· Clinical Research ·

Comparison of ocular biometric parameters between two swept-source optical coherence tomography devices and Scheimpflug tomography in patients with cataract

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Abstract
● **AIM:** To assess and compare the variations and agreements across different ocular biometric parameters using swept-source optical coherence tomography (SS-OCT) and Scheimpflug tomography in patients diagnosed with cataract.
● **METHODS:** This prospective case series was conducted at Tianjin Medical University Eye Hospital. In total, 212 eyes from 212 patients scheduled for phacoemulsification were included. Eyes were evaluated preoperatively using two SS-OCT devices (IOLMaster700 and CASIA2) and Scheimpflug tomography (Pentacam). Central corneal thickness (CCT), anterior chamber depth (ACD), aqueous depth (AQD), white-to-white distance (WTW), flat simulated keratometry (Kf), steep simulated keratometry (Ks), mean keratometry (Km), and total corneal keratometry (TKm) were measured. Intraclass correlation coefficient (ICC), 95% confidence intervals (CI) and limits of agreement (LoA) widths were conducted to assess differences and correlations between devices.
● **RESULTS:** All parameters, except for Ks, were significantly different. Pairwise comparison revealed no significant differences between keratometry obtained by IOLMaster 700 and Pentacam. LoA widths of all paired comparisons for Ks were >0.80 D. Except for WTW between IOLMaster 700 and CASIA2 and between CASIA2 and Pentacam, other Pearson's coefficients between devices showed a strong correlation (all r>0.95). The ICC of WTW (ICC=0.438, 95%CI 0.167-0.625) showed poor reliability. The reliability of CCT, ACD, and AQD was excellent (all ICC>0.95), whereas that of TKm was good (ICC=0.827, 95%CI 0.221-0.939). A significant linear correlation was also observed among devices.
● **CONCLUSION:** The ocular parameters derived from the use of IOLMaster700, CASIA2, and Pentacam exhibit significant discrepancies; as such, measurements from these devices should not be deemed as interchangeable.
● **KEYWORDS:** ocular parameters; swept-source optical coherence tomography; cataract
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INTRODUCTION
The evolution of cataract surgery has been marked by significant innovations. Fyodorov pioneered this transformative journey by publishing the first formula for intraocular lens (IOL) power calculation[1], a landmark achievement that forever changed the landscape of surgical ophthalmology. A significant milestone in the subsequent years was the introduction of the IOLMaster (Carl Zeiss Meditec, Jena, Germany), the first optical biometer, launched in 1999[2]. Since then, there has been an explosion of devices utilizing various principles such as partial coherence interferometry,

optical low-coherence reflectometry and interferometry, Scheimpflug camera systems, and more recently, swept-source optical coherence tomography (SS-OCT)-based ocular biometry devices. These advancements have enabled accurate measurement of several anterior segment parameters including central corneal thickness (CCT), anterior chamber depth (ACD), aqueous depth (AQD), white-to-white distance (WTW), flat simulated keratometry (Kf), steep simulated keratometry (Ks), mean keratometry (Km) of the anterior corneal surface, and total corneal keratometry (TKm).

Despite these advancements, a systematic deviation often exists when the same parameter is measured using different equipment, creating uncertainty in clinical practice. For instance, CCT measurement is crucial for glaucoma diagnosis and refractive surgery as it can affect the accuracy of intraocular pressure (IOP) readings. ACD and keratometry measurements are necessary for calculating intraocular lens (IOL) power while the size of an implantable collamer lens (ICL) depends on WTW and ACD measurements. The recent addition of posterior corneal data (*i.e.*, TKm) to the IOL power calculation formula has sparked further debate.

With technological advancements, new devices such as the IOLMaster 700 (Carl Zeiss Meditec, Germany), CASIA2 (Tomey, Nagoya, Japan), and Pentacam system (Oculus, Wetzlar, Germany) have emerged for measurements of ocular parameters, including TKm. However, only a limited number of studies have examined the differences and agreement of eye dimensions among these devices simultaneously[3-8].

Recognizing these gaps and controversies, our study aims to compare the differences and agreement between various ocular biometric parameters, including CCT, ACD, AQD, WTW, Kf, Ks, Km, and TKm, using IOLMaster 700, CASIA2, and the Pentacam Scheimpflug camera system. By doing so, we hope to provide a deeper understanding of the strengths, limitations, and agreements between these devices that could guide clinicians in making informed decisions in their practice.

SUBJECTS AND METHODS

Ethical Approval The ethical clearance for this study was granted by the Institutional Ethics Committee of Tianjin Medical University Eye Hospital (No.2023KY-04), complying with all principles outlined in the Declaration of Helsinki. Prior to participation, all individuals involved gave their informed consent after receiving a comprehensive explanation about the purpose and methodologies of the study.

Study Design We conducted a prospective, comparative case series at Tianjin Medical University Eye Hospital. This study consisted of 212 patients (212 eyes), aged 18y or older, with an average age of 66.2±9.4y, who were scheduled for uncomplicated cataract surgery between March and April 2023. All patients included in the study had completed a comprehensive preoperative examination. In instances where both eyes of a patient were eligible for the study, one eye was randomly chosen for inclusion.

Patients were excluded from the study if they were uncooperative or unable to fixate on the internal light during the examination process, or if they had a history of ocular trauma, surgery, or any other ocular diseases apart from cataract that could potentially affect postoperative visual acuity. Such ocular diseases include but are not limited to corneal disorders, glaucoma, vitreoretinal diseases, optic neuropathy, strabismus, or amblyopia.

The enrolled participants underwent a comprehensive preoperative ophthalmic examination conducted by the surgeon. The examination involved the assessment of visual acuity using a standard logarithmic visual acuity chart, anterior segment evaluation using a slit-lamp biomicroscope, and IOP measurement using a non-contact tonometer.

Following this thorough examination, ocular biometric measurements were obtained using the IOLMaster 700 (Carl Zeiss Meditec), CASIA2 (Tomey), and Pentacam (Oculus) devices. These measurements included CCT, ACD, AQD, Kf, Ks, real keratometry of CASIA2, and the total corneal refractive power (TCRP 4.0 mm) as determined by Pentacam.

Data acquisition and analysis were performed by two experienced technicians under standard dim light conditions. The necessary calibrations for all the devices were carried out at the beginning of each day, and all collected data were meticulously evaluated by an experienced examiner.

Instruments and Procedures

IOLMaster 700 The SS-OCT-based IOLMaster series has become the gold standard in clinical practice. Moreover, a new optical biometer, IOLMaster 700, has been widely used in the daily preoperative assessment of IOL power calculation, including the measurement of ocular biometric parameters, for patients with cataract. It allows visualization of the longitudinal section of the eye, eliminating the difficulty in obtaining measurements from uncooperative subjects. Additionally, it has enabled monitoring the imaging of the fovea in patients with poor fixation ability.

The IOLMaster 700 can measure several corneal values, such as the axial length (AL), CCT, ACD (the distance from the epithelium to the anterior region of the lens), AQD (the distance from endothelium to the anterior of the lens; AQD=ACD–CCT), and WTW. Additionally, it can obtain telecentric keratometry in three zones (1.5, 2.5, and 3.5 mm in a cornea with a radius of 7.9 mm, using a refractive index of 1.3375), including Kf, Ks, and TKm, by combining the anterior corneal data and pachymetry data measured by SS-OCT; the area scanned for K values was 2.5 mm. The structure of the macular fovea can be observed in the analysis interface when the signal quality indicator of the quality interface, the fixation confirmation image, and the analysis interface parameters are green, indicating that the fixation cooperation of the patients is good and the results are reliable.

CASIA2 CASIA2 is the latest anterior-segment SS-OCT device. It enables imaging at a deeper scanning depth (13 mm) with a faster scanning speed (50.000 A-scan/s) using a near-infrared laser with a wavelength of 1.3 μm. The instrument measures several corneal parameters using a complementary metal-oxide semiconductor camera. Additionally, corneal power is calculated using a refractive index of 1.3375. Furthermore, keratometry values are calculated on a 3.2-mm diameter[9]. Herein, the CCT, ACD, AQD, WTW, Kf, Ks, Km, and TKm (real average keratometry) were obtained.

Pentacam Pentacam, which is based on the principles of Scheimpflug imaging, is another device widely used in clinical practice for anterior segment analysis. Pentacam obtains images of the anterior compartment by rotating the Scheimpflug camera. A total of 25 images are acquired over a 180-degree rotation in 2s with 500 measurement points on the front and the back of the corneal surface. All images are captured by 3D scanning at a rate of 25 pictures per second[10]. Here, the central cornea was measured according to simulated keratometry (SimK, n=1.3375, 15°) for Kf, Ks, and Km, and the total corneal refractive power (TKm) was measured at the 4-mm zone.

Statistical Analysis All data were evaluated for normality using the Shapiro-Wilk test and normality assessment plots. Normally distributed data are presented as mean±standard deviation (SD), whereas non-normally distributed data are displayed as median with interquartile range. The range values were determined for all parameters.

Corneal biometric measurements obtained by the three devices were compared using the Friedman test (non-parametric analysis of variance), and Bonferroni adjustment was used for post-hoc pairwise comparisons between the devices. Pearson correlation coefficients, intraclass correlation coefficient (ICC) estimates, and 95% confidence intervals (CIs) were calculated based on a mean-rating, absolute-agreement, two-way mixed-effects model to reflect the correlations and agreements between the measurements. The Bland-Altman method with 95% limits of agreements (LoA), which plotted the differences between the devices (y-axis) against the mean value (x-axis) to assess the agreement between the devices, was used. The 95%LoA was defined as the mean±1.96SD of the difference between the devices. Additionally, LoA width was incorporated in the analysis as its use is more suitable in clinical practice.

Linear regression was used to evaluate the possible correlations between the instruments for the measurement of variable parameters. We followed the assumption[11] that at least 100 subjects should be enrolled in the agreement studies to calculate the sample size; thus, 212 patients (212 eyes) were selected for participation in the study. All statistical analyses were performed using SPSS software (version 25.0; IBM, Armonk, NY). P<0.05 was considered statistically significant.

Table 1 Patient characteristics

Characteristics	Variables	Range
Patients (eyes)	212 (212)	-
Age (y), mean±SD	66.2±9.4	33-87
Sex, female, *n* (%)	123 (58)	-
Right eye, *n* (%)	124 (58.5)	-
AL (mm), mean±SD	23.81±1.43	21.48-31.00
DM, *n* (%)	100 (47.2)	-
HP, *n* (%)	109 (51.4)	-
IOP (mm Hg), mean±SD	15.83±2.56	12-20
Smoking, *n* (%)	93 (43.9)	-

AL: Axial length; DM: Diabetes mellitus; HP: Hypertension; IOP: Intraocular pressure.

RESULTS

Overall, 123 females (58%) and 124 right eyes (58.5%) were included in the analysis; Table 1 summarizes the characteristics. The mean AL measured by IOLMaster 700 was 23.81±1.43 mm (range, 21.48–31.00 mm). Figure 1 demonstrates the distribution of the descriptive statistics. Table 2 presents the mean values and ranges of the measured parameters. The Friedman test with Bonferroni's post-hoc pairwise group analysis revealed significant differences in the CCT, ACD, AQD, WTW, Kf, Km, and TKm values obtained using the three devices (all P<0.001); however, no significant difference was observed in the Ks value (P=0.21). All pairwise comparisons between the two SS-OCT-based devices and the Scheimpflug system revealed significant differences in the CCT, ACD, AQD, and WTW values (all P<0.001).

Significant differences were observed between the keratometry values measured by the devices (all P<0.05), except for the K values measured using IOLMaster 700 and Pentacam (all P>0.05). The Pearson correlation coefficients showed a strong correlation between all comparisons, except for those between the WTW values measured by IOLMaster 700 and by CASIA2 and between those by CASIA2 and by Pentacam (r=0.576; Table 3). The ICCs with 95%CIs for Kf, Ks, and Km indicated excellent agreement among the three devices. The ICCs with 95%CIs for CCT, ACD, and AQD showed good to excellent agreement. However, the ICCs with 95%CIs for TKm showed poor to excellent agreement and that of WTW showed poor agreement among the SS-OCT devices and Scheimpflug system (Table 4).

Pentacam had the highest mean CCT, followed by IOLMaster 700 and CASIA2 (Table 2). The mean differences ranged from 4.2–9.4 μm, and the largest mean difference was observed

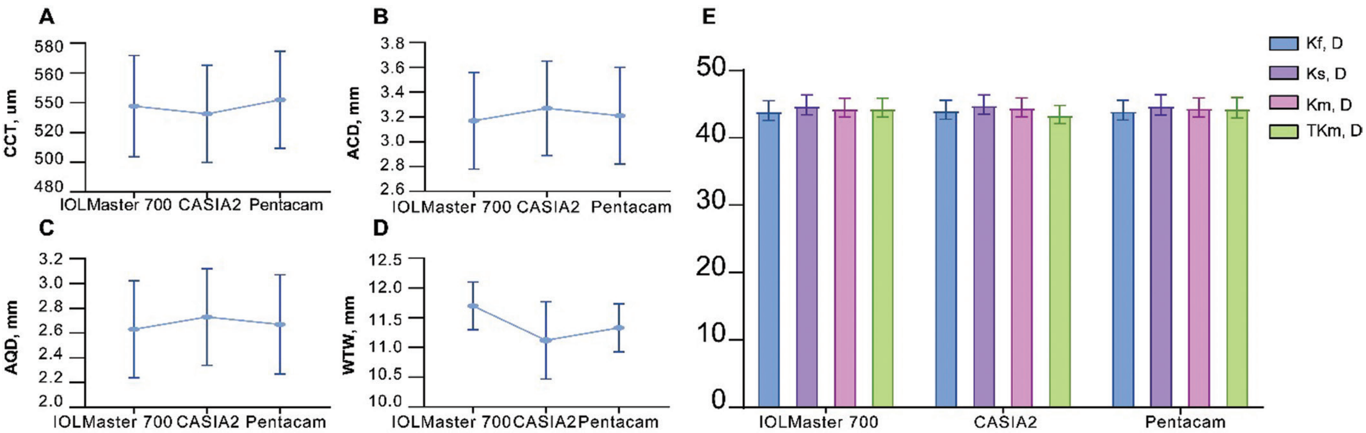

Figure 1 Distribution of parameters measured by the three devices A: Central corneal thickness (CCT); B: Anterior chamber depth (ACD); C: Aqueous depth (AQD); D: White-to-white distance (WTW); E: Flat simulated keratometry (Kf), steep simulated keratometry (Ks), mean keratometry (Km), total corneal keratometry (TKm).

Table 2 Comparison of corneal biometric measurements among IOLMaster 700, CASIA2, and Pentacam mean±SD (range)

Parameters	IOLMaster 700	CASIA2	Pentacam	^aP	^bP	^cP	^dP
CCT (μm)	537.69±34.08 (427-633)	532.52±32.62 (427-618)	541.93±32.66 (440-630)	<0.001	<0.001	0.001	<0.001
ACD (mm)	3.17±0.39 (2.12-4.31)	3.27±0.38 (2.23-4.42)	3.21±0.39 (2.11-4.42)	<0.001	<0.001	<0.001	<0.001
AQD (mm)	2.63±0.39 (1.62-3.77)	2.73±0.39 (1.73-3.88)	2.67±0.40 (1.56-3.87)	<0.001	<0.001	<0.001	<0.001
WTW (mm)	11.70±0.40 (10.80-12.70)	11.12±0.65 (8.80-13.97)	11.33±0.40 (10.50-12.30)	<0.001	<0.001	<0.001	<0.001
Kf (D)	44.05±1.46 (40.12-47.66)	44.17±1.39 (40.31-47.76)	44.11±1.46 (40.20-47.90)	<0.001	<0.001	1.000	<0.001
Ks (D)	44.90±1.46 (40.36-49.02)	44.92±1.45 (40.57-48.78)	44.91±1.50 (40.20-48.70)	0.21	0.606	0.298	0.367
Km (D)	44.47±1.42 (40.24-47.95)	44.55±1.39 (40.45-47.95)	44.50±1.44 (40.20-48.30)	<0.001	0.002	1.000	<0.001
TKm (D)	44.49±1.42 (40.48-47.88)	43.46±1.36 (39.49-46.78)	44.46±1.51 (40.00-48.80)	<0.001	<0.001	0.08	<0.001

^aP: Difference of all three devices by Friedman test; ^bP: Difference between IOLMaster 700 and CASIA2 by Bonferroni multiple-comparison test; ^cP: Difference between IOLMaster 700 and Pentacam by Bonferroni multiple-comparison test; ^dP: Difference between CASIA2 and Pentacam by Bonferroni multiple-comparison test. SD: Standard deviation; CCT: Central corneal thickness; ACD: Anterior chamber depth; AQD: Aqueous depth; WTW: Horizontal corneal diameter (white-to-white distance); Kf: Flat keratometry for anterior; Ks: Steep keratometry for anterior; Km: Anterior mean keratometry; TKm: Total corneal keratometry; D: Diopter.

between CASIA2 and Pentacam. The highest LoA width was 38.396 μm (IOLMaster 700 *vs* Pentacam), whereas the measurements between the IOLMaster 700 and CASIA2 showed a narrow 95%LoA (15.730 μm; Tables 2 and 3, Figure 2A-2C). CASIA2 had the highest mean ACD, and the mean differences among the devices ranged from 0.04–0.10 mm. The lowest LoA width was 0.107 mm (IOLMaster 700 *vs* CASIA2). The measurements between IOLMaster 700 and Pentacam (0.460 mm) and between CASIA2 and Pentacam (0.477 mm) were larger (Tables 2 and 3, Figure 2D-2F).

CASIA2 had the highest mean AQD, and the largest mean difference was observed between IOLMaster 700 and CASIA2 (0.11 mm) with the lowest LoA width (0.107 mm). CASIA2 and Pentacam had the highest LoA width (0.477 mm), followed by that between IOLMaster 700 and Pentacam (0.458 mm) (Tables 2 and 3, Figure 2G-2I). IOLMaster 700 had the highest WTW, followed by Pentacam and CASIA2. The largest mean difference was observed between IOLMaster 700 and CASIA2 (0.60 mm), with the highest LoA width (2.169 mm), followed by that between CASIA2 and Pentacam (2.092 mm). The lowest LoA width was observed between IOLMaster 700 and Pentacam (0.593 mm; Tables 2 and 3, Figure 2J-2L).

CASIA2 had the largest mean Kf, followed by Pentacam and IOLMaster 700. The largest mean difference was observed between IOLMaster 700 and CASIA2 (0.12 D), with the lowest LoA width (1.217 D). IOLMaster 700 and Pentacam had the highest LoA width (1.442 D), followed by that between CASIA2 and Pentacam (1.382 D; Tables 2 and 3, Figure 2M-2O). CASIA2 had the largest mean Ks, followed by Pentacam and IOLMaster 700. The largest mean difference (0.02 D) was observed between IOLMaster 700 and CASIA2. The largest LoA width (1.155 D) was observed between IOLMaster 700 and CASIA2, followed by those between IOLMaster 700 and Pentacam (1.439 D) and CASIA2 and Pentacam (1.314 D; Tables 2 and 3, Figure 2P-2R).

CASIA2 had the largest mean Km, followed by Pentacam and IOLMaster 700. The mean difference ranged from 0.03 D (IOLMaster 700 *vs* Pentacam) to 0.08 D (IOLMaster 700

Table 3 Agreement and correlation of biometric measurements among the three devices

Parameters	Difference		95%LoA	LoA width	*r*	*P*
	Mean±SD	95%CI				
CCT (μm)						
IOLMaster 700 *vs* CASIA2	5.165±4.013	4.622, 5.708	-2.700, 13.030	15.730	0.994	<0.001
IOLMaster 700 *vs* Pentacam	-4.245±9.795	-5.571, -2.919	-23.443, 14.953	38.396	0.958	<0.001
CASIA2 *vs* Pentacam	-9.410±8.917	-10.618, -8.203	-26.887, 8.066	34.953	0.963	<0.001
ACD (mm)						
IOLMaster 700 *vs* CASIA2	-0.100±0.027	-0.104, -0.096	-0.154, -0.047	0.107	0.998	<0.001
IOLMaster 700 *vs* Pentacam	-0.043±0.117	-0.059, -0.028	-0.273, 0.187	0.460	0.955	<0.001
CASIA2 *vs* Pentacam	0.057±0.122	0.040, 0.073	-0.182, 0.295	0.477	0.951	<0.001
AQD (mm)						
IOLMaster 700 *vs* CASIA2	-0.105±0.027	-0.109, -0.102	-0.159, -0.052	0.107	0.998	<0.001
IOLMaster 700 *vs* Pentacam	-0.039±0.117	-0.055, -0.023	-0.268, 0.190	0.458	0.956	<0.001
CASIA2 *vs* Pentacam	0.067±0.122	0.050, 0.083	-0.172, 0.305	0.477	0.952	<0.001
WTW (mm)						
IOLMaster 700 *vs* CASIA2	0.582±0.553	0.507, 0.657	-0.502, 1.667	2.169	0.535	<0.001
IOLMaster 700 *vs* Pentacam	0.378±0.151	0.358, 0.399	0.082, 0.675	0.593	0.930	<0.001
CASIA2 *vs* Pentacam	-0.204±0.533	-0.276, -0.132	-1.250, 0.842	2.092	0.576	<0.001
Kf (D)						
IOLMaster 700 *vs* CASIA2	-0.121±0.310	-0.163, -0.079	-0.730, 0.487	1.217	0.977	<0.001
IOLMaster 700 *vs* Pentacam	-0.055±0.368	-0.105, -0.005	-0.776, 0.666	1.442	0.968	<0.001
CASIA2 *vs* Pentacam	0.066±0.353	0.018, 0.114	-0.625, 0.757	1.382	0.970	<0.001
Ks (D)						
IOLMaster 700 *vs* CASIA2	-0.016±0.295	-0.056, 0.024	-0.594, 0.561	1.155	0.979	<0.001
IOLMaster 700 *vs* Pentacam	-0.008±0.367	-0.058, 0.041	-0.728, 0.711	1.439	0.969	<0.001
CASIA2 *vs* Pentacam	0.008±0.335	-0.037, 0.054	-0.649, 0.665	1.314	0.975	<0.001
Km (D)						
IOLMaster 700 *vs* CASIA2	-0.076±0.217	-0.105, -0.047	-0.501, 0.349	0.850	0.988	<0.001
IOLMaster 700 *vs* Pentacam	-0.035±0.315	-0.077, 0.008	-0.651, 0.582	1.233	0.976	<0.001
CASIA2 *vs* Pentacam	0.041±0.291	0.002, 0.081	-0.530, 0.612	1.142	0.980	<0.001
TKm (D)						
IOLMaster 700 *vs* CASIA2	1.028±0.225	0.998, 1.059	0.587, 1.469	0.882	0.988	<0.001
IOLMaster 700 *vs* Pentacam	0.030±0.464	-0.032, 0.093	-0.879, 0.940	1.819	0.955	<0.001
CASIA2 *vs* Pentacam	-0.998±0.397	-1.052, -0.944	-1.775, -0.221	1.554	0.967	<0.001

SD: Standard deviation; CCT: Central corneal thickness; ACD: Anterior chamber depth; AQD: Aqueous depth; WTW: Horizontal corneal diameter (white-to-white distance); Kf: Flat keratometry for anterior; Ks: Steep keratometry for anterior; Km: Anterior mean keratometry; TKm: Total corneal keratometry; D: Diopter; CI: Confidence interval; LoA: Limits of agreement; *r*: Pearson coefficient.

Table 4 ICC calculation using single-rating, absolute-agreement, and two-way random-effects model

Parameters	ICC	95%CI		*F* test with true value 0			
		Lower limit	Upper limit	Value	*df*1	*df*2	*P*
CCT	0.952	0.875	0.976	101.127	211	422	<0.001
ACD	0.952	0.896	0.973	90.864	211	422	<0.001
AQD	0.951	0.886	0.974	92.399	211	422	<0.001
WTW	0.438	0.167	0.625	5.324	211	422	<0.001
Kf	0.970	0.961	0.976	102.184	211	422	<0.001
Ks	0.974	0.968	0.980	114.267	211	422	<0.001
Km	0.980	0.975	0.985	155.092	211	422	<0.001
TKm	0.827	0.221	0.939	84.821	211	422	<0.001

CCT: Central corneal thickness; ACD: Anterior chamber depth; AQD: Aqueous depth; WTW: Horizontal corneal diameter (white-to-white distance); Kf: Flat keratometry for anterior; Ks: Steep keratometry for anterior; Km: Anterior mean keratometry; TKm: Total corneal keratometry; ICC: Intraclass correlation coefficient; CI: Confidence interval.

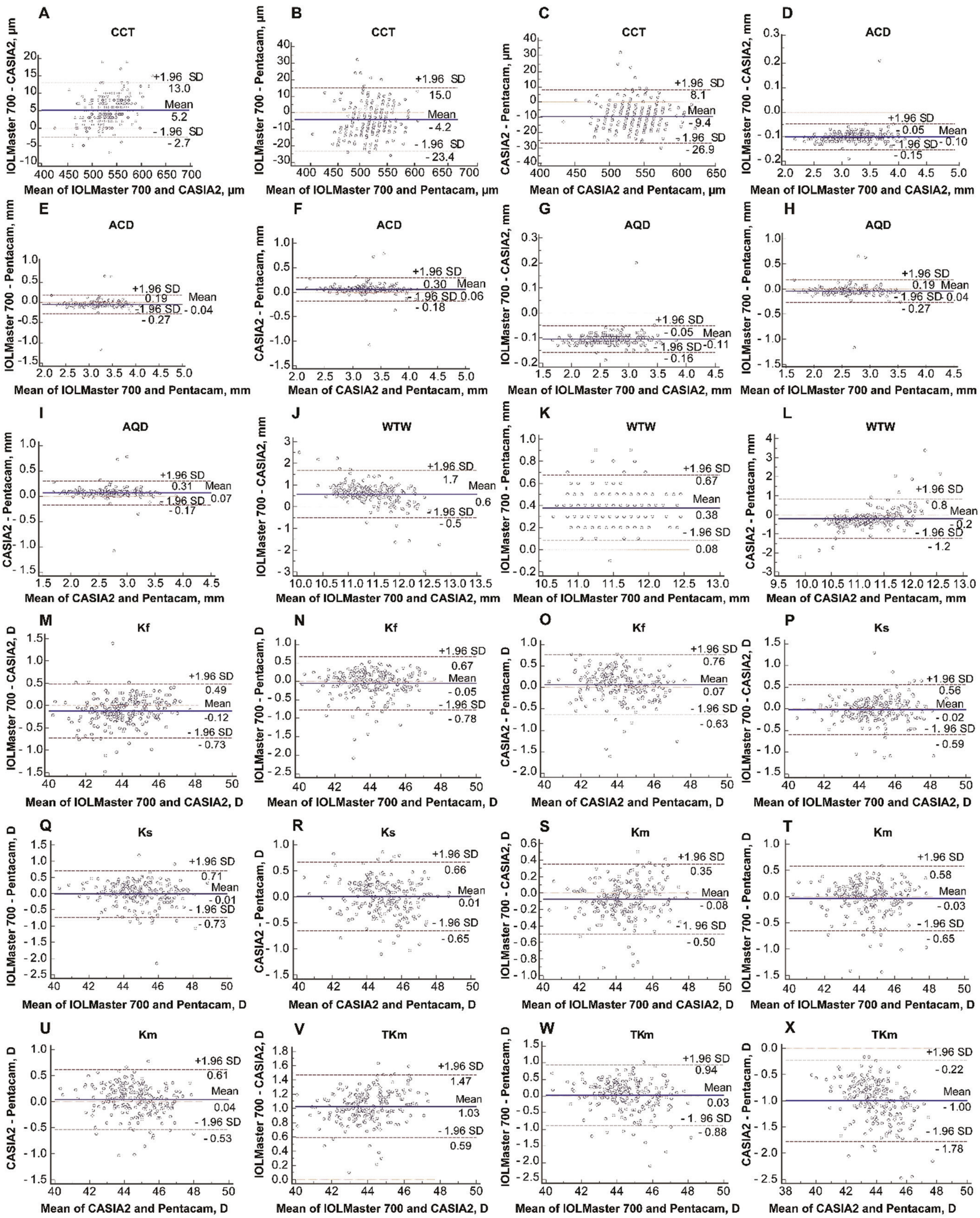

Figure 2 Bland-Altman plots of measurements obtained using IOLMaster 700, CASIA2, and Pentacam A, D, G, J, M, P, S, and V: IOLMaster 700 *vs* CASIA2. B, E, H, K, N, Q, T, and W: IOLMaster 700 *vs* Pentacam. C, F, I, L, O, R, U, and X: CASIA2 *vs* Pentacam. The values for central corneal thickness (CCT), anterior chamber depth (ACD), aqueous depth (AQD), white-to-white distance (WTW), flat simulated keratometry (Kf), steep simulated keratometry (Ks), mean keratometry (Km), and total corneal keratometry (TKm) are shown. The middle solid blue line represents the mean difference. The top and bottom red dotted lines represent the upper and lower 95% limits of agreement, respectively. The orange-red dotted line represents a mean difference of zero. The horizontal axis shows the mean of these devices, and the vertical axis shows the difference between the measurements.

vs CASIA2). The highest LoA width was observed between IOLMaster 700 and CASIA2 (0.988 D), followed by those between CASIA2 and Pentacam (0.980 D) and IOLMaster 700 and Pentacam (0.976 D; Tables 2 and 3, Figure 2S-2U). IOLMaster 700 had the highest mean TKm, followed by Pentacam and CASIA2. The mean difference ranged from 0.03 D (IOLMaster 700 *vs* Pentacam) to 1.03 D (IOLMaster 700 *vs* CASIA2). The highest LoA width of 0.988 D was observed between IOLMaster 700 and CASIA2, followed by those between CASIA2 and Pentacam (0.967 D) and IOLMaster 700 and Pentacam (0.952 D; Tables 2 and 3, Figure 2V-2X).

A linear regression equation was used to model the relationship between the SS-OCT-based equipment and the Scheimpflug camera system (Table 5). The measured corneal parameters in the devices based on other machines could be predicted.

Table 5 Linear regression analysis for CASIA2, IOLMaster 700, and Pentacam

Parameters	Conversion equation by linear regression
CCT (μm)	CASIA2=20.985+0.951×IOLMaster 700
	CASIA2=11.442+0.962×Pentacam
	Pentacam=48.280+0.918×IOLMaster 700
ACD (mm)	CASIA2=0.147+0.985×IOLMaster 700
	CASIA2=0.280+0.930×Pentacam
	Pentacam=0.156+0.964×IOLMaster 700
AQD (mm)	CASIA2=0.142+0.986×IOLMaster 700
	CASIA2=0.249+0.931×Pentacam
	Pentacam=0.129+0.966×IOLMaster 700
WTW (mm)	CASIA2=0.978+0.867×IOLMaster 700
	CASIA2=0.583+0.930×Pentacam
	Pentacam=0.409+0.933×IOLMaster 700
Kf (D)	CASIA2=3.005+0.935×IOLMaster 700
	CASIA2=3.177+0.929×Pentacam
	Pentacam=1.538+0.966×IOLMaster 700
Ks (D)	CASIA2=1.345+0.970×IOLMaster 700
	CASIA2=2.576+0.943×Pentacam
	Pentacam=0.326+0.993×IOLMaster 700
Km (D)	CASIA2=1.565+0.967×IOLMaster 700
	CASIA2=2.539+0.944×Pentacam
	Pentacam=0.457+0.991×IOLMaster 700
TKm (D)	CASIA2=1.300+0.948×IOLMaster 700
	CASIA2=4.738+0.871×Pentacam
	Pentacam=-0.643+1.014×IOLMaster 700

CCT: Central corneal thickness; ACD: Anterior chamber depth; AQD: Aqueous depth; WTW: Horizontal corneal diameter (white-to-white distance); Kf: Flat keratometry for anterior; Ks: Steep keratometry for anterior; Km: Anterior mean keratometry; TKm: Total corneal keratometry; D: Diopter.

DISCUSSION

This study identified significant differences in CCT measurements among the IOLMaster700, CASIA2, and Pentacam systems. To our understanding, our study notably adopts the practice of reporting ICCs with 95%CIs, a method recommended by Koo and Li[12]. This approach underscores the importance of evaluating ICCs with 95%CIs rather than estimating ICCs alone.

Consistent with recent papers such as Guo *et al*[13] and Shi *et al*[14], we found discrepancies in the measurements between different ocular biometric devices. However, our work introduces novelty in several ways. Unlike the mentioned studies, our research encompasses a larger patient sample (212 eyes from 212 patients) and includes additional parameters (CCT, AQD, Kf, Ks, and TKm).

Further, while these previous works focused on comparisons within the IOL-Master series, or solely on highly myopic eyes, we explored the differences and agreements among three different devices–IOLMaster700, CASIA2, and Pentacam– and included a diverse set of cataract patients, enhancing the generalizability of our findings.

CCT measurement plays an essential role in the assessment of patients with suspected glaucoma and IOP monitoring in clinical practice. Additionally, it has a significant role in evaluating the preoperative status before refractive surgery and physiological and pathological changes in the cornea. Yap *et al*[15] reported that the CCT obtained using Pentacam was higher than that obtained using OCT in normal eyes. Kiraly *et al*[16] reported a broad LoA width (36 mm) between Pentacam HR and IOLMaster 700, which was slightly smaller than that observed herein. In the study by Kumar *et al*[17], the mean CCT obtained using IOLMaster 700 was slightly larger than that using Pentacam. According to Rajabi *et al*[18], a large LoA width (32.1 μm) higher than the daily corneal thickness variation of 22 μm[19] and significant differences were observed between IOLMaster 700 and Pentacam, indicating that these devices are not interchangeable.

In contrast, the CCT values obtained by Ozyol *et al*[20] using Pentacam HR were significantly lower than those obtained using IOLMaster 700, and the mean difference and LoA width were -5.05 and 29.7 μm, respectively. Oh *et al*[21] reported that the mean difference in CCT between IOLMaster 700 and CASIA2 was <3 μm, indicating that their use may be interchangeable. Wylegala *et al*[22] reported that the mean CCT obtained using CASIA2 was 545.00±36.15 μm, whereas Li *et al*[23] reported a value of 537.36±23.33 μm, both larger than the values obtained herein. However, the mean difference between Pentacam and CASIA2 was 9.64 μm in the study by Li *et al*[23], and no significant differences were observed between them.

An overestimation of CCT by 12–17 μm is considered clinically significant in refractive surgery[10]. Moreover, approximately 1 mm Hg of correction is required for every

25 μm deviation from the average CCT value of 550 μm[24]. Although a strong correlation and moderate to excellent reliability were observed among the three devices herein, all comparisons had LoA widths of >15 μm with significant differences; therefore, these devices cannot be used interchangeably.

Accurate measurement of ACD plays a crucial role in the IOL power calculation formula and the diagnosis of primary angle-closure glaucoma[20]. Herein, CASIA2 had the largest mean ACD, whereas IOLMaster 700 had the lowest. Similarly, Reuland *et al*[25] reported that the largest mean ACD of Pentacam was larger than that of IOLMaster. The ACD values obtained by Woodmass and Rocha[26] using Pentacam and IOLMaster were 3.82 and 3.78 mm, respectively. de Bernardo *et al*[27] also reported that the measurements obtained using Pentacam were slightly larger than those obtained using IOLMaster. Sayed and Alsamman[28] reported that the mean ACD measurements obtained using IOLMaster and Pentacam were 3.40±0.37 and 3.54±0.35 mm, respectively, and the LoA width was 0.38 mm lower than that observed herein (0.46 mm).

Oh *et al*[21] reported that the mean differences of ACD between CASIA2 and IOLMaster 700 were <0.08 mm, which was lower than that observed herein (0.107 mm). In contrast, Güçlü *et al*[29] reported that the value obtained using IOLMaster was larger than that obtained using Pentacam. In the study by Karmiris *et al*[30], the values obtained by Pentacam were larger than those obtained using IOLMaster. In the comparison study by Li *et al*[23], the mean difference and LoA width between CASIA2 and Pentacam were -0.075 and 0.588 mm, respectively, which were larger than those observed herein.

Olsen[31] reported that a 1 mm deviation in the ACD measurement could lead to a refractive error of 1.5 D in the IOL power. Herein, the LoA widths were 0.107 mm (IOLMaster 700 *vs* CASIA2), 0.460 mm (IOLMaster 700 *vs* Pentacam), and 0.477 mm (CASIA2 *vs* Pentacam), and the LoA width of 0.107 mm did not appear to affect the IOL power. Thus, the data between the devices may be interchangeable; however, considering the significant difference, it should be used interchangeably with caution.

The mean WTW obtained using IOLMaster 700 was larger than that obtained using Pentacam and CASIA2. Similarly, Wei *et al*[32] evaluated the WTW values of 39 986 Chinese cataractous eyes using IOLMaster 700 and reported that the mean value was 11.69±0.46 mm. The WTW, defined as the horizontal visible extent of the iris or the limbus-to-limbus distance, is widely used in the diagnosis of ocular diseases in clinical practice, calculation of IOL power, refractive surgery, measurement of the size of the anterior chamber IOL, and selection of a suitable capsular tension ring size.

Sayed and Alsamman[28] reported that the measurements obtained using Pentacam were significantly shorter than those obtained using IOLMaster, with an LoA width of 0.84 mm, which was larger than that observed herein (0.593 mm). In our study, the mean differences between WTW values were larger than those reported for other parameters. Thus, as previously suggested[33], a difference of 0.50 mm or more in the selection of phakic IOL is clinically significant. The LoA widths ranged from 0.593–2.169 mm, and all values were >0.5 mm. The ICC also showed poor to moderate agreement, consistent with the findings of a previous study[8]. The differences can be attributed to the differences in digital image processing by the different devices. IOLMaster 700 and Pentacam measure WTW automatically from the gray-scale step to detect the limbus point in the photograph, whereas CASIA2 uses the anterior chamber angle as a landmark and provides the angle-to-angle distance. As a result, the values could be easily influenced by factors such as nose shadow, eyelash shadow, or the shadow of the device.

Olsen[31] reported that the measurement error of keratometry accounted for 22% of the refractive prediction error. Corneal power, which accounts for nearly two-thirds of the total power of the eye, plays a key role in the selection of IOL power. Currently, an increasing number of studies have emerged on the use of total corneal power for IOL power calculations. Additionally, precise measurement of the total corneal power is required since more patients who have previously undergone refractive surgery will undergo cataract surgery. Thus, advanced algorithms must be applied to measure the posterior surface.

Herein, CASIA2 had the steepest Kf, Ks, and Km, followed by Pentacam and IOLMaster 700. However, IOLMaster 700 had a higher TKm than did Pentacam and CASIA2, similar to the findings of Asawaworarit *et al*[8]. However, no significant differences were observed among the Ks values obtained by the three devices, and between all keratometry values obtained by IOLMaster 700 and Scheimpflug imaging. Similarly, Lu *et al*[34] and Srivannaboon *et al*[35] found that IOLMaster 700 had steeper values than did the Scheimpflug system.

Sayed and Alsamman[28] reported that the K-readings of Pentacam were higher than those of IOLMaster 700, with a 95%LoA width of 1.412 D, higher than that observed herein (0.976 D). In contrast, Molina-Martín *et al*[36] found that the K-readings of IOLMaster 700 were higher than those of Pentacam. The three devices showed excellent agreement for the anterior keratometry measurements; however, poor to excellent agreement was observed for TKm (ICC=0.827, range 0.221–0.939). All keratometry values were >0.8 D when evaluating the 95%LoA width, as a difference of 1.0 D in the K-readings leads to a difference of approximately 1.4 D in the IOL plane. Therefore, a difference of 0.8 D in the K values may result in a difference of approximately 1.12 D in IOL power prediction. As 0.5 D is the currently used IOL power step, all keratometry values derived from SS-OCT or Scheimpflug should not be interchanged when used for the IOL power calculation.

The differences among the instruments in CCT, ACD, AQD, WTW, and K-readings may be due to the different technologies and image analysis principles. IOLMaster 700 is an SS-OCT device with a 1055-nm wavelength, 2.5-mm measuring diameter, 2000-A-scan/s scanning speed, and 22-μm axial resolution[8]. CASIA2 is an anterior segment SS-OCT device with a 1310-nm wavelength, 3.2-mm measuring diameter, 50 000-A-scan/s scanning speed, and <10-μm axial resolution[37]. Pentacam, with a rotating Scheimpflug camera and 50-μm axial resolution, uses a ray-tracing method with Snell's law to calculate the refractive power at any point of the cornea.

Additionally, linear regression equations used herein should be employed to predict the measurement values of each device. However, the present study was performed on the normal eyes of patients with cataracts; therefore, the results cannot be generalized to other patients with corneal disorders.

Nonetheless, our study had some limitations. First, this study only enrolled patients with cataract with normal corneal status from one clinical center; thus, the differences and agreements in other populations, especially those with corneal diseases, warrant further evaluation. Second, the differences among the different corneal parameters obtained using the devices for the IOL power calculation formula are unknown and warrant further investigation.

In conclusion, our study reveals substantial discrepancies in ocular parameters when measured using IOLMaster700, CASIA2, and Scheimpflug camera tomography. As a result, these measurements should not be used interchangeably across these three devices. The interpretation of ICCs should always consider the 95%CIs, and Bland-Altman values should be evaluated with caution given the LoA widths. This underlines the importance of device-specific consideration in clinical decision-making or research comparisons.

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