ORIGINAL ARTICLE

Comparison of Central Corneal Thickness Measurements by Contact and Non-contact Pachymetry Devices

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Abstract

Aim and objective: To compare central corneal thickness (CCT) measurements obtained by handheld contact ultrasound pachymetry (HCUP) and non-contact pachymetry devices.

Materials and methods: Ninety eyes of 90 patients (52 male and 38 female) were included in the study. Measurements from two non-contact devices, —specular microscopy (SM, Konan Medical, CA, USA) and Oculus Pentacam (Oculus Inc., Germany)—were compared against HCUP (Pachmate 2, DGH Technology, Inc, PA, USA). Ultrasound measurements were obtained 3 times by the same user and averaged. The differences were calculated by one-way ANOVA. Agreement between measurements were assessed by Bland–Altman plots and intraclass correlation coefficient tests. Coefficient of repeatability (%, CR) was defined as 1.96*standard deviations of the differences between pairs of measurements divided by the average of the means.

Results: The mean age was 34.31 ± 14.39 (14–74) years, and the mean intraocular pressure was 16.48 ± 2.63 mm Hg (12–21). Mean CCT measured by HCUP, SM, and Pentacam was 557.76 ± 36.76 µm, 550.29 ± 43.74 µm, and 541.41 ± 35.7 µm, respectively ($p < 0.05$). In the Bland–Altman plot, 95% limit of agreements were 19.5 and 14.18 µm among HCUP measurements, 34.55 µm between HCUP and Pentacam, 41.49 µm between SM and Pentacam, and 46.98 µm between HCUP and SM. CR values (%) were 3.49, 2.54, 6.28, 7.68, and 8.47, respectively.

Conclusion: There were significant differences between the mean CCT values of the measurement devices.

Clinical significance: Contact and non-contact devices may not interchangeable in the clinical assessment of CCT.

Keywords: Central corneal thickness, Ocular tonometry, Pachmate, Pentacam, Specular microscopy.

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Introduction

Central corneal thickness (CCT) measurement is an important clinical assessment in the diagnosis of corneal diseases such as glaucoma and keratoconus, detection of edema caused by contact lens use, and before and after refractive surgery.[1–4] A 10% change in CCT alters intraocular pressure (IOP) by 3.4 mm Hg, and correcting for CCT is necessary to accurately measure IOP.[5,6]

CCT can be evaluated either with contact ultrasound pachymetry (UP) devices or non-contact devices such as the Oculus Pentacam, specular microscopy (SM), confocal biomicroscope, optic laser interferometer, and optic coherence tomography instruments. Currently, the gold standard method for pachymetry is the ultrasonic method. UP is the most common method as it can be easily applied to obtain CCT measurements and is repeatable and reliable. Disadvantages of this method are that it requires contact with the cornea, use of topical anaesthetic, and may cause epithelial defects and corneal infections. Placing the probe exactly centered, perfectly perpendicular, and without applying pressure to the cornea is essential for accurate measurement. However, changes in the tear film that may occur during measurement, pressure on the cornea, failure to measure from the exact center of the cornea, and placement of the probe at an oblique angle to the cornea may cause errors in the measurement.[7–11]

Non-contact devices have advantages such as minimizing user errors, not requiring topical anaesthetic, and performing rapid measurements. Moreover, with the device software, it is also possible to obtain IOP corrected for CCT value.[7,9]

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This study was conducted to compare the mean CCT values of handheld contact ultrasound pachymetry (HCUP) and non-contact pachymetry devices.

Materials and Methods

Our study was conducted in accordance with the clinical research principles in the Declaration of Helsinki, and approval was obtained from the university ethics committee. A total of 90 eyes of 90 patients who presented to ophthalmology outpatient clinic and had no signs of ocular pathology on ophthalmologic examination were included in the study.

CCT values were measured once using non-contact SM (Konan Medical, Irvine, CA, USA) and Oculus Pentacam (Oculus Inc., Germany) devices. Then, with the patient in seated position, a drop of topical anesthetic proparacaine hydrochloride (Alcaine, Alcon,

Melbourne) was instilled, the probe of the HCUP device Pachmate 2 (DGH Technology, Inc, PA, USA) was positioned on the central cornea at a perpendicular angle, and 3 manual measurements were obtained. All measurements were performed by the same user. During contact between the probe and cornea, the device automatically makes 25 measurements and gives their mean, and this value was recorded.

Statistical analysis of the results was performed using IBM SPSS Statistics for Windows, version 24.0 software (IBM Corp., Armonk, NY). The results were presented as mean ± standard deviation (SD). CCT measurements obtained using the 3 different pachymeters were compared using paired-samples one-way analysis of variance (ANOVA). Multiple comparisons of between-group variables were performed with the Bonferroni *post hoc* test correction. Repeatability of the measurements was analyzed using intraclass coefficient (ICC) analysis. ICC values reflects how similar items in the same group are; the widely accepted interpretation of these values is that ICC = 0–0.2 indicates very poor repeatability, 0.21–0.4 poor repeatability, 0.41–0.6 moderate repeatability, 0.61–0.8 good repeatability, and 0.81–1.0 excellent repeatability. Bland–Altman plots were used to analyze the 95% limit of agreement (LoA) of the measurement methods. In the Bland–Altman plot, *x*-axis represents the mean value of measurements obtained by two methods and the *y* axis represents the difference between measurements obtained by the two methods. Ideally, the mean difference in the *y*-axis should be 0. The range within ±1.96 SD of the mean difference was accepted as the 95% LoA. The coefficient of repeatability (CR) was defined as 1.96 SDs of the differences between pairs of measurements divided by the average of the means. A low CR indicates high consistency. A *p* value less than 0.05 was considered statistically significant.

Results

A total of 52 male and 38 female patients were included in the study. The mean age was 34.31 ± 14.39 (14–74) years, and the mean IOP was 16.48 ± 2.63 (12–21) mm Hg.

The mean CCT values measured by HCUP, SM, and Oculus Pentacam were 557.76 ± 36.768 µm, 550.29 ± 43.74 µm, and 541.41 ± 35.7 µm, respectively (Table 1). When CCT measurements were compared using one-way ANOVA, a significant difference was detected between the measurements ($p < 0.001$). When pairwise comparison was performed with Bonferroni correction, a statistically significant difference was detected between the devices ($p < 0.05$ for all values; Table 2).

ICC values for CCT measurements were between 0.81 and 1.0, indicating excellent repeatability. ICC was 0.98–0.99 among HCUP measurements, 0.89 between HCUP and Oculus Pentacam measurements, 0.91 between SM and Oculus Pentacam measurements, and 0.89 between HCUP and SM measurements (Table 3, $p < 0.001$ for all values).

The 95% LoAs in Bland–Altman plots were 19.5 and 14.18 µm among HCUP measurements, 34.55 µm between HCUP and Pentacam, 41.49 µm between SM and Pentacam, and 46.98 µm between HCUP and SM (Table 3 and Fig. 1). The CR values (%) were 3.49, 2.54, 6.28, 7.68, and 8.47, respectively (Table 3).

Table 1: Mean CCT values measured with HCUP, Oculus Pentacam and SM

	CCT (µm)	*Minumum (µm)*	*Maximum (µm)*
HCUP 1	558.73 ± 38.16	461	638
HCUP 2	556.27 ± 36.52	459	637
HCUP 3	558.29 ± 36.79	466	656
Mean HCUP	557.76 ± 36.76	463	644
Pentacam	541.41 ± 35.71	444	615
SM	550.29 ± 43.74	432	648

HCUP, Handheld contact ultrasound pachymetry; SM, specular microscopy; CCT, central corneal thickness

Discussion

When CCT values measured using contact and non-contact SM and Pentacam methods were compared, it was determined that CR of the CCT measurements ranged 6–9% (35–47 µm) between the devices. Intraobserver CR of the contact HCUP was 2–4%. The LoAs among the 3 devices for CCT measurements were not clinically acceptable.

CCT is an important parameter in the diagnosis of glaucoma and the diagnosis and follow-up of keratoconus patients. CCT can be measured using devices that touch the cornea or with non-contact devices.[1,2,7,8] CCT measurements vary between different types of pachymeter. Since a difference of 15 µm between two repeated CCT measurements corresponds to approximately 1 mm Hg of error in IOP measurement according to Ehlers factor, it is important to know the confidence intervals between measurements.[12] Several authors have reported that UP yields higher mean CCT measurements than non-contact devices. In CCT measurements performed on healthy eyes, Suzuki et al.[13] reported similar CCT values from the UP (548.1 ± 33 µm) and non-contact Orbscan II (546.9 ± 35.4 µm), while that obtained using SM was approximately 22 µm lower (525.3 ± 31.4 µm). Bovelle et al.[14] compared CCT measurements performed using SM and UP and determined that the CCT value obtained using UP was 32 µm higher. Lackner et al.[15] compared mean CCT values from the Oculus Pentacam (542 ± 29 µm), Orbscan (530 ± 34 µm), and UP (552 ± 32 µm) and observed that the value obtained using Pentacam was approximately 10 µm less than that of the UP. They also determined in the same study that measurement repeatability was higher and user error was lower when using Pentacam. In their study of normal corneas, O'Donnell et al.[16] found that CCT measurements obtained using UP (534 ± 47 µm)

Table 2: Differences (µm) between devices in CCT measurements

	Mean ± SD	*Minimum*	*Maximum*	*p value**
HCUP–Pentacam	16.35 ± 17.63	−69.33	68.67	<0.001
HCUP–SM	7.47 ± 23.97	−84.33	77	0.012
SM–Pentacam	8.87 ± 21.40	−55	101	<0.001

HCUP, handheld contact ultrasound pachymetry; SM, specular microscopy; SD, standard deviation

*One-way analysis of variance (ANOVA) with the Bonferroni correction.

Table 3: 95% LoA, CR and ICC values between measurements

	95% LoA (µm)	*CR (%)*	*ICC*
HCUP 1 vs HCUP 2	19.5	3.49	0.98
HCUP 2 vs HCUP 3	14.18	2.54	0.99
HCUP vs Pentacam	34.55	6.28	0.89
HCUP vs SM	46.98	8.47	0.89
SM vs Pentacam	41.94	7.68	0.91

HCUP, handheld contact ultrasound pachymetry; SM, specular microscopy; CR, coefficient of repeatability; ICC, intraclass correlation coefficient; %95 LoA, %95 limit of agreement of the difference between the devices

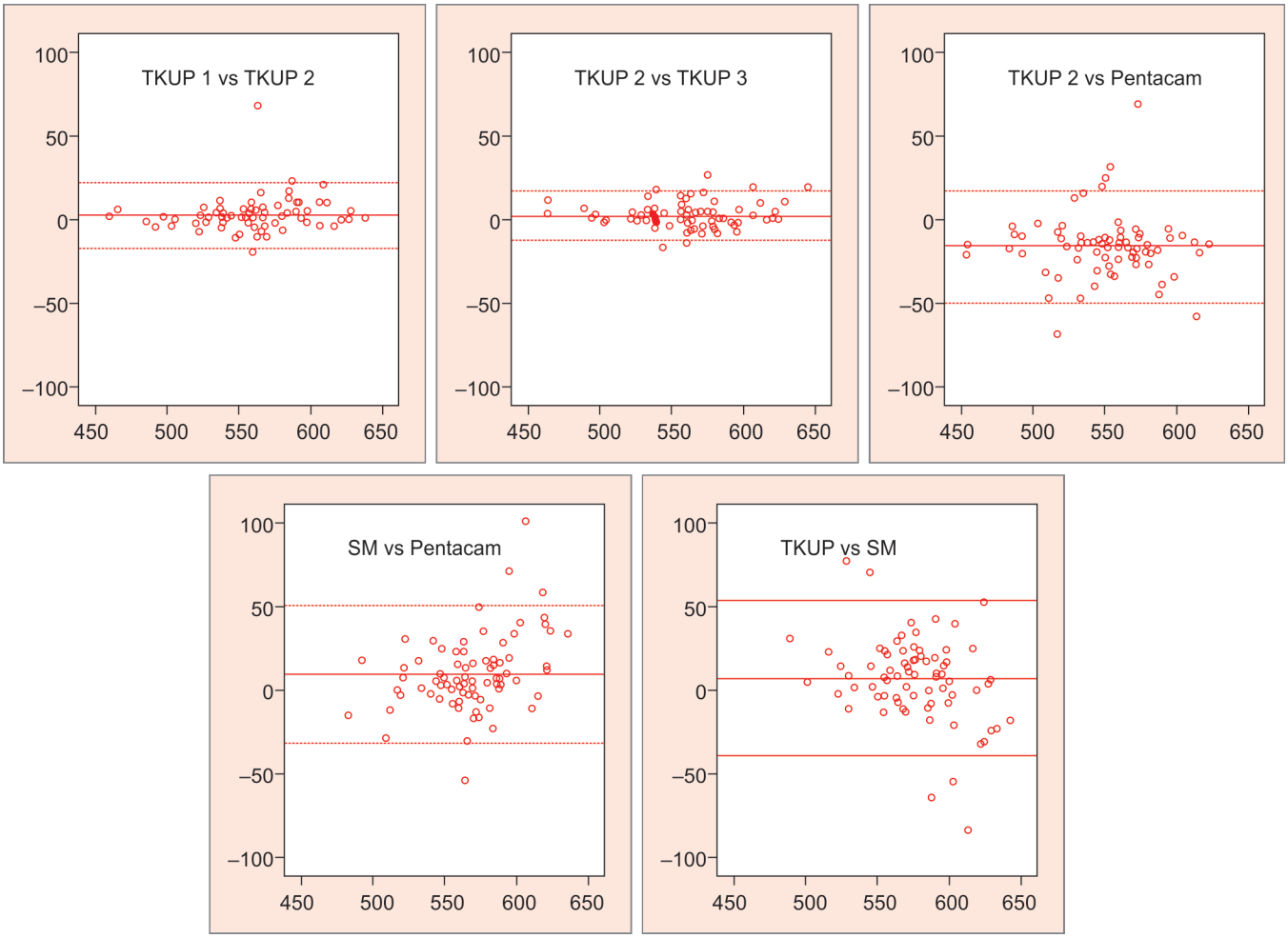

Fig. 1: Bland–Altman plots of CCT values measured using different pachymetry devices. Horizontal lines indicate the mean value of measurements from the two devices (µm); vertical lines indicate the difference between the measurements from the two devices (µm). The 95% LoA is shown with dashed horizontal lines above and below the horizontal solid line indicating the mean value (±1.96 SD). The 95% LoAs were 19.5 and 14.18 µm between HCUP measurements, 34.55 µm between HCUP and Pentacam, 41.49 µm between SM and Pentacam, and 46.98 µm between HCUP and SM

were approximately 6 µm higher than the measurements obtained using Oculus Pentacam (528 ± 45 µm). Desmond et al.[17] reported that CCT was higher when measured with HCUP (552 µm) compared to the non-contact Tonoref III (538 µm) and RS-3000 devices (548 µm). Their study showed that the Tonoref III and RS-3000 devices were rapid and reliable, and also had good repeatability. They also reported that a single CCT measurement performed using Tonoref III and RS-3000 could be 31 and 24 µm lower compared to measurements made using HCUP, respectively, and the clinician must evaluate whether these differences are acceptable. The 95% confidence intervals of HCUP vs the RS-3000 and Tonoref III were 15 µm and 4 µm, respectively. Wells et al.[18] analyzed 50 eyes and compared mean CCT values obtained with automated optical pachymetry (523.7 ± 42.3 µm), anterior segment optic coherence tomography (536 ± 36.9 µm), and HCUP (553.4 ± 40.7 µm). They reported that HCUP measured CCT 29.7 µm thicker than automated optical pachymetry and 17.4 µm thicker than anterior segment optic coherence tomography. In the literature, the higher mean UP and CCT values obtained with contact devices have been attributed to the formation of corneal edema related to topical anesthetic or to decentered and oblique probe positioning, due to the peripheral increase in corneal thickness.

However, various studies reported that UP underestimates CCT compared to other methods. Marsich et al.[19] reported that the Orbscan system had excellent repeatability in measuring CCT but that its mean CCT value (596 ± 40 µm) was higher than that obtained by UP (542 ± 33 µm). Yaylalı et al.[20] reported that mean CCT was 571.3 ± 6.21 µm with Orbscan and 543.3 ± 7.49 µm with UP, and that this difference was statistically significant. Al-Mezaine et al.[21] found that the mean CCT measured by Oculus Pentacam (552.4 ± 37 µm) was higher than with UP (544.1 ± 35.4 µm), but that CCT measurements from the two devices were strongly correlated and they could therefore be alternatives to each other. Fujioka et al.[22] reported that mean CCT measured by Oculus Pentacam (559.49 ± 38.44 µm) was higher than both UP (553.01 ± 39.33 µm) and SM (552.04 ± 42.95 µm) by approximately 6 µm. The authors speculated that the thinner CCT values measured using UP may be attributable to the thinning that may occur due to the dispersion of 7–40 µm thick tear film and thinning of the corneal epithelium due to corneal contact by the probe.[23] Moreover, because non-contact measurement devices such as the Orbscan measure the distance from the air–tear film boundary and the posterior corneal surface, the thickness of the tear film layer may result in a 7–30 µm increase in CCT thickness. In addition, the exactly point in the posterior

corneal surface at which the Orbscan measures is not known; it is speculated to lie anywhere between Descemet's membrane and the corneal endothelium, which may result in an increase of 3–10 µm in the measurement.[24]

We obtained similar results in the present study, corroborating previous studies suggesting corneal thickness is higher when measured using contact methods. Mean CCT measured by HCUP (557.76 µm) was 16.3 µm higher than with the Oculus Pentacam (541.41 µm) and 7.5 µm higher than with SM (550.29 µm). However, based on our results, it is not reliable to use these three methods interchangeably because 95% LoAs were 34 µm for HCUP and Pentacam, 42 µm for SM and Pentacam, and 47 µm for HCUP and SM.

Conclusion

HCUP devices may be preferred in clinical practice as they are portable, enable point-of-care testing, and are easy to use. However, it is of utmost importance that the user ensures the probe is exactly centered on the cornea for accurate CCT measurement. Otherwise, CCT may be measured thicker compared to non-contact methods.

Clinical Significance

There were significant differences between the mean CCT values of the contact and non-contact devices. The devices may not interchangeable in the clinical assessment of CCT.

Presentation at a Meeting

It was not presented at a meeting.

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