DOI: 10.4274/tjo.galenos.2021.22465
Turk J Ophthalmol 2022;52:318-323

Original Article

Comparison of Central Corneal Thickness Measurements with Four Different New Devices and Ultrasound Pachymetry

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Abstract

Objectives: To assess the central corneal thickness (CCT) with 5 different devices, evaluate the repeatability of the devices, and determine the possible relationship between thickness values and sex.

Materials and Methods: The study included 308 eyes of 154 patients (76 women, 78 men) between the ages of 18-30 who presented to the Ophthalmology Clinic of Muğla Sıtkı Koçman University Training and Research Hospital. Autorefractor (Topcon, Japan), ultrasound pachymetry (UP) (Ceniscan, USA), high-resolution Pentacam (Oculus, USA), anterior segment-optical coherence tomography (AS-OCT) (Optovue, USA), and Spectralis AS-OCT (Heidelberg, Germany) measurements were assessed.

Results: The mean age of the study participants was 23.2±0.2 years and the mean CCT was 540±14.1 µm, with no statistically significant difference in CCT between sexes (p>0.05). Mean CCT values were 557.0±26.7 µm with the autorefractor, 543.6±32.9 µm with UP, 533.8±30.2 µm with the Oculus Pentacam, 519.8±30.1 µm with Optovue AS-OCT, and 547.5±31.6 µm with Heidelberg AS-OCT. Pairwise comparisons between devices showed that the Optovue AS-OCT gave significantly lower CCT measurements than the autorefractor and Heidelberg AS-OCT device (p=0.027 and p=0.033, respectively). The coefficient of repeatability for autorefractor, UP, high-resolution Pentacam, Optovue AS-OCT, and Heidelberg AS-OCT CCT measurements were 1.51%, 2.46%, 3.72%, 2.57%, and 3.34%, respectively.

Conclusion: Measurements made with five different devices showed that CCT was comparable and clinically usable. However, it was determined that the Optovue AS-OCT showed lower CCT values compare to other devices. When compared in terms of repeatability, it was found to be lower in the Pentacam than other devices.

Keywords: Central corneal thickness, cornea, pachymetry, optical coherence tomography

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Received: 20.05.2021 **Accepted:** 06.10.2021

Cite this article as: Şimşek C, Kaya C, Karalezli A. Comparison of Central Corneal Thickness Measurements with Four Different New Devices and Ultrasound Pachymetry. Turk J Ophthalmol. Turk J Ophthalmol 2022;52:318-323

Introduction

Central corneal thickness (CCT) is an important parameter that is routinely measured in clinical ophthalmology practice and used in the diagnosis and follow-up of ocular diseases such as glaucoma, keratoconus, and corneal ectasia.[1] However, the accurate measurement of CCT is also used to monitor corneal edema and endothelial function, to plan refractive surgery, to obtain accurate postoperative results, and in follow-up.[2] Furthermore, CCT affects intraocular pressure measured by applanation tonometry and is an independent risk factor for the progression of ocular hypertension to primary open-angle glaucoma.[3] The ideal CCT measuring instrument should provide precise and accurate measurements, as well as provide maximum patient comfort, be fast and easy to operate, and be cost-effective and multifunctional. At present, ultrasound pachymetry (UP) is still considered the gold standard method and is widely used because of its ease of use, portability, and quick measurement time.[4] Disadvantages of UP include the need for topical anesthesia, the risk of epithelial erosion and corneal infection, and the possible effect of corneal indentation and probe misalignment on the accuracy of contact pachymetry.[5] Therefore, non-contact methods of measuring CCT may be preferred as long as accurate measurements can be obtained. There are currently various noninvasive techniques and devices for measuring CCT. Some of these are anterior segment-optical coherence tomography (AS-OCT), Scheimpflug-Placido disc-based corneal topography, coherence interferometry-based optical biometry, and specular microscopy (SM).[6,7] The reliability, repeatability, advantages, and disadvantages of these new techniques are not yet fully understood.

According to our literature review, there is no previous study comparing the reliability and repeatability of the devices used in this study. We believe the factors examined in this study will guide clinicians when deciding on a preferred method and device to measure CCT in busy ophthalmology practices. This study aimed to evaluate the repeatability, reliability, and inter-device agreement of CCT measurements obtained with 5 different devices in our clinic.

Materials and Methods

Ethics committee approval for this prospective, cross-sectional study was obtained from the Medical Research Ethics Committee of Muğla Sıtkı Koçman University Faculty of Medicine (approval number: 7/XIII, date: 03/2021). The study was conducted in accordance with the principles of the Declaration of Helsinki. All participants signed an informed consent form after being informed in detail about the nature and purpose of the study. Prior to the study, all participants underwent a complete ophthalmic examination including refraction, slit-lamp microscopy, and indirect ophthalmoscopy. Participants with any pathological findings on slit-lamp biomicroscopy, fundus photography, and AS-OCT, history of contact lens use in the last month, or corrected visual acuity of less than 0.8 were not included in the study. The study included 308 eyes of 154 patients (76 women, 78 men) aged 18-30 who presented to the Ophthalmology Outpatient Clinic of Muğla Sıtkı Koçman University Training and Research Hospital. All measurements were made by the same specialist and at the same time of day (10 am-3 pm). Each participant underwent measurements with an autorefractor keratometer (TRK-2P, Topcon, Tokyo, Japan), UP (Ceniscan, Quantel Medical, France), Scheimpflug camera (Oculus Pentacam HR, Type 70900, Wetzlar, Germany), AS-OCT (Optovue, Fremont, CA, USA), and Spectralis OS-OCT (Heidelberg Engineering, Heidelberg, Germany) (Figure 1). The participants were seated in the appropriate gaze position and instructed to look directly at the built-in fixation target on each device. After proper alignment, they were asked to blink and open their eyes immediately before each measurement. The participants were told to lift their head from the chin rest and return to the examination position after each measurement. After all non-contact measurements were completed, the final measurement was taken with UP. The cornea was first anesthetized with a drop of 0.5% topical proparacaine hydrochloride (Alcaine; Alcon, Belgium). The patient was asked to look directly at a fixation target and the probe was applied perpendicularly to the central corneal surface. After obtaining one measurement, the patient was instructed to blink, and repeated measurements were obtained. The ultrasound probe was sterilized with alcohol between participants.

Statistical Analysis

All statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean, standard deviation) were used to evaluate the data. CCT measurements and repeated measurements were compared using ANOVA. Repeatability coefficients were used as a measure of intra-subject variation per unit of the mean and allowed for a fair comparison of variations between the different methods utilized by different instruments. Smaller values showed that the device yielded measurements that were closer to each other and had higher repeatability. $P<0.05$ was considered statistically significant.

Results

The mean age of the study participants was 23.2±0.2 years (range: 18-30); 57% of the participants were women and 53% were men. The mean CCT was 540±14.1 µm, with no statistically significant difference in CCT between sexes ($p>0.05$). Mean CCT values were 557.0±26.7 µm with the autorefractor, 543.6±32.9 µm with UP, 533.8±30.2 µm with the Oculus Pentacam, 519.8±30.1 µm with Optovue AS-OCT, and 547.5±31.6 µm with Heidelberg AS-OCT (Table 1). Pairwise comparisons between devices showed that the Optovue AS-OCT gave significantly lower CCT measurements than the autorefractor and Heidelberg AS-OCT device ($p=0.027$ and $p=0.033$, respectively) (Figure 2). The strongest correlations with UP were obtained with the Oculus Pentacam (0.98) and Heidelberg AS-OCT (0.98). When compared with the other 4 instruments, the Optovue AS-OCT device had the

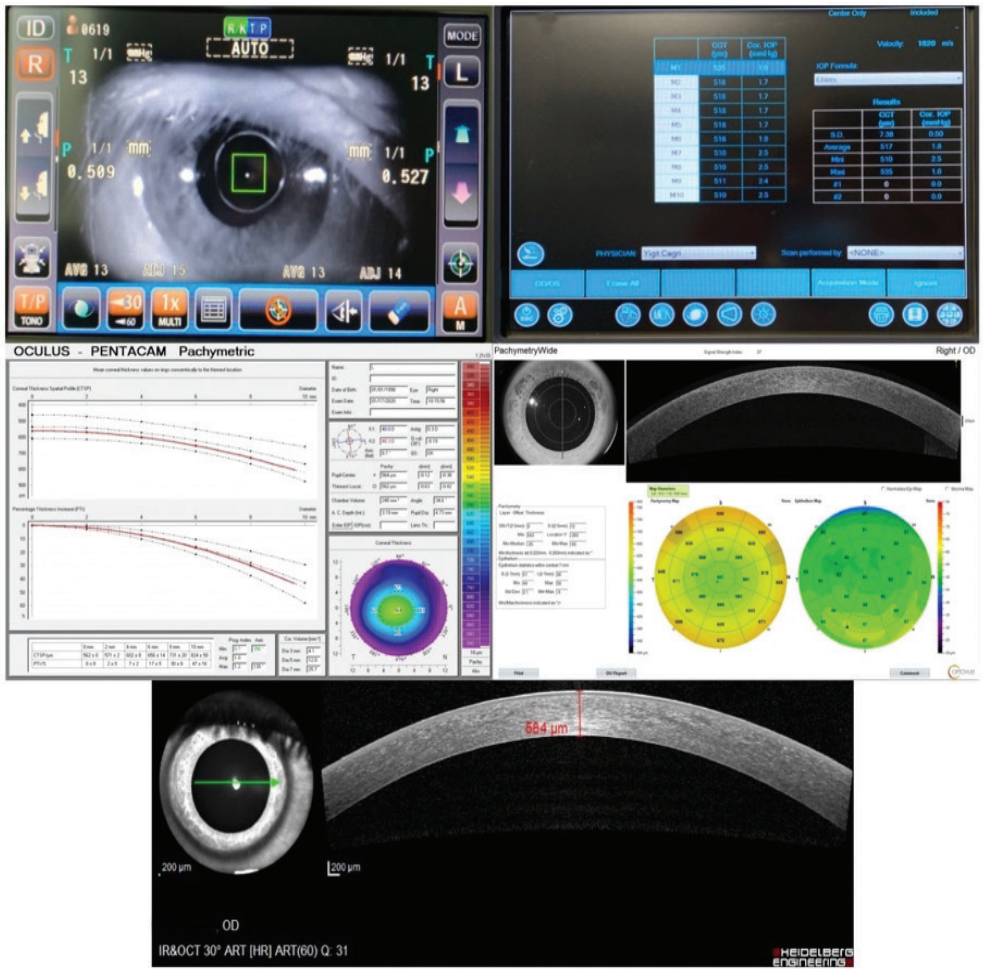

Figure 1. Sample output from measuring central corneal thickness with different instruments

Table 1. Mean, minimum, and maximum central corneal thickness values (µm) and repeatability coefficients (%) for each device

Method/instrument	Mean CCT ± SD (µm)	Minimum (µm)	Maximum (µm)	Repeatability (%)
Autorefractometry	557.0±26.7	497	608	1.51
UP	543.6±32.9	451	610	2.46
Oculus Pentacam	533.6±30.2	438	588	3.72
Optovue AS-OCT	519.8±30.1	426	581	2.57
Heidelberg AS-OCT	547.5±31.1	457	606	3.34

CCT: Central corneal thickness, SD: Standard deviation, UP: Ultrasound pachymetry, AS-OCT: Anterior segment-optical coherence tomography

lowest agreement (0.95). Repeatability coefficients for the autorefractor, UP, high-resolution Pentacam, Optovue AS-OCT, and Heidelberg AS-OCT were 1.51%, 2.46%, 3.72%, 2.57%, and 3.34%, respectively. Lower percentages indicate higher repeatability.

Discussion

CCT values are used in refractive surgical procedures and in the diagnosis and treatment of many ocular diseases. Accurate CCT measurement influences clinical decisions and thus treatment. Various methods are used in clinical practice to accurately measure CCT, each with its own merits and limitations.[8] In this study, we compared CCT measurements from an autorefractor, UP, high-resolution Pentacam, Optovue AS-OCT, and Heidelberg AS-OCT, which are frequently used in Turkey. Measurements made with five different devices showed that CCT was repeatable, comparable, and clinically usable with all methods. However, the autorefractor gave the highest

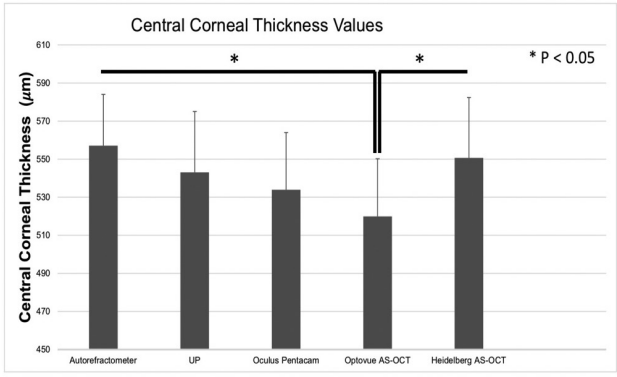

Figure 2. Comparison of mean central corneal thickness values. Pairwise comparisons between devices showed that the Optovue AS-OCT gave significantly lower CCT measurements than the CCT measurements autorefractor and Heidelberg AS-OCT device (*p<0.05)

CCT: Central corneal thickness, UP: Ultrasound pachymetry, AS-OCT: Anterior segment-optical coherence tomography

mean CCT value, followed in order by the Heidelberg AS-OCT, UP, and Pentacam. Optovue AS-OCT was found to give lower CCT values than the other devices. The Pentacam was found to have a longer measuring time than the other devices and lower repeatability. However, we believe it is beneficial to measure with the same device as much as possible during follow-up.

In our study, the highest agreement was between the results of UP and Heidelberg AS-OCT devices, followed by UP/Pentacam and Pentacam/Heidelberg AS-OCT. Our results show some differences from previous studies in the literature in this regard. This may be related to the different models and brands of instrument compared. Beutelspacher et al.[9] compared CCT measured using AS-OCT, UP, autorefractor, and Pentacam and found that autorefractor and UP measurements showed the closest agreement. Huang et al.[10] and Tai et al.[11] also found similar results in studies with similar methodology. O'Donnell and Maldonado-Codina[12] also observed close results for repeatability and agreement between Pentacam and UP measurements, whereas Pentacam measurements were found to be lower in our study. In our study, the mean CCT measured by UP was 10 µm higher than that measured by the Oculus Pentacam. This is because optical devices such as Pentacam pachymetry are affected by the precorneal tear film layer when measuring CCT, while the UP probe is in direct contact with the corneal epithelium, thereby displacing the precorneal tear film.[13] Optovue AS-OCT yielded the lowest mean CCT value, an average of 24 µm lower compared to values obtained by UP.

UP has been shown to provide less accurate measurements due to corneal irregularities, the effect of topical anesthesia, displacement of the precorneal tear film, and the variable posterior pole reflection point between Descemet's membrane and the anterior chamber.[8] In addition, UP is operator-dependent, whereas this has no effect in other non-contact methods. Nevertheless, UP is still regarded as one of the most reliable methods in various studies, including ours. Although CCT measurements performed with other non-contact optical pachymetry devices such as Pentacam, AS-OCT, and autorefractor show good correlation with UP measurements, UP is still considered the most reliable method. This may be associated with non-contact optical devices being affected by the precorneal tear layer, anterior corneal refractive strength, and differences in refractive index between the air and cornea.[14]

In a recent study comparing CCT measured by AS-OCT, non-contact SM, and UP, Scotto et al.[15] observed that they generally showed strong agreement. However, while AS-OCT CCT values showed a strong correlation with UP values, non-contact SM gave significantly higher CCT values than both of the other methods and had lower repeatability. As a result, the authors concluded that measurements obtained with different devices could not be used interchangeably. Gokcinar et al.[16] compared the CCT measurements of four different devices and reported that different devices could give different measurements and that patient follow-up should be performed with the same device or highly compatible devices. In another study comparing the CCT measurements of four different devices, González-Pérez et al.[17] reported that the tono-pachymeter gave lower values than the Scheimpflug system, AS-OCT, and UP. However, they concluded that the values given by the UP, Pentacam, and AS-OCT devices were comparable and showed linear correlation, and that these three devices could be used interchangeably in clinical practice. Doğan and Ertan[18] compared Scheimpflug-Placido topography (Sirius), AS-OCT (Spectralis), optical biometry (AL-scan), and UP in healthy individuals and concluded that CCT values correlated well with each other but could not be used interchangeably. Therefore, they recommended using the same imaging methods in CCT follow-up. Li et al.[19] compared Pentacam (Oculus) and AS-OCT (CASIA2) and showed that the measurements of these two devices were highly correlated and could be used interchangeably. Karaca et al.[20] compared the Scheimpflug camera system and two different brands of SM in their study comparing CCT values in healthy volunteers and showed that the CCT results correlated with each other. In another study comparing Orbscan 3, Pentacam HR, and UP, it was reported that there were still agreement issues between the obtained CCT measurements, and the authors did not recommend their interchangeable use in clinical practice.[21]

In terms of repeatability, Barkana et al.[13] found that an autorefractor had the highest repeatability and UP had the lowest. A study by de Sanctis et al.[22] involving patients with keratoconus showed that Pentacam had better repeatability than UP. Unlike our study, Tai et al.[11] reported that Pentacam measured CCT values 10 µm higher than UP. They proposed that this was because the precorneal tear layer may be included in the Pentacam measurement, while the corneal pressure in UP may affect measurements. In the same study, they found that values obtained with SM were 20 µm lower than those from UP. Another study showed that CCT measured using AS-OCT was significantly lower than UP values, with a mean difference of 16.5 µm.[23] In addition to reliability studies, the duration of

measurement is an important factor to consider when selecting the appropriate pachymetric device.

All five methods evaluated in our study showed good repeatability. The autorefractor had the highest repeatability, while high-resolution Pentacam and Heidelberg AS-OCT showed relatively lower repeatability. Although developing technologies seem to yield compatible measurements, it can be understood from the above-mentioned studies that there is still no literature consensus on the best method. In this context, the results of our study will contribute to the literature.

Study Limitations

Limitations of our study are that a small number of people were included and only healthy individuals were studied, which may have affected the statistical results. Furthermore, due to the lack of an SM device in our clinic, measurements could not be made with this device and included in the study.

Conclusion

Among the various instruments utilizing different technologies, the device that provides the most accurate, practical, and easy measurement of CCT should be preferred. Faster measurement time improves patient comfort and reduces examination time. The results of this study comparing five different measuring devices suggest that despite its disadvantages, UP provides fast and accurate measurements and is still applicable in current routine clinical practice. The autorefractor had the highest repeatability and relatively faster measurement than the other methods, whereas the Pentacam showed the lowest repeatability and longest measurement time.

Ethics

Ethics Committee Approval: Ethics committee approval for this prospective, cross-sectional study was obtained from the Medical Research Ethics Committee of Muğla Sıtkı Koçman University Faculty of Medicine (approval number: 7/XIII, date: 03/2021).

Informed Consent: All participants signed an informed consent form after being informed in detail about the nature and purpose of the study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: C.Ş., C.K., Concept: C.Ş., A.K., Design: C.Ş., Data Collection or Processing: C.Ş., C.K., Analysis or Interpretation: C.Ş., A.K., Literature Search: C.Ş., C.K., Writing: C.Ş., C.K.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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