·Clinical Research·

Comparison of anterior segment measurements using rotating Scheimpflug imaging and partial coherence interferometry

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Abstract

• **AIM: To compare central corneal thickness (CCT) and anterior chamber depth (ACD) measurements using rotating Scheimpflug imaging and partial coherence interferometry.**

• **METHODS: As part of the first phase of Shahroud Eye Cohort Study with 5 190 subjects of 40 to 64 years of age, CCT and ACD were measured using Scheimpflug imaging with the Pentacam (Oculus, Inc., Lynnwood, WA, USA) and partial coherence interferometry with the Allegro BioGraph (Wavelight, Erlangen, Germany).**

• **RESULTS: After applying exclusion criteria, we had data of 4 387 subjects with a mean age of 50.7±6.2 years. Mean CCT with Pentacam and BioGraph were 528.6 ± 33.2μm and 525.6±32μm respectively; the difference was statistically significant (*P*<0.001), but the correlation was high (R=0.920). Mean ACD measurements using Pentacam and BioGraph were 2.68 ±0.35mm and 2.62 ±0.33mm respectively; the inter-device difference was significant (*P*<0.001) with high correlation (R=0.944). The 95% limits of agreements between devices were -22.65μm to 28.61μm and -0.16mm to 0.29mm for CCT and ACD measurements, respectively.**

• **CONCLUSION: For both CCT and ACD, the BioGraph gave significantly lower values than the Pentacam (*P*<0.05). Despite the high inter-device correlation, the 95% limits of agreements were wide, and this may limit their interchangeability in measuring the CCT and ACD.**

• **KEYWORDS:** central corneal thickness; anterior chamber depth; Pentacam, BioGraph; agreement

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INTRODUCTION

The corneal thickness is now routinely measured in most ophthalmic patients either to ensure the health of the cornea or to be used in decision making[1-3]. Knowledge of the central corneal thickness (CCT) is essential in the assessment of disease conditions such as keratoconus, Fuch's endothelial dystrophy, as well as graft rejection [4]. The CCT is taken into account in planning surgical procedures and interventions such as keratorefractive surgery, corneal collagen crosslinking, and intrastromal ring segment implantation [5,6]. An accurate measurement of the intraocular pressure requires including the CCT in the intraocular pressure correction formulas [7]. Similarly, the anterior chamber depth (ACD) should be measured with accuracy so that readings can be used in surgical planning and follow-up of patients who have intraocular lens implantation, as well as risk assessment of angle closure glaucoma[8,9].

Both the CCT and ACD can be measured using a variety of techniques and diagnostic devices, and the ultrasound technique has long been the accepted gold standard for measuring CCT and a commonly practiced technique to provide ACD[10-14]. However, the ultrasound technique requires contact of an ultrasound probe with the corneal surface, which, in addition to patient discomfort, can be associated with the risk of infection. Also, the probe has to be placed as perpendicularly and gently as possible, and thus the method is very operator dependent. Another drawback of the ultrasonic method is the need to instill anesthetic drops which have been shown to cause structural changes as well as changes in the corneal thickness. For example, Asensio *et al*[15] found about ±10μm change in CCT in 11.53% of cases with two drops of oxybuprocaine. Similar observations have been reported with the use of other topical anesthetics [16,17]. These disadvantages have created a preference for non-contact methods of ocular biometry.

The Pentacam (Oculus, Inc., Lynnwood, WA, USA) is an anterior segment analyzer that implements the Scheimpflug principle in photography to capture slit images and generate a variety of data in a non-contact fashion. The system is equipped with a rotating Scheimpflug camera, and a light source that emits UV-free blue light with a wavelength of 475nm. All projected slits overlap at the central cornea to increase the accuracy of central data. A single acquisition provides users with color maps of the corneal topography and pachymetry, and elevation maps of the anterior and posterior corneal surfaces. Outputs include CCT and ACD readings of the examined eye as well.

Another non-contact method is partial coherence interferometry (PCI) which is gaining more attention recently and is suggested to be an accurate and reliable method[12,13]. PCI was first implemented in the IOLMaster (Carl Zeiss Meditec) to measure the axial length. The AC-Master was then developed by the same company for the measurement of ACD and CCT using PCI. A latest addition is the LenStar/Allegro BioGraph (WaveLight, Erlangen, Germany) which uses PCI to make non-contact measurements of ocular biometric parameters. The LenStar/BioGraph uses the optical low coherence reflectometry (OLCR) measurement principle and 820nm superluminescent diode technology to provide a variety of data including CCT and ACD readings[12-14,18-20].

In this study, we compare the Pentacam and BioGraph in terms of their CCT and ACD measurements using data derived from the first phase of the Shahroud Eye Cohort Study, and to our knowledge, this is the first study comparing these two devices in a large population-based population.

MATERIALS AND METHODS

Materials The Shahroud Eye Cohort Study was initiated in 2009 in Shahroud, a city located in the North of Iran. Details of the sampling strategy and methodology have been published elsewhere, and given here only in brief[21].

For the first phase of the cohort, which was completed in January 2010, random cluster sampling was done and 5 190 of the 6 311 invitees between the ages of 40 and 64 years participated in the study (82.2% response rate). After signing informed consent forms, all respondents had an interview to collect information including their demographics and medical history, and then they had complete eye examinations. The proposal of the study was approved by Ethics committee of Shahroud University of Medical Sciences.

Methods Ophthalmic examinations of the study were included, but were not limited to refraction and visual acuity tests, a slit lamp exam, and retinal exams. Also, same hour acquisitions with the LenStar/BioGraph and the Pentacam were performed by skilled technicians following the manufacturers' instructions before touching the corneal surface for any reason or instilling any drops. For acquisitions with either device, participants were seated at the device and instructed to place their chins on the chinrest and rest their foreheads against the strap. They were then asked to look straight ahead, fixate on the light emitted from the center, and refrain from blinking during the scanning process. For Pentacam, only measurements defined as "OK" for quality specification by the unit were included. For LenStar/BioGraph, measurements that were reliable, as flagged by the device, were included, and average of usable measurements was recorded.

For this part of the study, CCT and ACD readings for each eye were retrieved from the Pentacam and the LenStar/BioGraph. With both devices, ACD was defined as the distance between the posterior surface of the cornea and the anterior surface of the lens on the optical axis. We excluded data from eyes with any ocular condition except refractive errors, as well as those with a history of any type of eye surgery.

Statistical Analysis For statistical analysis, data are summarized into mean (±standard deviation) of each variable. Differences between paired CCT and ACD data are expressed as the mean and range of the absolute differences and examined with the paired *t*-test. We also calculated the 95% limits of agreement (LoA) between the two devices in measuring the CCT and ACD in this population, and demonstrated agreements with Bland Altman plots. *P* values less than 0.05 were considered statistically significant.

RESULTS

After applying the exclusion criteria to the 5 190 respondents, data from 4 387 examinees was extracted. We excluded people for having non virgin eyes (cataract surgery, glaucoma surgery, retinal surgery, post-traumatic surgery), and excluded erroneous images from the database. We used CCT data of 3 741 right eyes and ACD data of 3 735 right eyes. The mean age of the participants was 50.5±6.1 years, and 59.5% (n=2226) were female. Mean spherical equivalent was -0.07±1.8 diopter (D); 48.5% were emmetropes (-0.49D to +0.5D), 32.3% were myopes, and 19.1% were hyperopes.

Mean CCT, as measured with the Pentacam and LenStar/BioGraph and their differences in the studied population is shown in Table 1. Paired CCT readings with these two devices showed a very high correlation (Pearson correlation coefficient=0.934, P<0.001) (Figure 1A), and a

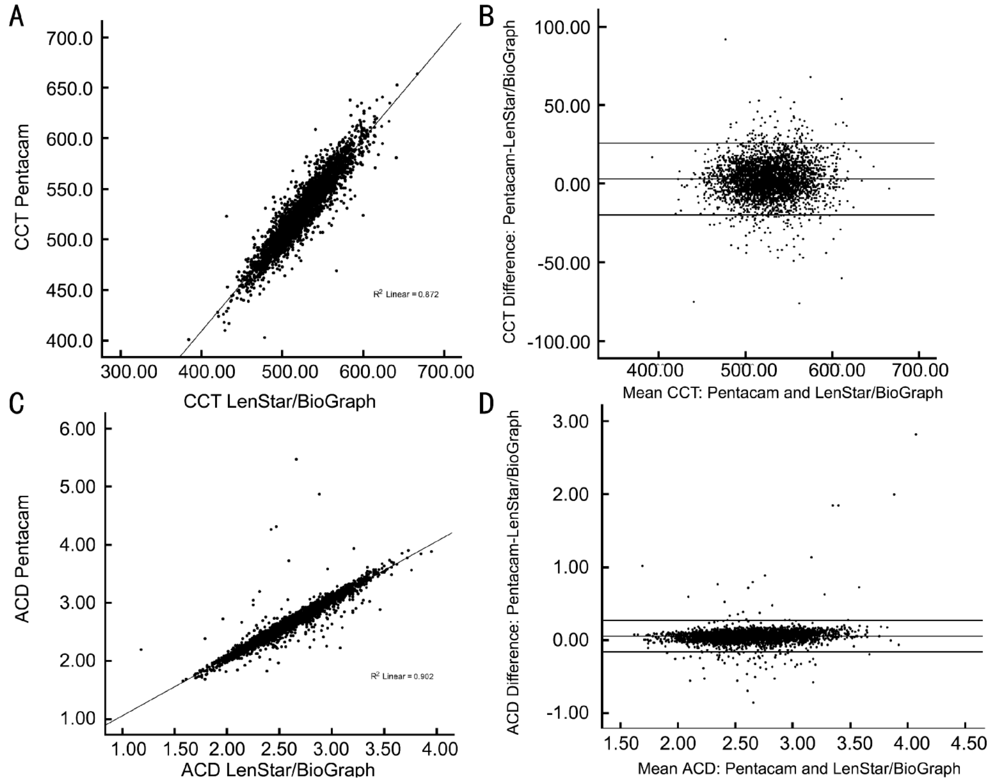

Figure 1 Correlation and the Bland−Altman plot agreement between Pentacam and LenStar/BioGraph measurements of CCT and ACD A: Correlation between Pentacam and LenStar/BioGraph measurements of CCT; B: Bland-Altman plot of the agreement between Pentacam and LenStar/BioGraph measurements of CCT; C: Correlation between Pentacam and LenStar/BioGraph measurements of ACD; D: Bland-Altman plot of the agreement between Pentacam and LenStar/BioGraph measurements of ACD.

Table 1 CCT and ACD readings summarized into the mean±standard deviation and range of means with each device, the average of the two, and inter-device differences

Parameters	Mean±SD	Range
CCT (μm)		
Pentacam	528.55±32.25	401.00-664.00
LenStar/BioGraph	525.49±31.72	384.00-667.00
Mean: Pentacam and LenStar/BioGraph	527.02±31.46	392.50-665.50
Difference: Pentacam-LenStar/BioGraph	3.06±11.64	-98.00-92.00
ACD (mm)		
Pentacam	2.68±0.35	1.58-5.48
LenStar/BioGraph	2.62±0.33	1.18-3.95
Mean: Pentacam and LenStar/BioGraph	2.65±0.34	1.58-4.07
Difference: Pentacam-LenStar/BioGraph	0.06±0.11	-0.85-2.82

statistically significant mean difference of 3.06 ±11.64μm (95% CI, 2.6 to 3.4μm). The 95% LoA between the two devices in measuring the CCT was -19.75μm to +25.87μm (Figure 1B). The equation derived from linear regression analysis was:

(LenStar/ BioGraph CCT x 0.95)+29.571=Pentacam CCT

Mean ACD values measured with the Pentacam and LenStar/BioGraph and their difference is shown in Table 1. The normal ACD range was 2.00 to 3.37mm and 1.97 to 3.27mm by Pentacam and LenStar/BioGraph, respectively. The correlation between paired ACD readings was high (Pearson correlation coefficient=0.950, $P<0.001$) (Figure 1C). The interdevice difference of 0.06 ±0.11mm for these measurements was statistically significant, and the 95% LoA was -0.16 to +0.28mm (Figure 1D). The ACD equation derived from linear regression analysis was:

(LenStar /BioGraph ACD x 1.002)+0.057=Pentacam ACD

Figure 2 show the distributions of inter-device differences of CCT and ACD measurements in the studied population, respectively.

DISCUSSION

In this study, we compared two non-contact devices, the Pentacam and the LenStar/BioGraph, in terms of their CCT and ACD measurements. Previous research has already shown high reproducibility for Scheimpflug imaging and PCI techniques in measuring CCT and ACD [21, 22]. Comparing these devices, CCT measurements using PCI were found to be even more reproducible than that with ultrasound pachymetry and when measuring ACD was compared, PCI appeared to have the best reproducibility and patient compliance [20, 23-28].

In measuring the CCT, Pentacam and LenStar/BioGraph readings were highly correlated (r =0.934); however, the mean difference between them was statistically significant. This can be indicative of systematic differences between these two devices which cause significantly different readings despite high correlations. CCT readings with the LenStar/BioGraph were overall smaller compared to Pentacam. Smaller readings with PCI have been reported

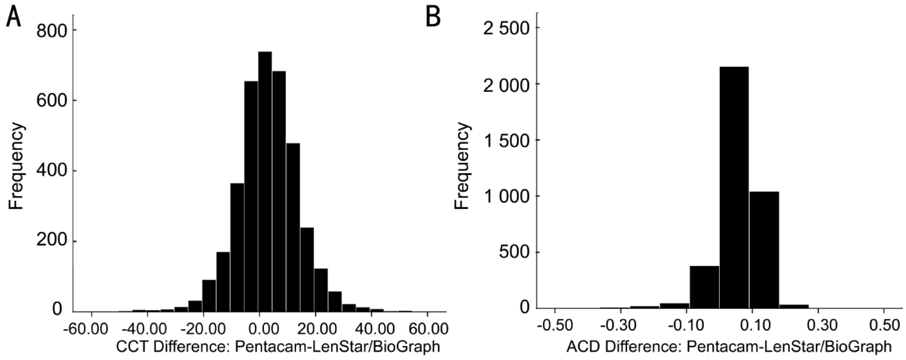

Figure 2 Distribution of interdevice differences in CCT and ACD measures in the studied population A: CCT; B: ACD.

previously as well [12]. With a mean difference of 3.06μm in paired readings, and a wide 95% LoA (-19.75 to 25.87μm), the two devices should not be used interchangeably. Many other studies have examined different optical techniques with ultrasound pachymeters and there is general agreement that readings are not similar enough for substitution [26,29-30]. A similar conclusion was drawn in a comparative study between the Haag-Streit optical OLCR pachμmeter and the Zeiss AC Master. Both devices measure the CCT using the PCI technique and paired readings were comparable [31]. Overall, it seems that inter-device differences mainly arise from the technique incorporated in their design, and two devices using the same technique show better agreement.

In measuring the ACD, Pentacam and LenStar/BioGraph readings showed a very high correlation too (r=0.950); this was even higher than that for CCT readings. Again, mean difference between paired readings was statistically significant, and ACD readings generated by LenStar/BioGraph were lower than those with the Pentacam. Lower readings with PCI have been reported in previous studies[20, 32].

To our knowledge, the only study comparing Pentacam and LenStar/BioGraph was conducted on 108 cases by Huang *et al* [33]. Their findings in terms of measurements with the LenStar/BioGraph were in agreement with ours and readings were lower compared to Pentacam readings. However, the inter-device differences CCT and ACD measurements were not statistically significant. The reported correlation was 0.981 for CCT, 0.966 for ACD from the endothelium, and 0.963 for ACD from the epithelium. For CCT measurements, the 95% LoA was -8.2 to 15.7μm with a mean difference of 3.72±6.10μm, and for ACD measurements, the 95% LoA was -0.11 to 0.15mm with a mean difference of 0.02±0.07mm between two devices. Based on these findings, the authors concluded that Pentacam and LenStar/BioGraph were interchangeable for CCT and ACD measurements [32]. Major differences between our study and the study by Huang *et al*[33] lie in the sample size and age distribution. As far as we know, our study is the first to compare these two devices with such a large sample size. In terms of age, the mean age of the participants in the study by Huang *et al* [33] was 22.8±3.5 which makes them considerably younger. How these factors can bring about such differences in results should be explored.

As indicated by the 95% LoA, inter-device differences in ACD readings were between -0.16 and +0.28mm in 95% of the cases. This may seem small, but accurate ACD measurements are needed for phakic intraocular lens (IOL) implantation and IOL calculations before cataract surgery. An error of 0.20mm can lead to undesirable outcomes.

In this study, we only used data from virgin eyes, and our results cannot be generalized to operated eyes or those with pathologic conditions. In a study by Rohrer *et al* [29], measurements with the LenStar/BioGraph, including ACD and CCT were studied in virgin, cataractous, aphakic, and pseudophakic eye, as well as eyes filled with silicon, and they found very good agreement with readings from the IOLMaster and the Pachμmeter (Haag-Streit) which utilizes the OLCR technique. According to Gaujoux *et al* [34], pachymetry measurements with OLCR are very comparable to those with ultrasound pachymetry, however, in cases of lamellar keratoplasty, the accuracy is better with OLCR than with ultrasound. Thus, measuring the CCT must be done with caution in cases with a history of lamellar keratoplasty because of the interface and possible changes in the refractive index[33].

In summary, noncontact methods of ocular biometry are preferred to contact methods such as ultrasonic devices. Both Pentacam and LenStar/BioGraph are modern devices that allow a variety of measurements simultaneously, fast, with minimum patient discomfort, and least user dependence. We found small mean inter-device differences, although statistically significant, and very high correlation between paired CCT and ACD readings. Each device can be used independently for diagnosis and follow-up. However, the 95% LoA between readings were too high to validate their interchangeability, and some differences should be expected when examining a patient with different systems.

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