



Comparison of a new anterior segment optical coherence tomography and Oculus Pentacam for measurement of anterior chamber depth and corneal thickness

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Background: Accurate measurements of anterior chamber depth (ACD) and regional corneal thickness are especially important for the diagnosis and treatment of many ocular disease. This study aimed to evaluate the repeatability and reliability of a new swept source anterior segment optical coherence tomography (AS-OCT) and its agreement with Oculus Pentacam for measurements of ACD and corneal thickness (CT).

Methods: The central corneal thickness (CCT), superior corneal thickness (SCT), inferior corneal thickness (ICT), nasal corneal thickness (NCT), temporal corneal thickness (TCT) and ACD of the right eye from forty-nine adults aged 18 to 36 years (24.78 ± 4.36 years old) were measured with Pentacam and AS-OCT (CASIA2). All subjects were measured twice with each device. The repeatability was determined using the coefficient of repeatability (COR), the relative COR and the limits of agreement (LOA). Bland-Altman plot was also used for evaluating the agreement between parameters from the two devices.

Results: For the repeatability of CASIA2, the COR of the two measurements of ACD, CCT, SCT, ICT, NCT and TCT was 0.31 mm, 18.58, 25.83, 28.32, 26.71 and 22.09 μm respectively. There were no statistically significant differences between the CT and ACD measurements by CASIA2 ($P > 0.05$). For measurements with Pentacam and CASIA2, the COR of ACD, CCT, SCT, NCT, ICT and TCT was 0.294 mm, 13.10, 51.57, 48.06, 56.21 and 47.69 μm respectively. No significant differences were found between the values measured by CASIA2 and Pentacam for CT and ACD ($P > 0.05$). The Bland-Altman analysis also suggested high consistency between measurements obtained by Pentacam and CASIA2.

Conclusions: Our results suggest that Pentacam and CASIA2 have good agreement in CT and ACD measurements. The two devices can be considered interchangeable for these parameters' measurements in healthy subjects when monitoring corneal conditions or planning ocular surgery. However, subtle differences between CASIA2 and Pentacam should also be kept in mind for certain specific clinical or research purposes.

Keywords: Anterior chamber depth (ACD); corneal thickness; swept source anterior segment optical coherence tomography; Oculus Pentacam

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Introduction

Accurate biometric measurements of the anterior ocular segment are of great importance for both diagnostic and therapeutic purposes. Measurement of the anterior chamber depth (ACD) is important when monitoring the changes of the anterior segment during accommodation (1), screening of primary angle-closure glaucoma (2), and performing the optical power calculation of phakic and pseudophakic intraocular lenses (IOLs) (3-5). Measurement of central corneal thickness (CCT) is essential for planning refractive surgery procedures (6,7), monitoring corneal conditions (8) and accurate measurement of intraocular pressure (9,10). To add, peripheral corneal thickness has also been proposed to be a useful parameter for the clinical identification of corneal disease with corneal thinning such as keratoconus (11,12).

Nowadays, increased attention has been paid to ACD (13-15) and regional corneal thickness measurements (12,16) from different devices. The Pentacam (Oculus Inc., Wetzlar, Germany) is a rotating Scheimpflug system which makes the noninvasive assessment of the anterior chamber structures accessible (16). Many studies have proved it as a noninvasive, repeatable, accurate, and reliable method for the measurement of corneal thickness and ACD (17-19).

Lately, new instruments have been utilized to measure corneal thickness and ACD. Anterior segment optical coherence tomography (AS-OCT) can be used to examine the cornea or anterior segment and can provide qualitative and quantitative information to assess the corner and anterior chamber (20-22). The CASIA2 AS-OCT (Tomey, Nagoya, Japan) is a novel swept-source optical coherence tomography (OCT) with a faster scan speed of 50,000 A-scans per second, a much wider and deeper imaging, and a higher-resolution imaging of 800 A/B-scans, a more advanced development from the prior generation CASIA SS-1000.

Several previous studies have compared ocular parameters such as ACD, angle-to-angle (ATA) distance, white-to-white (WTW) distance and pupil size using CASIA SS-1000 and various instruments other than Pentacam (23-27). One study has compared the measurement of aqueous depth (AQD) performed by CASIA2 and Pentacam (28). However, there is not yet a study that compares the CASIA2 AS-OCT device with the Pentacam in measuring central and peripheral corneal thickness or ACD. The purpose of this study is to compare central and regional corneal thickness values and ACD values obtained by CASIA2 and

those obtained by Pentacam, and to evaluate the reliability and validity of the CASIA2 AS-OCT.

Methods

This prospective cross-sectional study was performed from May 2018 to July 2018 at the Zhongshan Ophthalmic Center at Sun Yat-sen University in Guangzhou, China, with forty-nine healthy subjects recruited. All subjects were informed of the experimental purpose and procedures in detail before each examination was performed. The study was conducted in compliance with the Declaration of Helsinki (as revised in 2013) and was approved by institutional board of Zhongshan Ophthalmic Centre of Sun Yat-sen University (IRB-ZOC-SYSU) and informed consent was taken from all the participants. All records and information of participants were anonymized and de-identified before being analyzed.

Subjects and measurements

The inclusion criteria were as follows: (I) participants older than 18 years of age and (II) no history of ocular disease such as glaucoma or cornea disease, as this would affect ACD and corneal thickness. Participants with any ocular surgery or ocular trauma were also excluded. All eligible subjects in our study were randomly selected through recruitment according to the above inclusion criteria.

The exclusive criteria were as follows: (I) spherical equivalent power greater than -6.00 D; (II) wearing contact lenses within the past 2 weeks of recruitment date; and (III) severe cataract or with apparent ocular diseases (such as corneal scarring, keratoconus, active ocular surface disease, pterygium, or retinal detachment). Subjects that displayed low levels of cooperation or study compliance were also excluded.

The right eye of each subject was scanned with both Pentacam (Oculus Inc., Wetzlar, Germany) and CASIA2 (Tomey Corporation, Nagoya, Japan) without dilation after 5 minutes of dark adaptation. Each examination was performed by the same experienced operator. Before each measurement, the operator would explain to patients the procedure for each examination. To ensure all images were obtained without lid artefacts, the operator held the subjects' eyelid gently while avoiding pressing the eyeball. To prevent illumination—dependent or time—differences in ocular anatomy, the sequence of the devices was selected

Table 1 Comparison of first examination and second examination with the AS-OCT of the same eye

Variable	First examination (mean ± SD)	Second examination (mean ± SD)	Mean difference (mean ± SD)	COR	Relative COR, %	LLOA	ULOA	LOA range	R ²	P
Central CT (μm)	536.71±23.85	538.00±23.76	-1.28±9.48	18.58	3.46	-19.86	17.30	31.17	<0.01	0.948
Superior CT (μm)	640.84±35.07	643.69±32.77	-2.86±13.18	25.83	4.02	-28.69	22.97	51.67	0.0314	0.223
Inferior CT (μm)	608.04±32.57	609.16±29.50	-1.12±14.45	28.32	4.65	-29.44	27.20	56.64	0.048	0.132
Nasal CT (μm)	618.98±29.26	621.67±29.12	-2.69±13.63	26.71	4.31	-29.40	24.02	53.43	<0.01	0.941
Temporal CT (μm)	598.32±27.61	597.51±24.58	0.816±11.27	22.09	3.69	-21.27	22.91	44.18	0.056	0.055
ACD (mm)	3.20±0.27	3.22±0.28	-0.012±0.16	0.31	9.52	-0.32	0.29	0.061	0.007	0.575

COR, coefficient of repeatability; LLOA, lower limit of agreement; ULOA, upper limit of agreement; CT, corneal thickness; ACD, anterior chamber depth.

randomly.

The Pentacam system uses a rotating Scheimpflug camera (360 degrees) and a monochromatic slit-light source (blue light-emitting diode at 475 nm) which rotate together around the optical axis of the eye to calculate a 3-dimensional (3D) model. It can capture 25 slit-images of the anterior chamber per measurement in 2 seconds automatically.

For CASIA2, all subjects were measured under non-mydratic conditions after 5 minutes of adaptation under dark room conditions. The CASIA2 is a novel swept-source OCT specifically designed for imaging the anterior segment. It uses 1,310 nm swept-source laser wavelength at a frequency of 0.3 seconds, producing 128 cross-sectional images performed evenly spaced 1.4 degrees apart.

The parameters involved in this study were all automatically calculated by the two devices, and were documented by two independent investigators after examination. Parameters collected for comparison included CCT and ACD, and the two devices both had peripheral corneal thickness measurements obtained at the 6mm radius in the superior, inferior, nasal and temporal regions.

Statistical analysis

All statistical analyses were performed by Stata 12.0 (Stata Corp., College Station, TX, USA). The Kolmogorov-Smirnov test was used to check normality of all the parameter values, and mean ± standard error (SE) was used for statistical description. The coefficient of repeatability (COR = 1.96-fold SE), the relative COR (rCOR = COR/average measurement) and the limits of agreement (LOA

= mean ± COR) were calculated to assess the repeatability of CASIA2 and the agreement of CASIA2 and Pentacam. The Bland-Altman plot was used to assess the agreement between parameters from the two devices. P values <0.05 were considered statistically significant.

Results

In total, data from forty-nine eyes of forty-nine healthy adults were analyzed. The mean ± age of the subjects was 24.78±4.36 (range, 18–36) years old. The 49 subjects consisted of 28 males and 21 females.

The mean difference, COR, relative COR, lower and upper LOA and P values of the two measurements obtained by CASIA2 are shown in *Table 1*. For the two examinations of corneal thickness with CASIA2, CCT has the lowest COR with 18.58 μm and the inferior corneal thickness (ICT) has the highest COR with 28.32 μm. For the repeatability measurement of ACD by CASIA2, the COR was 0.31 mm. However, the P value suggests there is no statistically significant difference between the two measurements both for corneal thickness and for ACD by CASIA2 (P>0.05).

For the agreement of corneal thickness and ACD measured by Pentacam and CASIA2, the mean difference of CCT, superior corneal thickness (SCT), ICT, nasal corneal thickness (NCT), temporal corneal thickness (TCT) and ACD were 9.64, 25.22, 14.66, 29.86, 22.04 μm and -0.075 mm, respectively. COR was 13.10, 51.57, 48.06, 56.21, 47.69 μm and 0.294 mm, respectively. The mean difference and COR of peripheral corneal thickness was significantly higher than that of CCT (*Table 2*).

Table 2 Comparison of two measurements with the AS-OCT and Pentacam of the same eye

Variable	Mean difference (mean \pm SD)	COR	Relative COR, %	LLOA	ULOA	LOA range	R ²	P
Central CT (μ m)	9.64 \pm 6.68	13.10	2.42	-3.46	22.74	26.21	0.005	0.639
Superior CT (μ m)	25.22 \pm 26.31	51.57	7.87	-26.35	76.79	103.14	0.003	0.717
Inferior CT (μ m)	14.66 \pm 24.51	48.06	7.80	-33.40	62.72	96.12	0.022	0.314
Nasal CT (μ m)	29.86 \pm 29.85	56.21	8.85	-26.35	86.07	112.43	0.014	0.425
Temporal CT (μ m)	22.04 \pm 24.32	47.69	7.83	-25.65	69.73	95.37	0.015	0.410
ACD (mm)	-0.075 \pm 0.15	0.294	9.26	-0.37	0.22	0.588	0.013	0.430

COR, coefficient of repeatability; LLOA, lower limit of agreement; ULOA, upper limit of agreement; CT, corneal thickness; ACD, anterior chamber depth.

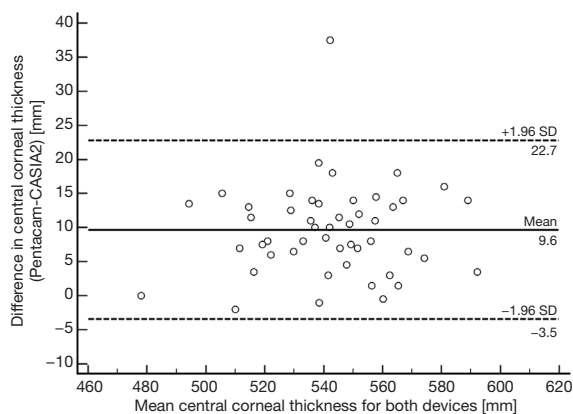


Figure 1 Bland–Altman plots comparing differences in CCT between CASIA2 and Pentacam. The solid line indicates the mean difference (bias), and the dotted lines indicate 95% LOA. CCT, central corneal thickness; LOA, limits of agreement.

The Bland-Altman analysis of corneal thickness obtained by Pentacam and CASIA2 is shown in *Figures 1,2*. The Bland-Altman analysis of CCT for the examination with Pentacam and CASIA2 shows a mean difference of 9.64 μ m, COR of 13.10 μ m, relative COR of 2.42% with $P=0.639$ (*Figure 1*). There was also no statistically significant difference for measurements of peripheral corneal thickness between Pentacam and CASIA2 ($P=0.717$ for SCT, $P=0.314$ for ICT, $P=0.425$ for NCT, $P=0.410$ for TCT).

Comparing the two measurements of the Pentacam and CASIA2, the mean difference, COR, and LOA range of ACD was -0.075, 0.294 and 0.588 mm, respectively, which were lower than that of corneal thickness. There was no significant difference between the two measurements of the two devices with $P=0.4304$ (*Figure 3*).

Discussion

Central and peripheral corneal thickness evaluation is important for planning keratorefractive surgical procedures (6,7), monitoring corneal conditions (8), diagnosing keratoconus (11,12) and assessing intraocular pressure accurately (9,10). ACD, another important ocular parameter, has become an essential factor for IOL power calculations in patients about to undergo cataract surgery (3,4). In our study, we assessed the repeatability of the automatic corneal thickness and ACD measurements provided by CASIA2 AS-OCT and compared systematic difference of evaluation obtained with CASIA2 AS-OCT and Pentacam Scheimpflug imaging system for normal eyes. CASIA2 demonstrated excellent intradevice reproducibility for both central and peripheral corneal thickness and ACD. In addition, there were no statistically significant differences between Pentacam and CASIA2 in these parameters.

We reported the average CCT was 537.36 \pm 23.33 μ m measured by CASIA2, which was similar to the results published by Simon and Katarzyna (29,30). In the current study, our results show that the average ACD is 3.21 \pm 0.28 mm measured by CASIA2, which are similar to the results reported by Xu *et al.*, who reported a mean ACD value of 3.13 \pm 0.29 mm in healthy subjects (31). For the repeatability of CASIA2, our results show that there is no statistically significant difference between the two examinations in healthy subjects not only for corneal thickness in different regions but also for ACD (all $P>0.05$). Moreover, small relative COR values of CCT, SCT, ICT, NCT, TCT and ACD (3.46%, 4.02%, 4.65%, 4.31%, 3.69% and 9.52%, respectively) also suggested high-repeatability for regional corneal thickness and ACD measurements with CASIA2 AS-OCT in normal

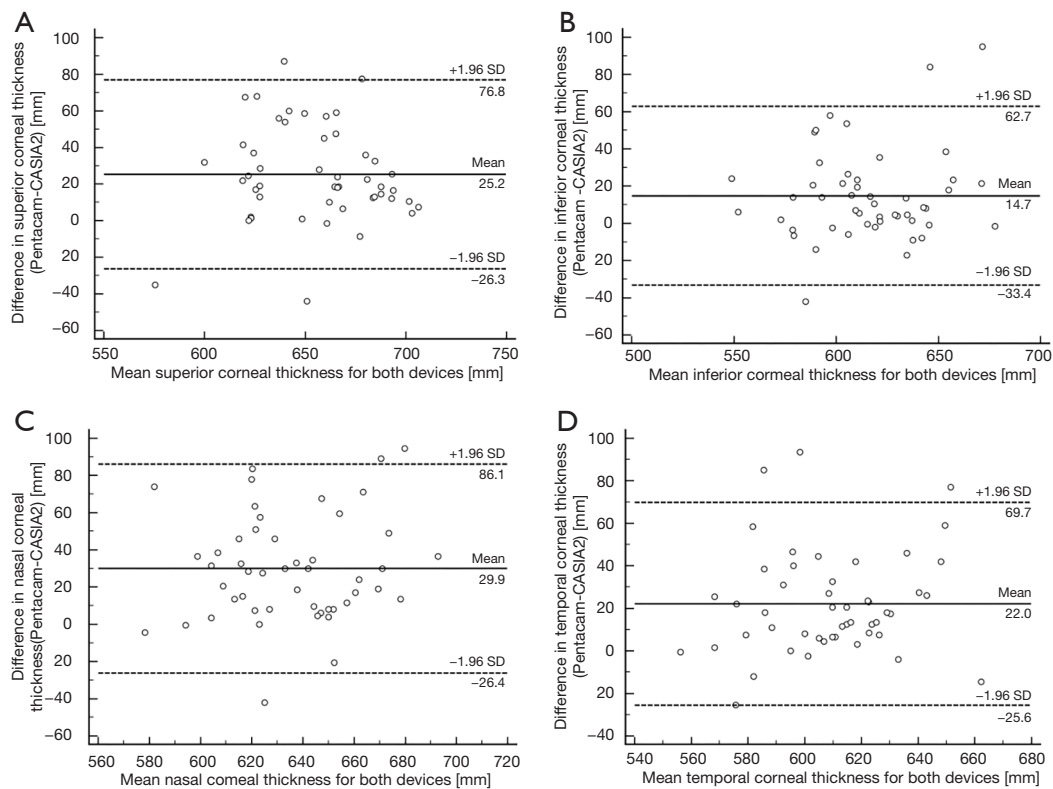


Figure 2 Bland-Altman plots comparing differences between CASIA2 and Pentacam in (A) SCT, (B) ICT, (C) NCT, (D) TCT. The solid line indicates the mean difference (bias), and the dotted lines indicate 95% LOA. SCT, superior corneal thickness; ICT, inferior corneal thickness; NCT, nasal corneal thickness; TCT, temporal corneal thickness; LOA, limits of agreement.

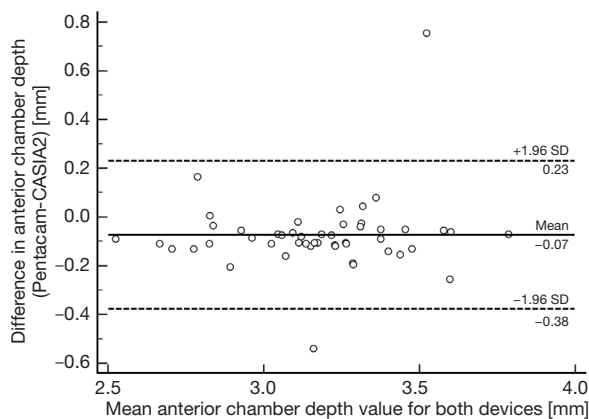


Figure 3 Bland-Altman plots comparing differences in CCT between CASIA2 and Pentacam. The solid line indicates the mean difference (bias), and the dotted lines indicate 95% LOA. CCT, central corneal thickness; LOA, limits of agreement.

eyes, indicating that the CASIA2 could provide good reproducible measurements for the corneal thickness in different regions and ACD.

Many studies have evaluated the accuracy of the Pentacam measurement of ACD and corneal thickness parameters (32,33). So far, there have been few studies comparing corneal thickness and ACD measured by Pentacam and Swept-Source OCT. Fukuda *et al.* reported that there was no statistically significant difference in the CCT and AQD between the CASIA2 and CASIA SS-1000 (28). The results reported by Krysik *et al.* show the average CCT evaluated by Pentacam is significantly higher than that obtained by CASIA SS-1000 (30). In our study, Pentacam pachymetry measurements also show slightly higher CCT values when compared with CASIA2 measurements. However, there was no statistical significance in the differences of corneal thickness in different regions and ACD measured by the two devices ($P > 0.05$). The differences in values of measured parameters may be possible due to the

systematic difference. Small relative COR values of CCT, SCT, ICT, NCT, TCT and ACD (2.42%, 7.87%, 7.80%, 8.85%, 7.83% and 9.26%, respectively) also suggest that the Pentacam and the CASIA2 had excellent agreement. Moreover, the Bland-Altman plots of corneal thickness and ACD showed a good correlation between the two devices.

One advantage of the CASIA2 AS-OCT is that it was specifically designed for imaging the anterior segment. With a scan speed of 50,000 A-scans per second, and a frame size of 800 A-scans, it takes only 0.016 s to capture a single cross-sectional image (34). The shortened scanning time can reduce the effects of motion artifacts resulting from involuntary ocular movement and patient stress, making it easier for patients to tolerate and cooperate with examinations.

Another advantage of this AS-OCT scanner is that it uses a 1,310 nm infrared light source, which can minimize the effects of the measurement light on pupil movement and miosis (34). Moreover, this kind of light theoretically achieves better penetration of light into the opaque tissues than the visible light (475 nm) used in the Pentacam (35,36). Because some corneal opacities or scars may scatter the visible light in the Pentacam, this can make it difficult to digitize the corneal surfaces precisely. Using the AS-OCT, we can accurately measure corneal parameters of patients with a history of corneal disease or corneal surgery.

Our study shows that the AS-OCT is reliable, valuable, and accurate in terms of corneal thickness and ACD measurements, meaning that the AS-OCT is an option to be considered in the diagnosis of corneal disease and planning of refractive surgery. However, our findings are limited to healthy Chinese people, as the study only includes Chinese people without a history of previous ocular surgery or remarkable ocular and systemic diseases. Therefore, more multi-center clinical trials are still needed to verify the validity and reliability of AS-OCT in terms of corneal thickness and ACD measurements in different populations in the future.

Conclusions

In conclusion, CASIA2 offered excellent repeatability for corneal thickness and ACD measurements in healthy subjects and good agreement with Pentacam. CASIA 2 can be used as an alternative to Pentacam for measuring corneal thickness and ACD when monitoring corneal conditions, measuring intraocular pressure or planning ocular surgery.

We believe there is value in the reliability and clinical convenience of the automatic corneal thickness and ACD measurements with CASIA2 AS-OCT, and its faster scanning speed, higher resolution, and deeper and wider scanning range may be useful in the diagnosis of various types of corneal diseases. However, subtle differences between the CASIA2 and Pentacam should also be kept in mind for certain specific clinical or research purposes.

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Footnote

Data Sharing Statement: Available at <http://dx.doi.org/10.21037/atm-20-187>

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/atm-20-187>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in compliance with the Declaration of Helsinki (as revised in 2013) and was approved by institutional board of Zhongshan Ophthalmic Centre of Sun Yat-sen University (IRB-ZOC-SYSU) and informed consent was taken from all the participants.

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