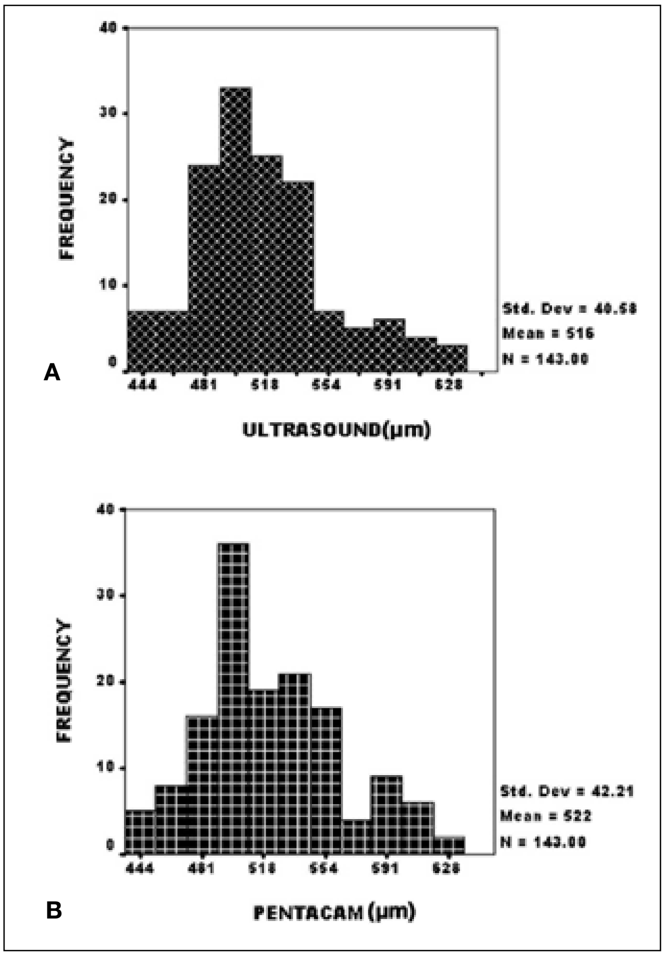

Fig. 1 - *Histogram of central corneal thickness, as measured by the Oculus Pentacam* **(A)** *and ultrasound pachymetry* **(B)**.

riables, and the 95% limits of agreement were calculated. The mountain plot graph was used to assess the percentile distributions of negative and positive differences. Data are presented as ± standard deviation. The MedCalc statistical software version 9.3, Statistical Product and Service Solutions (SPSS) version 11.5, and BMDP 2007 software were used for the analysis. A p value less than 0.05 was considered significant.

RESULTS

CCT measurements were performed in a total of 143 (72 right, 71 left) post-LASIK myopic eyes of 72 patients using UP and Pentacam. The mean postoperative period of measuring the CCT was 7.30±1.6 weeks (range, 6–16 weeks). The mean myopic spherical equivalent (SE) was –3.90±1.97 D (range, –9.75 to –0.75D). We used graphical and analytical methods to investigate the equivalence of measurement results obtained with the 2 methods. As shown in Figure 1, A and B, the ultrasound and the Pentacam measurements show close similarities in distribution as well as in central tendency and dispersion. The mean ± SD for the ultrasound distribution of CCT measurements was 516.2±40.6 μm as compared with 522.0±42.2 μm for the Pentacam CCT measurements.

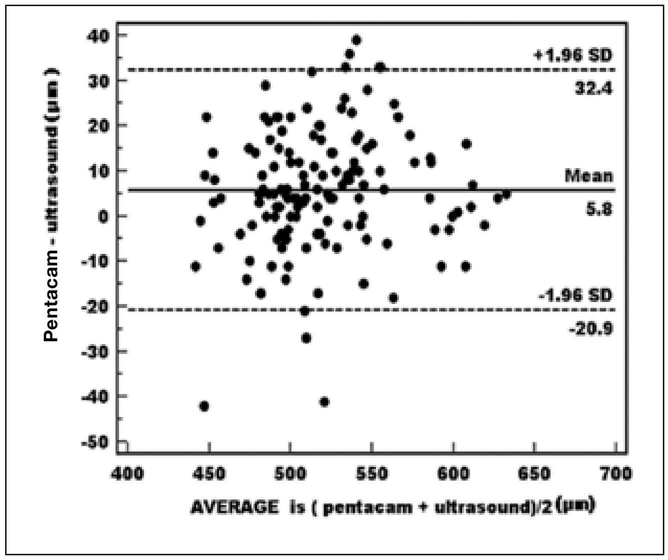

Fig. 2 - *A Bland-Altman plot for the Pentacam minus ultrasound differences.*

The Bland-Altman graph is shown in Figure 2. The mean ± SD for the differences was 5.8±13.6 μm, with 95% confidence interval (CI) limits ranging from –20.9 μm to 32.6 μm. The graph shows that, with the exception of a few outlier differences, the majority of differences between the Pentacam and the ultrasound measurements fell within the 95% confidence interval for the distribution of differences. A test of statistical significance indicated that the mean differences of 5.8±13.6 μm differed significantly from zero ($p<0.001$; Wilcoxon signed rank test), thus indicating that the Pentacam measurements tended to overestimate CCT compared with UP.

The distribution of Pentacam–ultrasound differences was further investigated using a mountain plot graph (Fig. 3). The graph should be symmetrical about a value of zero, along the horizontal axis, if the percentile distributions of negative and positive differences were similar. The graph

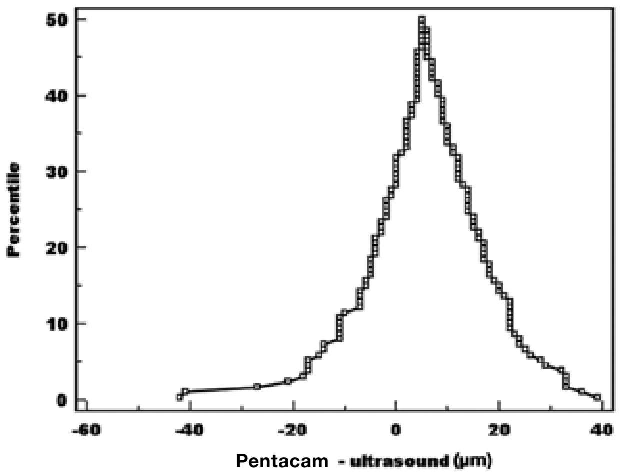

Fig. 3 - *A mountain plot demonstrating percentiles of differences in the distribution between the Pentacam minus ultrasound pachymetry values.*

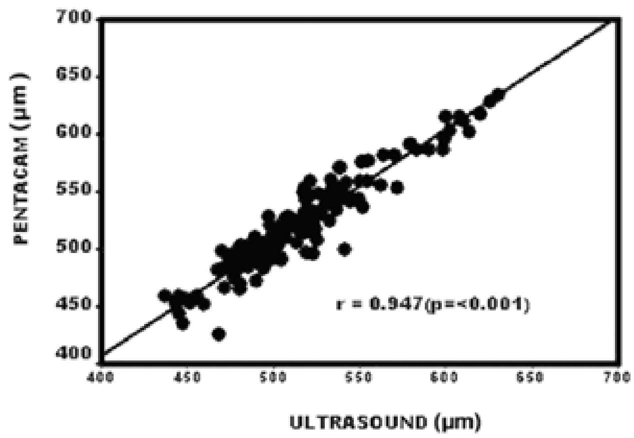

Fig. 4 - *Scatterplot graph of the central corneal thickness, as measured by the Pentacam versus ultrasound pachymetry.*

is slightly shifted to the right of zero, thus indicating that CCT measurements obtained by the Pentacam were often higher than those by UP. As shown in Figure 4, a very strong correlation (r=0.947; p<0.001) exists between measurements obtained using the 2 methods.

DISCUSSION

In this prospective case series, we compared CCT measurements between the Pentacam and UP in post-LASIK eyes for myopia. Although the CCT measurements using the 2 devices were highly correlated, Pentacam significantly overestimated CCT compared to US pachymetry.
Because biomechanical stability of the cornea after excimer laser surgery depends on residual corneal thickness, postoperative pachymetry is very important, especially in candidates for enhancement surgery. Overestimation of corneal thickness may increase the risk of corneal ectasia in ineligible patients. On the other hand, underestimation can result in exclusion of patients who may be candidates for safe refractive surgery (15).
Previously, few studies evaluated CCT using the Pentacam and UP in eyes that had undergone LASIK (12-14). Ciolino et al (13) demonstrated that CCT measurements obtained using the Pentacam have good correlation and agreement with those obtained using UP; therefore, they suggested that the Pentacam can be used as a substitute for UP in post-LASIK patients. In contrast, Ho et al (12) showed that the Pentacam significantly underestimated CCT compared with UP. In addition, Hashemi et al (14) demonstrated that Pentacam underestimated CCT in comparison to UP in a series of 38 eyes that had LASIK.
Our study showed that the Pentacam significantly overestimated CCT measurements compared to UP in post-LASIK eyes. We are not sure of the reason for the discrepancy between different reports. This discrepancy may have occurred because the ultrasound probe requires corneal touch—it is well known that the applanation force can displace the 7- to 30-µm-thick tear film or that the probe compression may thin the epithelium, thus resulting in slightly thinner CCT when measured with UP (16, 17). In addition, UP includes the use of a local anesthetic, which may alter the corneal thickness (18-20). Moreover, the location where the ultrasonic probe is applied may vary in repeated measurements because there is no fixation target for controlling eye movement (21). Other possible causes of the inconclusive results might be explained by any of the following: pachymeters with low reproducibility, inexperienced observers, or no consideration of diurnal variation. Further studies are needed to address the causes of such discrepancies.

The reproducibility of optical devices such as Pentacam and Orbscan that rely on measurements of scattered reflected light beams through the corneal tissues might be questionable when the corneal medium is not clear or has optical interference such as cases post corneal surgery. Recently, Matsuda et al (22) showed that the CCT measurements with Pentacam compared to Orbscan were statistically stable in postoperative corneas and corneas with haze. They hypothesized that with Orbscan, the camera, which faces the cornea, catches scattered reflected light beams as it moves to the right and left. As the angle of illumination changes, the distance at which the instrument captures images changes. As a result, the perfect focal distance cannot be achieved for both the anterior and posterior cornea. Corneal haze causes additional distortion and lowers the brightness of the posterior edge of the cornea, resulting in a lower quality posterior surface edge. In comparison, the Scheimpflug camera of the Pentacam catches rotating, scattered reflected light beams which are set at the front of the cornea. The camera itself rotates about an imaginary line through the center of the cornea, keeping a stable angle with the central corneal axis, thereby fulfilling the Scheimpflug principle. The Scheimpflug camera system provides the advantages of a higher depth of focus and a sharp, undistorted picture. Thus, Pentacam is more accurate at measuring CCT compared to Orbscan.

In conclusion, the results from our study are based on a reasonably large sample of post- LASIK eyes in which CCT was measured using Pentacam (a noncontact optical pachymeter) and UP. Although both methods showed very strong correlation, Pentacam significantly overestimated CCT compared to UP. Considering the systematic differences (different technological methods and operating techniques) between both tools that resulted in different values, we believe that CCT measurements cannot simply be substituted between both modalities and Pentacam cannot be used interchangeably with UP in post-LASIK eyes for myopia.

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