Agreement Between Swept-Source Optical Biometry and Scheimpflug-based Topography Measurements of Anterior Segment Parameters

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• PURPOSE: To estimate the agreement of anterior segment parameters between a swept-source optical biometry (IOLMaster 700; Carl Zeiss Meditec AG, Jena, Germany) and a Scheimpflug-based topography with high resolution (Pentacam HR; OCULUS, Wetzlar, Germany).

• DESIGN: Interinstrument reliability analysis.

• METHODS: A total of 62 eyes from 62 young adults were included in the study. Average keratometry (AveK) and simulated keratometry (SimK) along 2.0-mm-ring measurements provided by Pentacam HR, keratometry readings provided by IOLMaster 700, and central corneal thickness (CCT) and anterior chamber depth (ACD) values obtained from both devices were recorded. J0 and J45 vectoral components of astigmatism were obtained using power vector analysis. Mean keratometry (Km) values of IOLMaster 700 were compared for each type of Km value from Pentacam HR, while other parameters were compared between devices. To assess the agreement between measurements of the devices, Bland-Altman analysis was performed.

• RESULTS: The Pentacam HR exhibited significantly lower Km and CCT measurements ($P < .001$, for all); however, no significant difference emerged in J0, J45, and ACD measurements ($P = .057$, $P = .574$, and $P = .64$, respectively). The mean difference between AveK, SimK 2.0 mm, and the IOLMaster 700 Km was −0.20 diopter (D) and −0.14 D, respectively, while the mean difference between J0, J45, CCT, and ACD measurements was 0.07 D, −0.016 D, −5.05 μm, and 0.004 mm, respectively.

• CONCLUSION: In clinical practice, Pentacam HR and IOLMaster 700 can be used interchangeably to measure J0 and J45 vectoral components of astigmatism for SimK 2.0 mm and IOLMaster keratometry values, as well as ACD and CCT measurements. However, SimK 2.0 mm and AveK values can be not interchangeable, as the devices have clinical and statistical differences in measurements. (Am J Ophthalmol 2016;169: 73–78. © 2016 Elsevier Inc. All rights reserved.)

FOR CLINICAL APPLICATIONS SUCH AS REFRACTIVE and cataract surgery, accurate anterior segment measurements are critical for enhancing the success of vision correction.[1–3] Currently, several devices are available for measuring anterior segment parameters, including those that perform Scheimpflug topography, optical coherence tomography (OCT), swept-source (SS) optical biometry, optical low-coherence reflectometry, and partial coherence interferometry (PCI), as well as slit-scanning topography and pachymetry systems.[4–7] When using those devices, however, clinicians need to consider interdevice differences in measurement.

Among these devices, with the help of a rotating Scheimpflug camera, the Pentacam HR (OCULUS, Wetzlar, Germany) is designed to analyze anterior ocular segments. The device has a special 3-dimensional, high-resolution scanning mode, with which the camera captures 138 000 data points in fewer than 2 seconds. As a result, a single scan can produce topographic maps of the anterior and posterior corneal surfaces, anterior chamber analysis, and complete corneal pachymetry.

At the same time, optical biometry has become the gold standard for determining biometric measurements and intraocular lens (IOL) power calculations.[8] Among devices that can achieve those ends, a newly available SS-OCT-based optical biometry device, named the IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany), also enables OCT imaging and visualization across the entire length of the eye. In so doing, it provides corneal keratometry, central corneal thickness (CCT), anterior chamber depth (ACD), white-to-white distance, pupil diameter, axial length, and lens thickness measurements.

Advances in anterior segment imaging have allowed clinicians to objectively evaluate and measure parameters characterizing the eye's anterior segment. In fact, parameters generated by both Pentacam and IOLMaster 700 have demonstrated excellent repeatability.[9,10] However, it remains unknown whether the measurements obtained with those devices are interchangeable or even comparable. In response, the present study was conducted to estimate the agreement of anterior segment

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parameters' keratometry, CCT, and ACD in normal eyes between an SS-OCT biometry device and a Scheimpflug-based topography device with high resolution.

METHODS

• **PARTICIPANTS AND PROTOCOL:** This study, designed as an interinstrument reliability analysis, was approved by the ethics committee of Mugla University and conducted according to the Declaration of Helsinki. Each participant was informed of the purpose of the study and signed a written consent form.

All participants received a standard examination during a single visit to the clinic that included general anamnesis to gather data regarding age, sex, and medical history. Each participant was also subjected to spherical refractive error and intraocular pressure measurements using the TRK-2P automated Kerato-Refractometer tono-pachymeter (TOPCON Corp, Tokyo, Japan), anterior slit-lamp biomicroscopy, Scheimpflug-based corneal topography using the Pentacam HR (version 1.20r76), and SS optical biometry using the IOLMaster 700 (software version 1.5). Measurements were performed prior to pupil dilation. After Pentacam HR and IOLMaster 700 measurements, the pupil was dilated for posterior segment examination.

Participants with poor fixation, corneal disease, cataract, glaucoma, or dry eye; those who wore contact lenses; and those who had undergone previous ocular surgery were excluded.

• **DEVICES AND MEASUREMENTS:** Using a rotating Scheimpflug camera (180 degrees) and monochromatic slit-light source (ie, blue LED lights at 470 nm) combined with a static camera, the Pentacam HR can provide a 3-dimensional model of the anterior segment, as well as elevation maps of the anterior and posterior corneal surfaces, pachymetry maps, biometric measurements of the anterior segment, and anterior and posterior corneal power calculations. The average keratometry (AveK) is calculated as the arithmetic means of the pair of meridians 90 degrees apart (K1 and K2) within the central 3-mm zone. Power Distribution Display permits evaluation of the simulated keratometry (SimK) values in preferred zone or ring.

The IOLMaster 700 uses SS-OCT technology (laser with variable wavelength) to generate optical B-scans, or optical cross-sections, to determine biometric eye data.[11] The device can obtain multiple measurements for each of the various parameters in a single capturing process and presents their average value. More specifically, the SS-OCT technology acquires the CCT, ACD, anterior aqueous depth, lens thickness, and axial length measurements from the single OCT image aligned with the eye's visual axis. Meanwhile, white-to-white distance is measured using the light-emitting diode light source according to iris configuration, whereas the SS-OCT optical biometer measures keratometry using telecentric keratometry. The IOLMaster 700 software provides keratometry measurements in the 2.5-mm zone. To calculate corneal power, the device uses the anterior corneal radius and standardized keratometric index of 1.3375.

Pentacam HR and IOLMaster 700 measurements were taken in random order in the same dimly lit room with a 10-minute rest period from 9:00 AM to 12:00 PM in order to minimize variation in the results.

SimK 2.0 mm values (flat K, steep K, their corresponding axes, and mean SimK) were obtained from Power Distribution Display by centering x and y axes at 0.0 mm and selecting the 2.0 mm ring diameter option. AveK, CCT, and ACD values automatically provided by the Pentacam HR software were also recorded. Using the IOLMaster 700, mean keratometry (Km), flat K, steep K; and their corresponding axes values; CCT; and ACD measurements were taken.

Power vector analysis was conducted using the method proposed by Thibos[12,13] for obtaining vectors along the 0-degree and 45-degree meridians according to the following equations: (1) vector along the 0-degree meridian $(J0) = [-(Ksteep - Kflat)/2 \times Cos2\alpha]$; (2) vector along the 45-degree meridian $(J45) = [-(Ksteep - Kflat)/2 \times Sin2\alpha]$. SimKflat, SimKsteep, and axes values in 2.0 mm ring for Pentacam HR and Kflat, Ksteep, and axes values automatically provided by IOLMaster 700 software were used for the above-mentioned calculations.

Using both devices, ACD was measured from the corneal epithelium to the anterior lens surface; only scans with an examination quality specification of "OK" using the Pentacam HR were retained for analysis. Quality control criteria were used with the IOLMaster 700 in accordance with manufacturer recommendations. For each device, 3 measurements obtained from the same eye were recorded, and their means were used in statistical analysis. The Km values of IOLMaster 700 were compared for each type of Km value from the Pentacam HR, while other anterior segment parameters were compared between measurements from both devices.

• **STATISTICAL ANALYSIS:** The Kolmogorov-Smirnov test was used to confirm the normal distribution of data. A paired *t* test was applied to compare the mean values of parameters provided by the Pentacam HR and IOLMaster 700. To assess the agreement between the measurements of the devices, Bland-Altman analysis was performed. All statistical tests were performed using the Statistical Package for Social Sciences, version 18.0 (SPSS Inc, Chicago, Illinois, USA). Significance was set at $P < .05$.

RESULTS

THIS PROSPECTIVE STUDY RECRUITED 62 ADULT PARTICIPANTS (34 men and 28 women) with a mean manifest

TABLE. Mean Values of Parameters Provided by Pentacam HR and IOLMaster 700

	Pentacam HR	IOLMaster 700	Difference	*P* Value
AveK/Km (D)	43.0 ± 1.3	43.2 ± 1.3	−0.20 ± 0.09	<.001
SimK 2.0 mm/Km (D)	43.06 ± 1.5	43.2 ± 1.3	−0.14 ± 0.16	<.001
J_0 (D)	0.35 ± 0.23	0.28 ± 0.22	0.07 ± 0.09	.057
J_{45} (D)	−0.018 ± 0.18	−0.002 ± 0.16	−0.016 ± 0.15	.574
CCT (μm)	538.3 ± 45	543.35 ± 48.8	−5.05 ± 7.67	<.001
ACD (mm)	3.48 ± 0.38	3.476 ± 0.36	0.004 ± 0.04	.64

ACD = anterior chamber depth; AveK = average keratometry; CCT = central corneal thickness; D = diopter; J_0 = corneal astigmatism vector along the 0-degree meridian; J_{45} = corneal astigmatism vector along the 45-degree meridian; Km = mean keratometry; SimK = simulated keratometry.

spherical equivalent refraction of −0.37 ± 0.75 diopters (D) (range +1.0 to −1.0 D). The mean age of participants was 35.3 ± 4.3 (range 18–40) years.

The Table demonstrates Km measurements, J0 and J45 vector components of astigmatism, CCT, and ACD values for both the Pentacam HR and IOLMaster 700. The Pentacam HR exhibited significantly lower keratometry and CCT values than the IOLMaster 700 ($P < .001$, for all parameters) However, no significant difference emerged in J0, J45, and ACD measurements between the devices ($P = .057$, $P = .574$, and $P = .64$, respectively).

Figure 1 shows the Bland-Altman plot for the Pentacam HR AveK and IOLMaster 700 Km. The mean difference was −0.20 D, at 95% limits of agreement (LoA) (−0.02 and −0.38). Figure 2 shows the Bland-Altman plot for Pentacam HR SimK 2.0 mm and the IOLMaster 700 Km. The mean difference of keratometry measurements was −0.14 D (95% LoA, 0.17 and −0.45). Meanwhile, Figures 3 and 4 show the Bland-Altman plots for J0 and J45 vector components of astigmatism between the devices, and the mean difference was 0.07 D (95% LoA, 0.24 and −0.10) and −0.016 D (95% LoA; 0.27 and −0.31), respectively.

Figures 5 and 6 display the Bland-Altman plots for CCT and ACD values between the Pentacam HR and IOLMaster 700; the mean difference was −5.05 μm (95% LoA, 9.8 and −19.9) and 0.004 mm (95% LoA, 0.09 and −0.08), respectively.

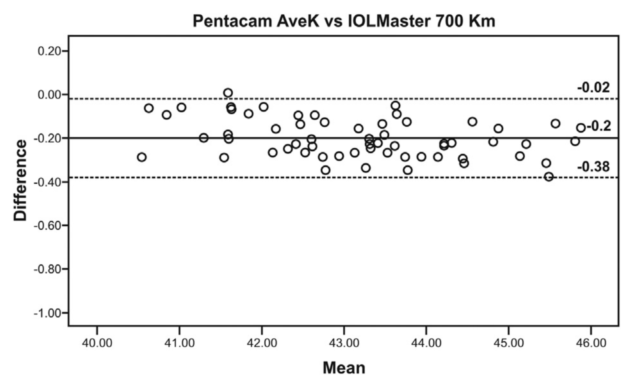

FIGURE 1. Evaluation of agreement between swept-source optical biometry and Scheimpflug-based topography measurements of anterior segment parameters: Bland-Altman plot for Pentacam HR average keratometry (AveK) and IOLMaster 700 mean keratometry (Km).

DISCUSSION

THE NEED FOR PRECISE MEASUREMENTS OF ANTERIOR segment characteristics has always promoted the innovation of reliable measurement devices. However, among those various devices, it is essential to know their interchangeability in clinical practice. Accordingly, this research evaluated the comparability of anterior biometric measurements between the Pentacam HR and IOLMaster 700 in the eyes of healthy young adults. Results showed that the Pentacam HR and IOLMaster 700 generated statistically significant differences in corneal keratometry and CCT measurements for normal eyes. The 2 devices agreed on J0 and J45 vectoral components of astigmatism and ACD measurements for our sample.

With improved axial length measurement techniques, including PCI and immersion ultrasound, keratometry remains an important source of biometric error.[14] Earlier research has shown the excellent repeatability of SS-OCT biometer, as well as its agreement with PCI biometer and optical low-coherence reflectometry.[15] Although the Pentacam HR undoubtedly provides more options for measuring the cornea, it is useful to know whether its measurements agree with those of the IOLMaster 700. As per our results, keratometry values exhibited lower K values with the Pentacam HR than with the IOLMaster 700, and SimK 2.0 mm values showed less interdevice variation than with the AveK compared with the IOLMaster 700 Km. The mean difference between the SimK 2.0 mm and IOLMaster 700 Km was −0.14 D with 95% LoA of 0.17 and −0.45 D. The mean difference between the AveK and IOLMaster 700 Km was also −0.2 D, with the measured

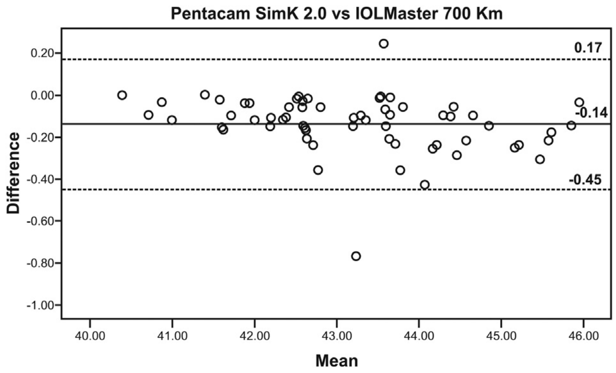

FIGURE 2. Evaluation of agreement between swept-source optical biometry and Scheimpflug-based topography measurements of anterior segment parameters: Bland-Altman plot for Pentacam HR simulated keratometry (SimK) 2.0 mm and IOLMaster 700 mean keratometry (Km).

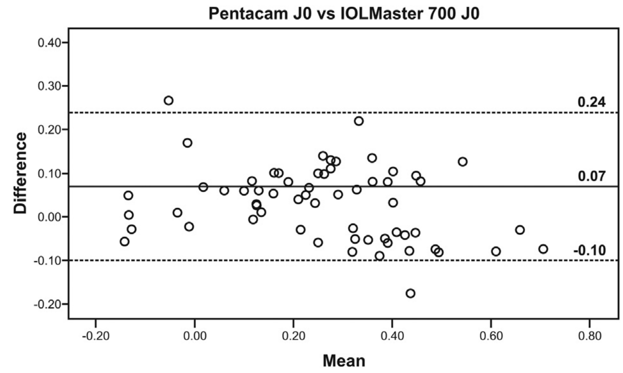

FIGURE 3. Evaluation of agreement between swept-source optical biometry and Scheimpflug-based topography measurements of anterior segment parameters: Bland-Altman plot for J0.

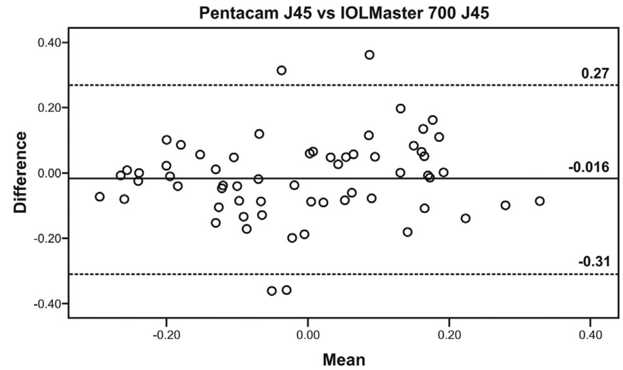

FIGURE 4. Evaluation of agreement between swept-source optical biometry and Scheimpflug-based topography measurements of anterior segment parameters: Bland-Altman plot for J45.

95% LoA limits of −0.02 and −0.38 D in our study. The difference in AveK between Pentacam and PCI biometer was −0.11 D, as reported by Symes and Ursell,[16] −0.30 D by Savini and associates,[17] −0.47 D by Elbaz and associates,[18] and −0.35 D by Woodmass and Rocha.[19]

Although the difference in keratometry measurements between devices is comparable on average, it is also important to be considering the range of variation in order to gauge the interchangeability of 2 devices. In this study, the 95% LoA range for the Pentacam HR AveK and IOLMaster 700 Km was 0.36 D, while the 95% LoA range was reported to be 2.08 D by Symes and Ursell,[16] 1.77 D by Savini and associates,[17] 2.01 D by Elbaz and associates,[18] and 0.92 D by Woodmass and Rocha[19] for Pentacam AveK and PCI biometer Km. The 95% LoA range for the Pentacam HR SimK 2.0 mm and IOLMaster 700 Km was also 0.62 D.

According to our results, Pentacam HR and IOLMaster 700 cannot be used interchangeably for SimK 2.0 mm and AveK measurements, as the difference of −0.14 D and −0.20 D are sufficient to give different optimized constants for IOL power calculation. Appropriate IOL formula constant adjustment is suggested according to the difference in magnitude in the Km value.[16] Karunaratne[20] has also demonstrated that constant optimization may be a necessary way to minimize the differences between keratometric devices. Therefore, a constant would be less for the SimK 2.0 mm and AveK in our study.

Significant preoperative corneal astigmatism is common among cataract patients.[21] For surgical corrections of astigmatism with a toric intraocular lens, consistency of astigmatism measurements is mandatory. For a valid comparison of astigmatism, vector analysis was used to transform the astigmatism values into the vector components of J0 and J45 in this study. Our results show that neither J0 nor J45 vector components of astigmatism demonstrated significant difference between 2 devices. The mean difference was 0.07 D and −0.016 D for J0 and J45 vector components, respectively. Because the difference between the devices was not significant, the interchangeability of these measurements could also be considered. Similarly, Dong and associates[22] found no significant difference in J0 and J45 vector components of astigmatism between Pentacam HR and PCI biometer.

Accurate ACD measurements are needed in different clinical applications, including calculating IOL in fourth-generation formulas such as Holladay II and Olsen,[2,23] implanting phakic IOL,[24] and screening for risk factors for glaucoma.[25] Several methods for measuring ACD are available that use different techniques, including reflected sound waves and Jaeger or Scheimpflug principles.[26] Our results show that ACD measurements obtained by the Pentacam HR did not significantly differ from those obtained with the IOLMaster 700; the difference between the devices was 0.004 mm, and the 95% LoA range was 0.17 mm. Because the difference between the modalities was too small to indicate any noticeable difference, as in IOL calculation (eg, in the NuVita Nomogram, the

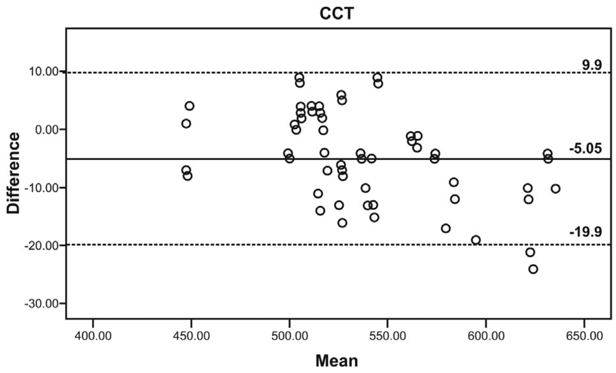

FIGURE 5. Evaluation of agreement between swept-source optical biometry and Scheimpflug-based topography measurements of anterior segment parameters: Bland-Altman plot for central corneal thickness (CCT).

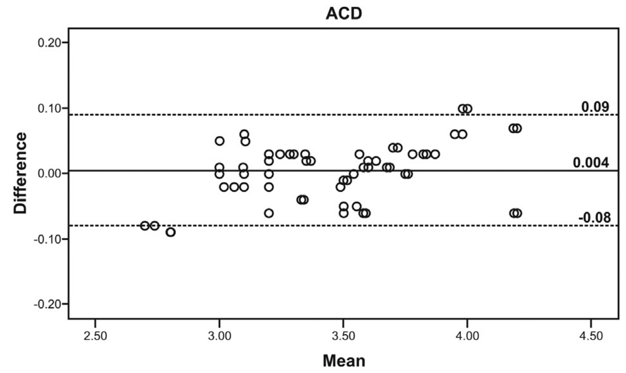

FIGURE 6. Evaluation of agreement between swept-source optical biometry and Scheimpflug-based topography measurements of anterior segment parameters: Bland-Altman plot for anterior chamber depth (ACD).

required IOL power varies by 0.1 D for each 0.2 mm of ACD),[27] the interchangeability of both devices for this measurement should also be considered. Significant differences in ACD measurements between the Pentacam and PCI biometer have previously been reported.[22,28,29] For Utine and associates,[28] ACD measurements were an average of 0.11 mm less than Pentacam measurements, with a 95% LoA range of 0.6 mm. Similarly, Dong and associates[22] reported a significant difference of −0.08 mm and 95% LoA range of 0.88 mm between devices in eyes with a refractive error of <3 D. Moreover, in a large white population, Fernández-Vigo detected a significant difference of 0.035 mm between the Pentacam and PCI biometer.[29] The differences could be attributable to different optical biometer technologies—namely, slit-imaging and SS-OCT technologies for PCI and SS-OCT biometers, respectively. Srivannaboon and associates[10] and Kunert and associates[15] have also reported that SS-OCT biometer ACD measurements tend to be longer than PCI biometrical ones, which also supports our results.

CCT measurement is important in calculating corrected intraocular pressure and completing any preoperative assessment for keratorefractive surgery. Kunert and associates[15] compared SS-OCT and optical low-coherence reflectometry CCT measurements and found good correlation, with a mean difference of 1.7 μm and 95% LoA range of 17.68 μm. Huang and associates[30] reported a mean difference of 3.72 μm with a 95% LoA range of 23.9 μm between the Pentacam HR and optical low-coherence reflectometry. In our study, the mean difference for CCT measurements between the Pentacam HR and IOLMaster 700 was −5.05 μm, with a 95% LoA range of 29.7 μm. The reason for the differences could be the inconsistent measurement point, different measurement principles, diurnal variation, or different group refractive status. Nevertheless, our results are comparable to those demonstrating the reliability of the devices in current clinical use. In fact, the 95% LoA range of CCT measurements using the Pentacam and IOLMaster 700 for repeatability were also reported as 22.1 (−10.2 to 11.9) μm and 27.22 (−11.31 to 15.91) μm.[10,31] From a different angle, Kohlhaas and associates[32] have reported a value of ±1.5 mm Hg to be clinically relevant, which complies with a CCT value of approximately ±37.5 μm. Considering the mentioned limits, we conclude that the devices can be interchangeable for taking CCT measurements in clinical practice.

A potential limitation of our study is that the population consisted of only young, healthy participants with normal corneas. Further research is thus necessary to determine the accuracy of anterior segment measurements with the Pentacam system and IOLMaster 700 biometer in elderly patients; in eyes with irregular corneas, including those with keratoconus; and in eyes that have undergone corneal surgery.

In conclusion, our data suggest that the Pentacam HR and IOLMaster 700 have good concordance and can be used interchangeably to measure J0 and J45 vectoral components of astigmatism for SimK 2.0 mm and IOLMaster keratometry values, as well as ACD and CCT measurements. However, caution must be used regarding SimK 2.0 mm and AveK values, for the devices have clinical and statistical differences, and measurements can therefore be not interchangeable.

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