• Clinical Research •

Comparison of ocular parameters of two biometric measurement devices in highly myopic eyes

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Abstract

• AIM: To compare the differences and agreement of ocular biometric parameters in highly myopic eyes obtained by optical biometric measurement instruments, the OA-2000 and IOLMaster 500.

• METHODS: Totally, 90 patients (90 eyes) were included. They were divided into high myopia group and control group. Ocular parameters, including axial length (AL), mean keratometry (Km), anterior chamber depth (ACD), and white to white (WTW), were obtained from the OA-2000 and IOLMaster 500.

• RESULTS: For the control group, we applied Bland-Altman graphs to assess the 95% limits of agreement (LoA) for most parameters including AL, ACD, Km, and WTW (-0.24 to 0.29 mm, -0.22 to 0.45 mm, -0.39 to 0.31 D, and -0.90 to 0.86 mm, respectively). In high myopia patients, AL, ACD, Km values had wider 95% LoA (-0.34 to 0.32 mm, -0.36 to 0.34 mm, -0.57 to 0.47 D, respectively), except WTW (-0.80 to 0.68 mm). Differences were not statistically significant between these two instruments (*P*>0.05).

• CONCLUSION: Most parameters obtained by the OA-2000 and IOLMaster 500 are comparable, including the AL, ACD, and K values. Among them, the agreement of the high myopia patients is poor compared to the patients without high myopia.

• KEYWORDS: high myopia; optical biometric measurement; agreement; difference

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INTRODUCTION

With improvements in the medical level of ophthalmology and the resulting quality of life, people's demand for vision is not limited to the improvement of visual acuity but also includes the improvement of visual quality[1]. Intraocular lens (IOL) implantation is an essential procedure for cataracts surgery, which depends on the accuracy of ocular biometry to get the ideal postoperative refractive outcomes[1-3]. Optical biometry has been well accepted as the gold standard since the introduction of the IOLMaster (Zeiss, Germany) optical biometer in 1999[4-5], which is based on partial coherence interferometry (PCI) measurements with a laser wavelength of 780 nm[6-7]. As the severity of a cataract increases, the accuracy of IOLMaster 500 measurements gradually decreases. For serious cataracts, such as posterior capsule cataract (*P*>3.5), hypermature cataract, and leukoplakia, vitreous hemorrhage IOLMaster 500 measurement cannot be performed. To improve the accuracy of the biometric parameters of the eyeball, different eye biometric instruments have emerged. The OA-2000 (Tomey, Japan) is a newly introduced optical biometer based on swept-source optical coherence tomography (SS-OCT) and uses a longer wavelength of approximately 820 nm[8]. For corneal curvature using a Placido disc-based topography technique, the keratometry (K) value, axial length (AL), anterior chamber depth (ACD), and white to white (WTW) parameters can be obtained by one measurement. This will accordingly reduce the error caused by multiple focus eye movement.

Currently, several studies have compared the biometrics of the OA-2000 with those of the IOLMaster 500, focusing mainly on healthy eyes or cataract patients[9-12]. However, there have been few reports that have explored the difference or agreement in obtained results between the OA-2000 and IOLMaster 500 in the analysis of patients with high myopia. It has been reported that 54% of postoperative refractive error originates from the AL measurement[13]. The goal of current study was to compare the output of the OA-2000 and IOLMaster 500 using patients with high myopia as subjects and observe whether the longer eye axis affects the calculation of IOL power.

SUBJECTS AND METHODS

Ethical Approval The study protocol was approved by the Office of Research Ethics Committee at Beijing Friendship

Table 1 Characteristics of the OA-2000 and IOLMaster 500

Instruments	Wavelength	Topographic pattern	Central corneal zone	Advantage
OA-2000	820 nm	Placido disc-based topography techniques; 9 rings each 256 points	5.5 mm zone; 2 mm, 2.5 mm and 3 mm central corneal curvature is available	Stronger penetration and better stability than IOLMaster 500
IOLMaster 500	780 nm	6 points of light from the tear film surface at a hexagonal pattern	2.3 mm in diameter	

Hospital Affiliated to Capital Medical University (2018-P2-009-01), and it was performed in accordance with the principles of the Declaration of Helsinki. The purpose of the study was explained to prospective participants in detail, and all participating subjects provided written informed consent.

Patients This prospective study enrolled 90 subjects (90 eyes, 45 with high myopia) at Beijing Friendship Hospital of Capital Medical University, aged 25 to 60 (47.96±10.17)y. High myopia was here defined as spherical equivalent (SE) ≤-6.0 diopters (D), and/or AL≥26.5 mm, and the control group was made up of patients whose SE >-6.0 D and AL<26.5 mm.

Inclusion Criteria 1) No history of glaucoma, keratopathy, uveitis, or ocular trauma; 2) No history of other refractive surgery; 3) No use of rigid contact lenses within the 4wk immediately prior to the experiment and no use of soft contact lenses within the 2wk immediately prior to the experiment; 4) Intraocular pressure (IOP) within the range of 10-21 mm Hg.

Exclusion Criteria 1) Corneal disease (*e.g.,* corneal leukoplakia, corneal astigmatism more than 3.0 D or keratoconus); 2) Ocular inflammation; 3) Severe dry eye; 4) History of eye trauma; 5) Patient uncooperative or with poor fixation (*e.g.,* vitreous opacity, maculopathy or retinal detachment with poor vision).

Instruments and Measurement Protocol Some characteristics of two instruments are given in Table 1.

All participants underwent a comprehensive ophthalmic examination, including refractometry, best corrected visual acuity (BCVA) and IOP. Parameters were obtained with the same machine of OA-2000 and IOLMaster 500 (Carl Zeiss, Germany), which were operated by an optometrist who was skilled in the use of both devices.

IOLMaster 500 measurement method All the subjects were asked place their chin on the instrument's jaw support apparatus. The examinee looked at the visual mark in the instrument, and the examiner manually measured after focusing. The examiner manually measured the AL 5 times and K, ACD, and WTW 3 times, and then these values were averaged.

OA-2000 measurement method All subjects were requested to sit with their foreheads against the headrest, and the chin was placed on the mandible tray of the instrument to adjust the apparatus to the height of the patient's eye. The examinee looked at the red light on the measurement window. The eyes widened and the cornea was fully exposed. The examinee followed the computer screen to focus, the AL, K value, ACD, and WTW were automatically measured, and then averaged after 3 times. Measurements were successfully obtained from all patients.

Table 2 Characteristics of the high myopia group and the control group

Characteristics	High myopia	Control	*P*
No. of eyes	45	45	-
Sex (M:F)	19:26	14:31	-
Age, y	48.42±10.77	47.49±9.63	0.480
IOP, mm Hg	16.00±3.86	16.18±2.03	0.691
BCVA, logMAR	0.22±0.41	0.01±0.33	0.011
SE, D	-9.79±3.86	-1.42±2.18	<0.001

IOP: Intraocular pressure; BCVA: Best corrected visual acuity; SE: Spherical equivalent.

Statistical analysis Data were analyzed by SPSS software (version 22.0; IBM Corporation, USA) and MedCalc statistical software (version 15.8, MedCalc Software Inc., Belgium). A *P* value of less than 0.05 was considered as statistical significance. The Kolmogorov-Smirnov test was applied to verify whether the data were normally distributed. If this was confirmed, then paired *t*-tests were used to evaluate the differences in parameters between two devices. If the measurement data did not meet the normal distribution, then the rank sum test was used to analyze the differences. Bland-Altman plots were used to assess the agreement between OA-2000 and IOLMaster 500[14]. The 95% limits of agreement (LoA) was expressed as the mean difference±1.96 the standard deviation (SD) of the difference, referring to an interval within which 95% of the differences between measurements were expected to lie[15]. In Bland-Altman plots, the solid line indicates the mean difference. The interval between the upper and lower lines represents the 95% LoA. Pearson's correlation was used to determine relationships between IOLMaster 500 and OA-2000.

RESULTS

Ninety eyes from 90 patients (57 women, 33 men), with a mean age of 47.96±10.17y (range: 25 to 60y), were enrolled. The patient characteristics are summarized in Table 2. Table 3 shows the mean and SD values of the parameters for the high myopia group and the control group obtained by the OA-2000 and IOLMaster 500. We found that the AL, ACD, and K showed excellent correlations for two groups; however, there was a

Table 3 Comparison of ocular parameters in the high myopia group and the control group as measured using the OA-2000 and IOLMaster 500 mean±SD

Parameters	High myopia				Control			
	OA-2000	IOLMaster 500	*P*	*r*	OA-2000	IOLMaster 500	*P*	*r*
AL (mm)	27.84±1.32	27.85±1.30	0.971	0.991	23.49±1.29	23.47±1.30	0.934	0.995
ACD (mm)	3.51±0.38	3.52±0.34	0.902	0.877	3.00±0.33	2.89±0.36	0.122	0.875
Km (D)	44.41±1.62	44.46±1.63	0.881	0.983	44.61±1.60	44.64±1.66	0.921	0.995
WTW (mm)	11.48±0.51	11.55±0.36	0.501	0.684	11.37±0.46	11.39±0.35	0.853	0.415

AL: Axial length; ACD: Anterior chamber depth; Km: Mean keratometry; WTW: White to white; SD: Standard deviation.

Table 4 Difference in biometric measurements of all patients between the OA-2000 and IOLMaster 500

Parameters	AL			ACD			Km			WTW		
	All patients	High myopia	Control	All patients	High myopia	Control	All patients	High myopia	Control	All patients	High myopia	Control
Mean difference±SD	0.01±0.14	-0.01±0.17	0.02±0.13	0.05±0.19	-0.01±0.19	0.11±0.17	-0.04±0.21	-0.05±0.26	-0.04±0.18	-0.04±0.43	-0.06±0.37	-0.02±0.45
t	0.82	-0.19	0.09	-3.28	-0.30	4.44	-1.59	-0.88	-1.35	-0.88	-1.41	-0.24
P	0.675	0.926	0.900	0.459	0.617	0.118	0.053	0.884	0.917	0.358	0.997	0.852
95% LoA	-0.30, 0.32	-0.34, 0.32	-0.24, 0.29	-0.31, 0.42	-0.36, 0.34	-0.22, 0.45	-0.46, 0.37	-0.57, 0.47	-0.39, 0.31	-0.85, 0.77	-0.80, 0.68	-0.90, 0.86

AL: Axial length; ACD: Anterior chamber depth; Km: Mean keratometry; WTW: White to white; SD: Standard deviation; LoA: Limits of agreement.

Table 5 Differences in biometric measurements between the OA-2000 and IOLMaster 500 for power calculation of intraocular lens in the high myopia group and the control group

Parameters	Mean difference±SD	*t*	*P*	95% LoA
⩾26.5 mm (Holladay1)	0.00±0.67	0.00	1.00	-1.25, 1.26
<26.5 mm (SRK/T)	-0.06±0.49	-0.45	0.651	-1.02, 0.91

SD: Standard deviation; LoA: Limits of agreement.

weak correlation between the two devices with respect to the WTW diameter (r=0.684 and 0.415, respectively). Differences were not statistically significant between two devices in Table 4. Table 5 shows that different formulas were used to calculate the IOL power of the two groups, with no statistical difference (P>0.05).

The 95% LoA obtained by the two instruments for AL, Km, WTW, and ACD ranged from -0.30 to 0.32 mm, -0.46 to 0.37 D, -0.85 to 0.77 mm, and -0.31 to 0.42 mm for all 90 patients (Figure 1). Among the 45 patients in the control group, 95% LOA was obtained by both two instruments for AL, Km, WTW, and ACD, ranging from -0.24 to 0.29 mm, -0.39 to 0.31 D, -0.90 to 0.86 mm, and -0.22 to 0.45 mm, respectively (Figure 2). For the 45 patients with high myopia, there were 4.4% (2/45), 2.2% (1/45), 2.2% (1/45), and 4.4% (2/45) points outside the 95% LoA (Figure 3). The 95% LoA ranged from -0.34 to 0.32 mm, -0.57 to 0.47 D, -0.80 to 0.68 mm, and -0.36 to 0.34 mm, respectively. The Bland-Altman analysis showed the narrow 95% LoA for AL, ACD, and Km.

The third-generation formula Holladay1 was used for the high-myopia group, and the 95% LoA range was (-1.25, 1.26) D. The SRK/T formula was used for the control group, with a 95% LOA range from -1.02 to 0.91 D (Figure 4).

DISCUSSION

Precise biometric data are essential for ideal outcomes after cataract surgery[3]. Several previous studies are available that compare the OA-2000 with the IOLMaster, Lenstar, and other biometric instruments[10-12,16-19]. For example, Hua *et al*[12] showed that the mean difference in AL for 108 normal subjects measured with the OA-2000 and IOLMaster was 0.058 mm. Huang *et al*[10] also determined the mean difference between the two instruments, although that study analyzed normal or non-high myopia subjects. Hua *et al*[12] reported that the AL was 24.56 mm, and Huang *et al*[10] reported an AL of 25.68 mm. Few studies have examined high myopia patients[9,11]. The measurement of the preoperative IOL power is mainly related to factors such as AL, K, ACD, and formula selection[20-22]. Among these, AL measurement is especially critical[23]. The error between the calculated and actual IOL power depends on the accuracy of the AL measurement. Therefore, we divided all patients into a high myopia group and control group and compared the agreement and difference of the output of the OA-2000 and IOLMaster 500.

Here, the parameters obtained by the OA-2000 and IOLMaster 500 were compared. The mean differences in all cases for AL, Km, WTW, and ACD were 0.01±0.14 mm, -0.04±0.21 D, -0.04±0.43 mm, and 0.05±0.19 mm, respectively. Additionally, differences were not statistically significant (P>0.05). Additionally, the Bland-Altman analysis showed a narrow 95% LoA for AL, ACD, and K values.

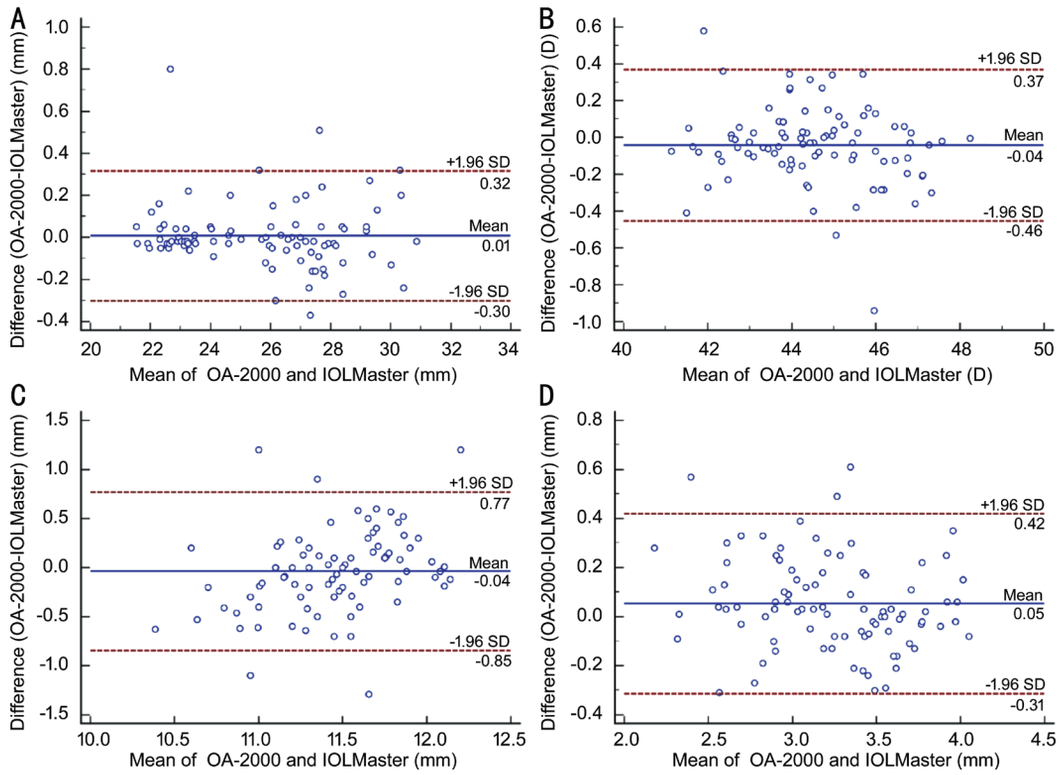

Figure 1 Bland-Altman plots present the mean plotted against the differences in values for AL (A), Km (B), WTW (C), and ACD (D) for a comparison between the OA-2000 biometer and IOLMaster 500 in all patients (*n*=90).

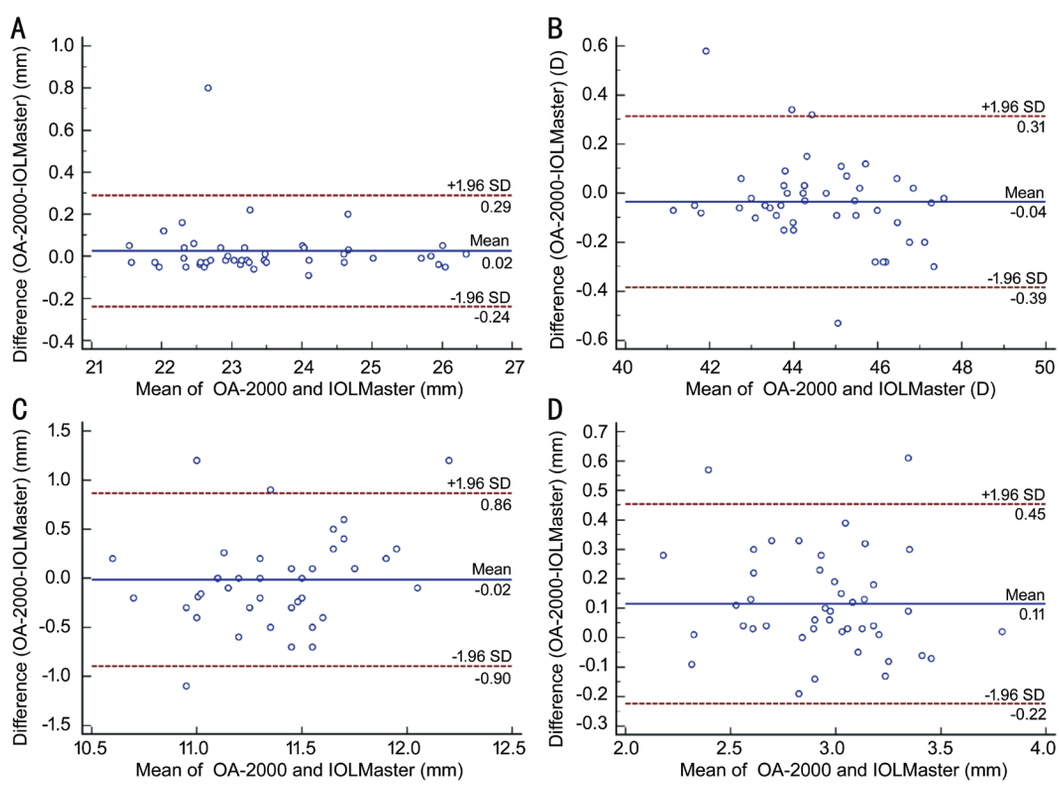

Figure 2 Bland-Altman plots present the mean plotted against the differences in values for AL (A), Km (B), WTW (C), and ACD (D) for a comparison between the OA-2000 and IOLMaster 500 in the control group (*n*=45).

The difference in the obtained AL values between the two devices of our study was rather small (on average 0.01±0.14 mm). The difference in the obtained values between these two instruments was significantly less than the values obtained between optical low-coherence reflectometry (OLCR) and PCI in the study by Hoffer *et al*[24] (0.026 mm) and Cruysberg *et al*[25] (0.03±0.02 mm). For the high myopia group, the mean difference in AL was 0.01 mm in our study. Usually, a 0.10 mm

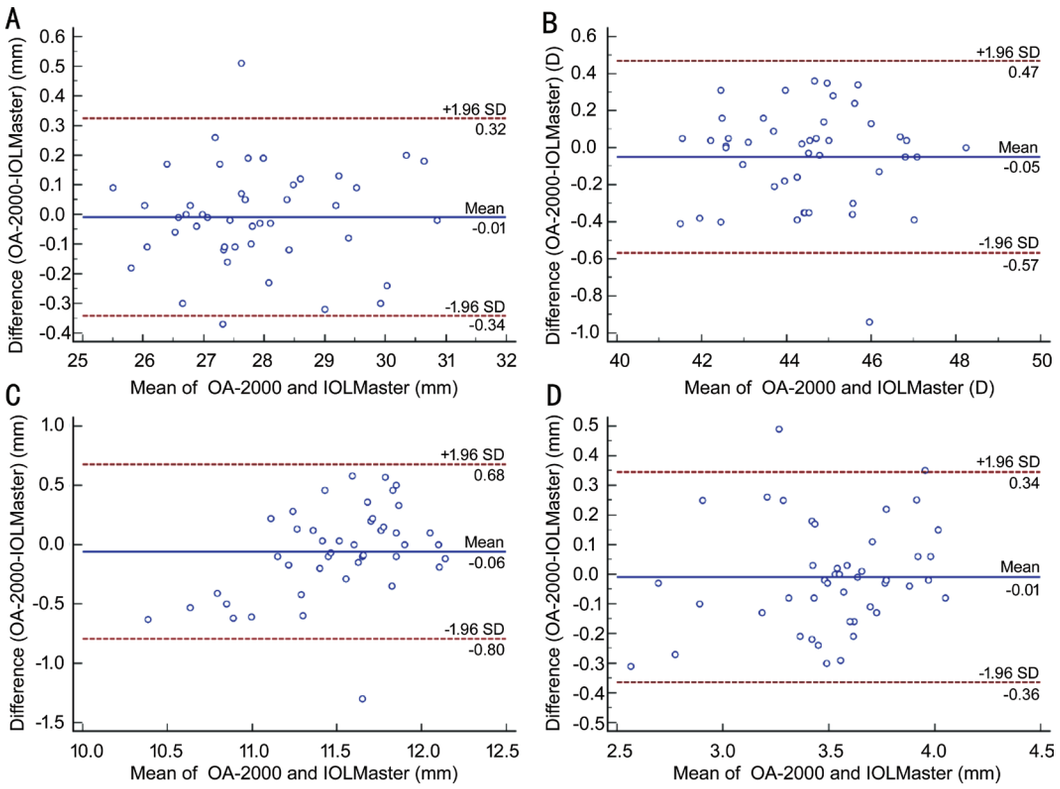

Figure 3 Bland-Altman plots present the mean plotted against the differences in values for AL (A), Km (B), WTW (C), and ACD (D) for a comparison between the OA-2000 and IOLMaster 500 in the high myopia group (*n*=45).

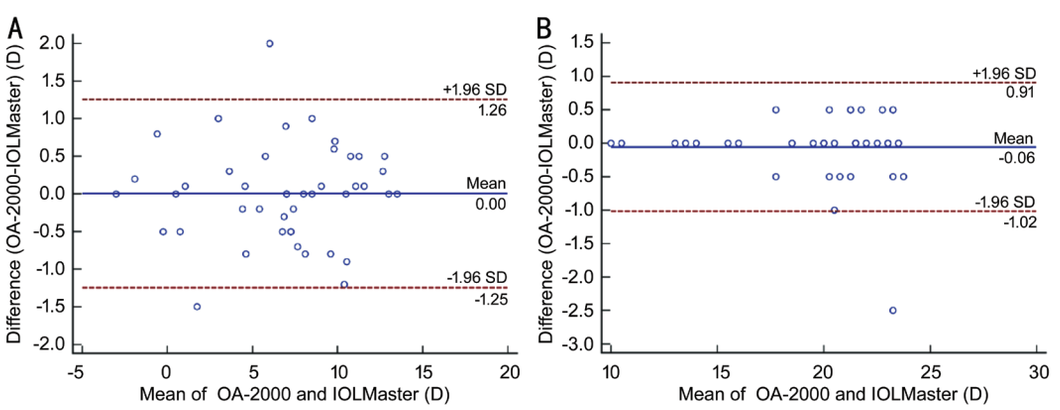

Figure 4 Bland-Altman plots present the mean plotted against the differences for power calculation of intraocular lens in the high myopia group (A) and the control group (B) by the OA-2000 and IOLMaster 500.

error in AL is equivalent to an error of approximately 0.27 D in the spectacle plane, and the smallest detectable difference that causes subjective refraction is 0.25 D[26]. Therefore, it can be stated from our study that the errors in the refractive prediction due to AL variability are negligible.

The ACD measurement of the OA-2000 was 0.05 mm higher than the average of the IOLMaster 500 and similar to previous studies. The difference in ACD values between the OA-2000 and the IOLMaster 500 in the Kongsap[9] study was approximately 0.09 mm. Liampa *et al*[27] observed a difference of 0.2 mm in ACD values between Lenstar and a PCI biometer. Goebels *et al*[16] observed a difference of 0.08 mm in ACD values between Lenstar in and a new OLCR biometer. These differences likely depend on the different technologies used to measure ACD. The reason for the difference may be related to the different principles of the two instruments[7]. With a longer wavelength, an alternative light source, and an adjustable fixation target, the OA-2000 measures the ACD on the optical axis while fixating on the visual axis, whereas the IOLMaster 500 applies a multimode laser. Base on this, distances can be obtained more accurately applying the principle of OLCR[8,16]. Fortunately, the average difference between the two instruments in the high myopia patients was 0.01 mm, and there was a range from -0.36 to 0.34 mm for the 95% LoA in our study.

The OA-2000 biometer applies Placido disc-based topography techniques to measure the corneal curvature, while the

IOLMaster 500 uses 6 points of light from the tear film surface at a hexagonal pattern[28-29]. Here, the data was collected from the 2.5-mm zone and found that all keratometry values obtained by the OA-2000 were significantly lower than those obtained by the IOLMaster 500 (0.05 D, 0.04 D, respectively) in patients with either high myopia or not. This is consistent with the findings of Kongsap[9], who found that the K value measured by the OA-2000 was lower (0.11 D). At the same time, we also found that there is less consistency in the high myopia patients as compared to the control group. It is known that a difference of 1.0 D in K values leads to a difference of approximately 1.4 D in the IOL power prediction[30-31]. Therefore, a difference of approximately 0.05 D in the K value would result in a difference of 0.07 D in the IOL power prediction, which can be considered that this is clinically negligible.

The agreement of WTW values was not always optimal in previous studies, and the repeatability and reproducibility were relatively low for the AL-Scan, IOLMaster, Aladdin, and Lenstar[18-19,32]. Wang *et al*[33] reported on the reproducibility and reproduction of the OA-2000 and found that they were relatively poor for WTW and lens thickness. Kongsap *et al*[9] found that the agreement was relatively good between the analyzed OA-2000 and IOLMaster 500, except that the WTW value had a wide 95% LoA (-1.85, 1.42 mm). Our results show that the 95% LoA for the WTW value had a wide range from -0.80 to 0.68 mm for the high myopia group and -0.90 to 0.86 mm for the control group. Also, the WTW value of the high myopia group was 0.04 mm larger than that of the control group. The OA-2000 biometer measures the WTW by distinguishing the light and shade interface between the cornea and sclera. The elderly patients we included had a high prevalence of arcus senilis. It is likely that the variations in the method of detection influenced the identification of this edge. Srivannaboon *et al*[19] also reported that the weak correlations could result from a difference in the algorithms for edge detection around the iris and the dissimilarity of the light source for image acquisition between the devices, which may be the cause of the difference[32].

According to the different AL values, the IOL power was calculated by adopting different formulas. The IOL of the high myopia group was calculated using the third-generation formula Holladay1; the SRK/T formula was used for the control myopia group. The results of the high myopia group showed that the 95% LoA was wider than the control group (-1.25 to 1.26 D, -1.02 to 0.91 D, respectively).

In summary, most parameters were comparable between the two devices, including AL, ACD, and K values. Among them, the agreement of the high myopia group was poor as compared to the control group.

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Authors' contributions: Guo XX, You R, Li SS, Yang XF, Zhao L and Zhang F contributed to the data collection and statistical expertise. Guo XX, You R, Wang YL and Chen X analyzed the data. Guo XX, Wang YL, and Chen X designed the project. Guo XX and Chen X prepared the manuscript. All authors read and approved the final manuscript.

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