· Clinical Research ·

The binocular intraocular lens power difference in eyes with different axial lengths

Ming–Hui Deng[1,2,3], *Xiao–Gang Wang*[4], *Song Chen*[1,2], *Xue–Feng Shi*[1,2]

[1]Clinical College of Ophthalmology, Tianjin Medical University, Tianjin 300070, China

[2]Tianjin Key Lab of Ophthalmology and Visual Science, Tianjin Eye Institute, Tianjin Eye Hospital, Tianjin 300020, China

[3]Department of Cataract, Linfen Yaodu Eye Hospital, Linfen 042000, Shanxi Province, China

[4]Department of Cataract, Shanxi Eye Hospital Affiliated to Shanxi Medical University, Taiyuan 030002, Shanxi Province, China

Co-first authors: Ming-Hui Deng and Xiao-Gang Wang

Correspondence to: Song Chen and Xue-Feng Shi. Clinical College of Ophthalmology, Tianjin Medical University, Tianjin 300070, China. songchen1632021@163.com; shixf_tmu@163.com

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Abstract

● **AIM:** To investigate the binocular intraocular lens (IOL) power difference in eyes with short, normal, and long axial lengths (AL) using Lenstar LS 900 optical biometry.

● **METHODS:** A total of 716 (1432 eyes) participants were included. The groups were categorized into short (group A: AL<22 mm), normal (group B: 22 mm≤AL≤25 mm), and long AL groups (group C: AL>25 mm). The central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), AL, anterior corneal keratometry, white-to-white (WTW), pupil diameter (PD), as well as IOL power calculated using embedded Barrett formula were assessed. Bland-Altman plots were used to test the agreement of the binocular parameters.

● **RESULTS:** In group A, the CCT of the right eye was significantly thinner than that of the left eye (P=0.044) with a difference of -2±8 μm [95% limits of agreement (LoA), -17.8 to 13.2 μm]. For group B, the PD and IOL power in the right eye were significantly lower than those of the left eye (P=0.001, <0.001) with a difference of -0.05±0.32 mm (95%LoA, -0.68 to 0.58 mm) and -0.18±1.01 D (95%LoA, -2.2 to 1.8 D). The AL of right eye was longer than that of the left eye (P=0.002) with a difference of 0.04±0.25 mm (95%LoA, -0.45 to 0.52 mm). No significant difference was observed for all the binocular parameters in group C. The percentage of participants with binocular IOL power difference within ±0.5 D were 62% (31/50), 68.3% (339/496), and 38.8% (66/170) in groups A, B, and C, respectively.

● **CONCLUSION:** The binocular parameters related to IOL power are in good agreement, but the binocular IOL power difference of more than half of participants with long AL is more than 0.50 D.

● **KEYWORDS:** axial length; intraocular lens power; binocular difference

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INTRODUCTION

The symmetric biometric parameters' hypothesis was popular in the clinic, especially for intraocular lens (IOL) power calculation for cataract surgery. Based on the above-mentioned hypothesis, some researchers used the postoperative refractive outcome of the first eye for reference to improve the prediction of the second eye[1-4]. However, the benefit of using the second eye data was uncertain, and certain controversies still exist. Even for the positive result, only nearly 50% of cases work[2-6]. This phenomenon could be attributed to both the potential incongruence of IOL power calculation related to binocular parameters [especially anterior chamber depth (ACD) and lens thickness (LT) for effective lens position estimation] and the accuracy of IOL power calculation formulas used in each study[1-7].

The Lenstar LS900 (Haag-Streit Diagnostics, Köniz, Switzerland) has been available since 2008[8-10]. It is based on optical low-coherence reflectometry; it can measure axial length (AL), ACD, and LT *etc*., in a single scan[3]. Its latest software (version 2.5.2) includes the Barrett Universal II formula, providing cataract surgeons with more precise target refraction values[11].

In a previous study comparison of binocular keratometry (K) reading and AL in 2258 normal participants, approximately 4.5% (101/2258) of the participants demonstrated more than

1.0 D for the average K difference readings, and nearly 19.2% (433/2258) of the participants showed more than 0.4 mm AL difference. These above-mentioned differences would attribute to more than 1.0 D IOL power difference individually[1]. With the development of IOL power calculation formulae, more input parameters were warranted. Therefore, we aimed to test the combined effect of related IOL power calculation parameters and analyze the potential correlations not only for normal cases, but also for short and long eyes in this study to test the hypothesis of binocular symmetry biometry.

SUBJECTS AND METHODS

Ethics Approval This study was performed at the Shanxi Eye Hospital (Taiyuan, Shanxi Province, China). The research protocols were approved by the Ethics Committee of Shanxi Eye Hospital and were conducted in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all individual participants included in this study.

Participants Prospectively, consecutive patients from the outpatient department were enrolled between August 2019 and October 2020. The inclusion criteria were no systemic disease, no pathological alteration of the anterior segment such as keratoconus, zonular dialysis, pseudoexfoliation syndrome, and corneal opacity, no retinal diseases impairing visual function, and no previous anterior or posterior segment surgery. Patients unable to cooperate with the data capture, failed either eye for data capture, or those with poor data quality were excluded from the study.

Data Capture The biometry data capture was performed in natural illumination without pupil dilation using the Lenstar LS900 (ver. 2.5.2, Haag-Streit AG, Koeniz, Switzerland). Briefly, the participants placed their chin on a chin rest, pressed their forehead against a forehead strap, and aligned the investigated eye to the visual axis by using a central fixation target. Participants were asked to fixate on the internal target, and the device was focused based on the image of the eye on the monitor. The participants were asked to blink before data capture to ensure the tear film was smoothly over the cornea. Three consecutive measurements were automatically obtained for each eye. For each participant, all the measurements were taken within 10min on the same day in the same sequence of right eye and left eye. According to the manufacturer's calibration guidelines for measurements, the function check runs for the first time when the instrument is commissioned. The same experienced examiner (Wang XG) performed all the function checks and examinations. The Lenstar LS900 system automatically determined the AL, CCT, ACD, LT, flat K, steep K, pupil diameter (PD), and white-to-white distance (WTW). In the automatic measurements of the PD, the pupil margins should be double-checked and redefined for cases with improper profiles as described before[12].

The internal embedded Barrett formula (lens factor 2.09 or A constant 119.39) was used to calculate the IOL power[13]. We set the target refraction to zero to observe the binocular IOL power correlations. To calculate the ideal IOL power, we chose the ZCB00 (AMO) as the target IOL model for each eye.

The participants were categorized into short AL eye (group A: AL<22 mm), normal AL eye (group B: 22 mm≤AL≤25 mm), and long AL eye groups (group C: AL>25 mm)[14].

Statistical Analysis Statistical analyses were performed using a commercial software (SPSS ver. 13.0; SPSS Inc., USA). A paired sample *t*-test was performed to compare the binocular quantitative measurement values. Pearson's correlation test was used to test the correlations for binocular parameters in each group. Bland-Altman method was used to test the agreement of the binocular parameters in each group[15-16]. All the tests had a significance level of 5%.

RESULTS

A total of 716 (1432 eyes) patients were included in the final data analysis. There were 50 participants (100 eyes, 11 males, 39 females) in group A with mean age 67.1±16.4y (range 5-87y), 496 participants (174 males, 322 females, 992 eyes) in group B with mean age 67.4±14.3y (range 5-92y), and 170 participants (66 males, 104 females, 340 eyes) in group C with mean age 53.7±19.7y (range 6-91y).

In group A, the mean CCT of the right eye was approximately 2 μm thinner than that of the left eye (P=0.044) and the 95% limits of agreement (LoA) was -17.8 to 13.2 μm (Figure 1). One (2%) participant showed more than 0.4 mm AL difference. No statistical significance was observed for the binocular value comparison, including ACD, LT, AL, flat K, steep K, WTW, PD, and IOL power (all P>0.05; Table 1). Moreover, significant correlation was found for all the binocular parameters with correlation values from 0.566 to 0.974 (all P<0.001; Table 1, Figure 2).

In group B, significant differences were observed for the binocular parameters including AL, PD, and IOL power (all P<0.05; Table 2) and the 95% LoA were -0.45 to 0.52 mm, -0.68 to 0.58 mm, -2.2 to 1.8 D, respectively (Figure 3). Thirty-nine (7.8%) participants showed more than 0.4 mm AL difference. No statistical significance was observed for the other binocular values (all P>0.05; Table 2). Moreover, significant correlation was observed for all the binocular parameters with correlation values from 0.688 to 0.966 (all P<0.001; Table 2, Figure 4).

In group C, no significant differences were observed for all the binocular parameters (all P>0.05; Table 3). Eighty (47.1%) and 9 (5.3%) participants showed more than 0.4 mm AL difference, and more than 1.0 D for mean K difference, respectively. Significant correlation was observed for all the binocular parameters with correlation values ranging from

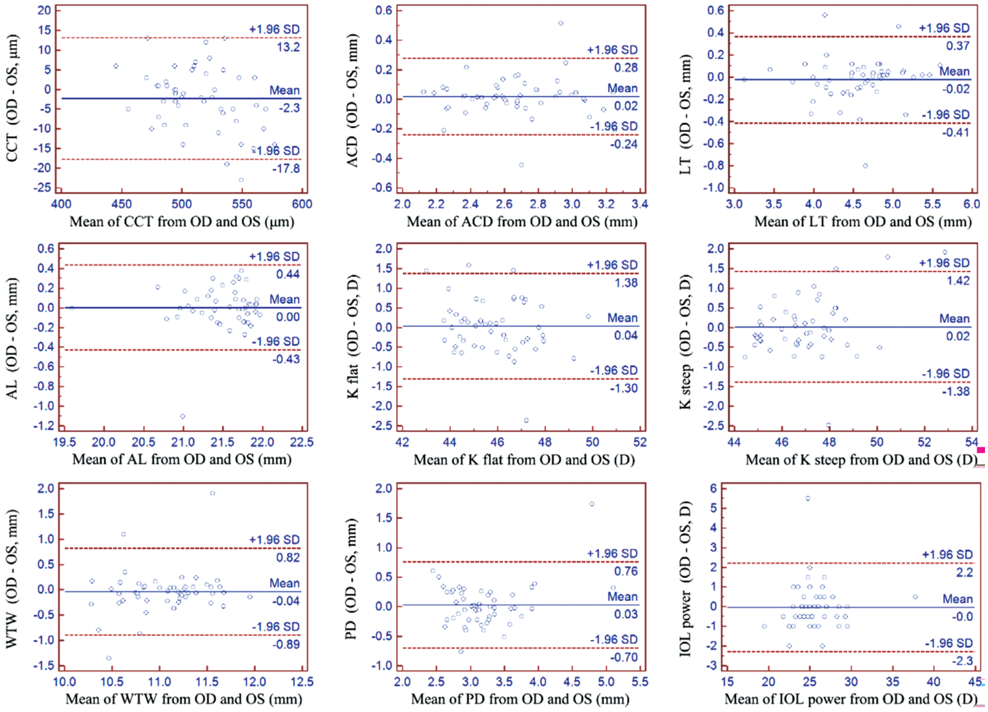

Figure 1 The Bland-Altman plots of the CCT, ACD, LT, AL, Kflat, Ksteep, WTW, PD, and IOL power between the right and left eyes in group A The mean difference is demonstrated by the continuous line, whereas the 95% limits of agreement are indicated by the dashed lines. CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens.

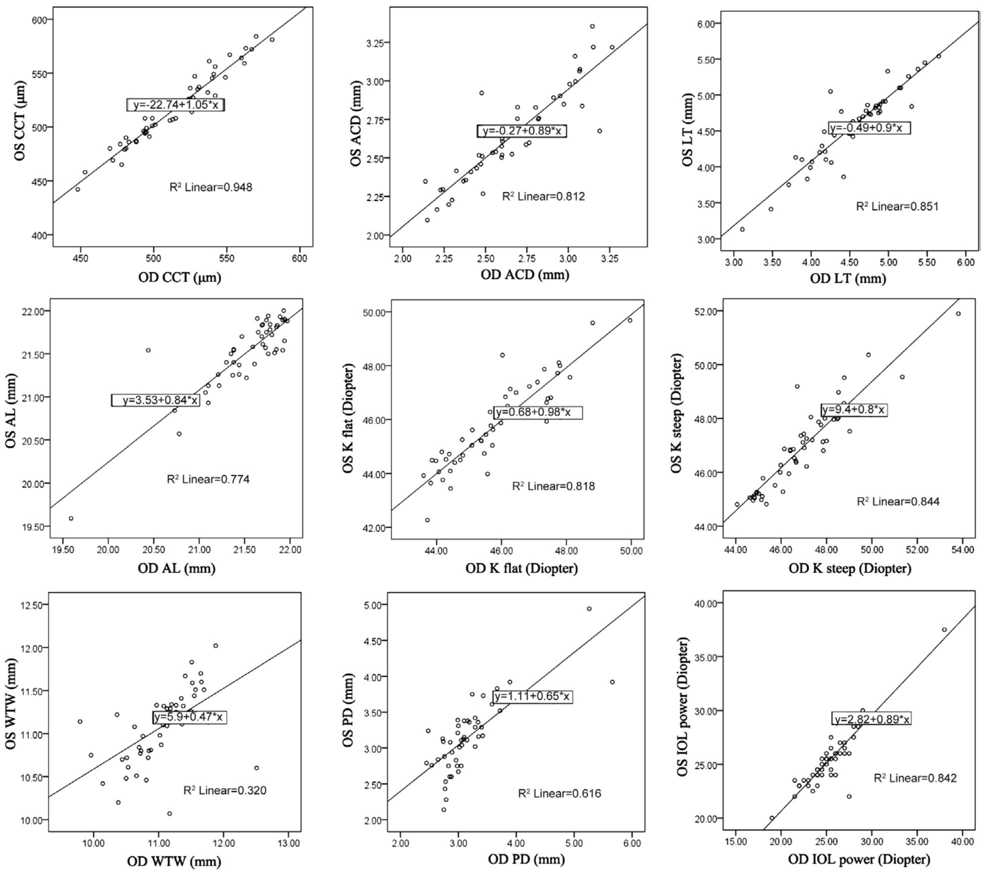

Figure 2 Scatterplots demonstrate the correlation between CCT, ACD, LT, AL, Kflat, Ksteep, WTW, PD, and IOL power for the binocular parameters in group A The regression equation is demonstrated in the rectangular box (x represents right eye; y represents left eye). CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens.

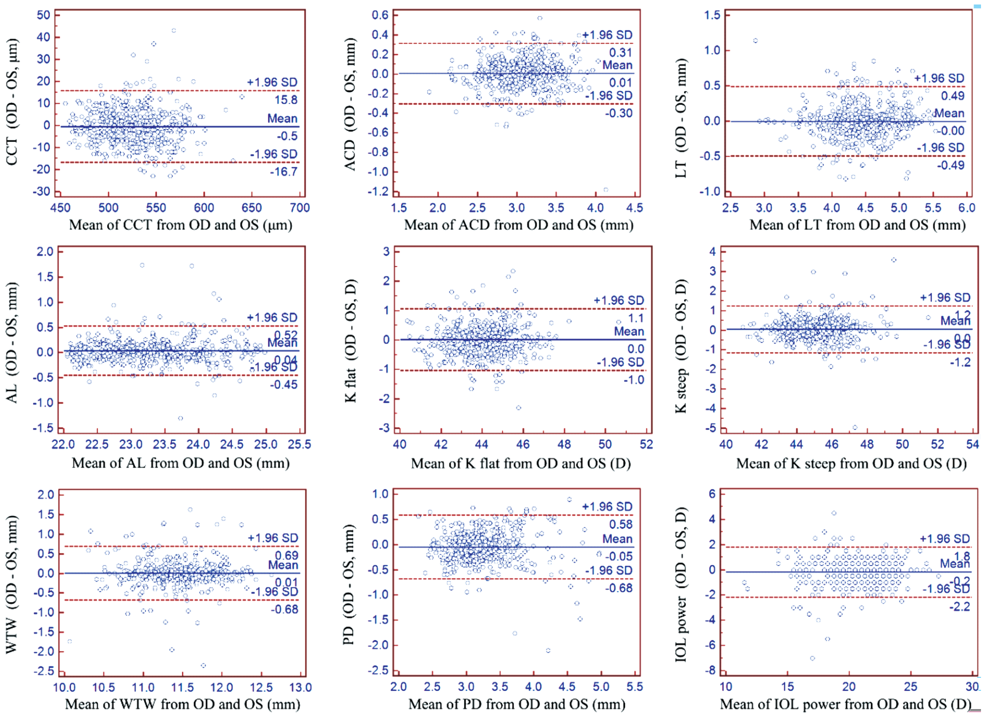

Figure 3 The Bland-Altman plots of CCT, ACD, LT, AL, Kflat, Ksteep, WTW, PD, and IOL power between right and left eyes in group B The mean difference is demonstrated by the continuous line, whereas the 95% limits of agreement are indicated by the dashed lines. CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens.

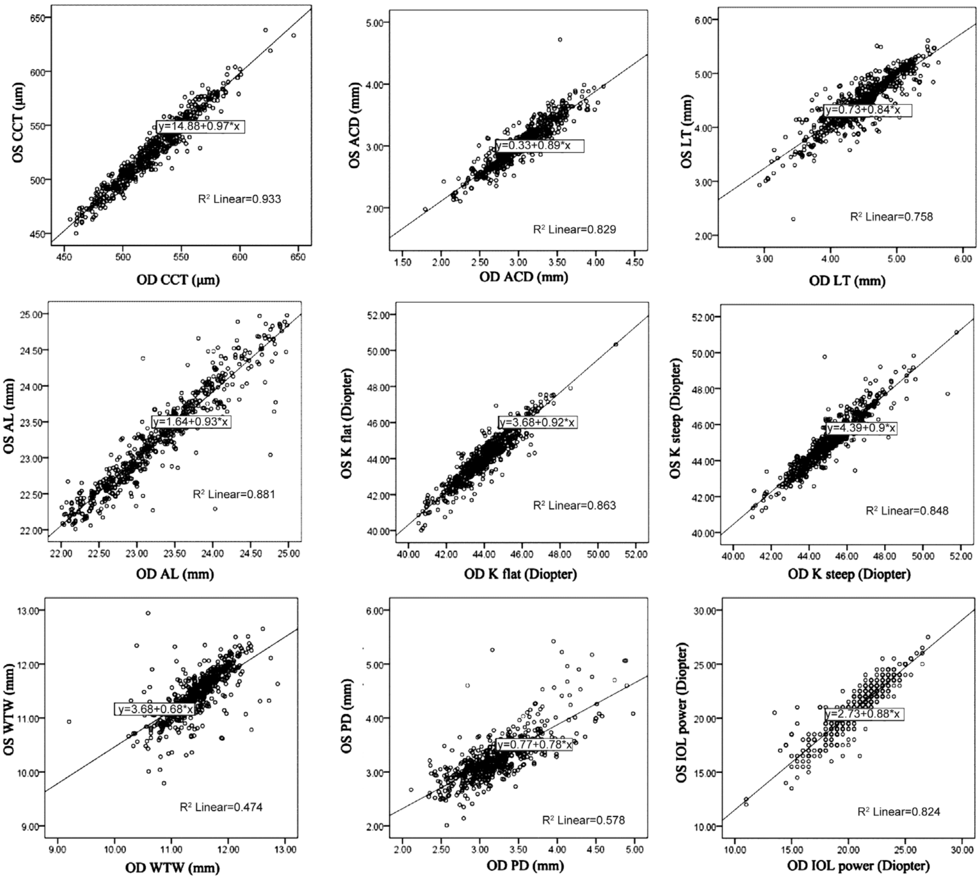

Figure 4 Scatterplots demonstrate the correlation between the CCT, ACD, LT, AL, Kflat, Ksteep, WTW, PD, and IOL power for the binocular parameters in group B The regression equation is demonstrated in the rectangular box (x represents right eye; y represents left eye). CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens.

Table 1 The difference and correlation between binocular data of short AL eyes mean±SD (range)

Parameters	OD (*n*=50)	OS (*n*=50)	OD-OS	*P*	Correlation (*P*)
CCT (μm)	514.0±32.0 (448.0-581.0)	517.0±34.0 (442.0-584.0)	-2.0±8.0	0.044	0.974 (<0.001)
ACD (mm)	2.67±0.30 (2.14-3.27)	2.65±0.30 (2.10-3.35)	0.02±0.13	0.335	0.901 (<0.001)
LT (mm)	4.54±0.51 (3.11-5.65)	4.57±0.50 (3.13-5.54)	-0.02±0.20	0.419	0.922 (<0.001)
AL (mm)	21.50±0.46 (19.59-21.97)	21.50±0.44 (19.59-21.99)	0.00±0.22	0.893	0.880 (<0.001)
Kflat (D)	45.86±1.47 (43.6-49.96)	45.82±1.60 (42.27-49.68)	0.04±0.68	0.702	0.904 (<0.001)
Ksteep (D)	46.96±1.80 (44.06-53.81)	46.94±1.57 (44.81-51.89)	0.02±0.72	0.837	0.919 (<0.001)
Kmean (D)	46.41±1.58 (43.89-51.89)	46.38±1.53 (43.54-50.79)	0.03±0.50	0.680	0.950 (<0.001)
WTW (mm)	11.04±0.51 (9.79-12.51)	11.08±0.42 (10.07-12.02)	-0.04±0.44	0.567	0.566 (<0.001)
PD (mm)	3.21±0.60 (2.45-5.66)	3.17±0.49 (2.14-4.94)	0.03±0.37	0.548	0.785 (<0.001)
IOL power (D)	25.55±2.85 (19-38)	25.59±2.77 (20-37.5)	-0.04±1.15	0.806	0.917 (<0.001)

CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; Kmean: Mean keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens; OD: Right eye; OS: Left eye; SD: Standard deviation.

Table 2 The difference and correlation between binocular data of normal AL eyes mean±SD (range)

Parameters	OD (*n*=496)	OS (*n*=496)	OD-OS	*P*	Correlation (*P*)
CCT (μm)	526.0±32.0 (455.0-646.0)	527.0±32.0 (450.0-638.0)	-0.5±8.0	0.198	0.966 (<0.001)
ACD (mm)	3.04±0.37 (1.80-4.10)	3.03±0.37 (1.98-4.72)	0.01±0.16	0.467	0.911 (<0.001)
LT (mm)	4.47±0.50 (2.93-5.63)	4.47±0.48 (2.30-5.61)	0.00±0.25	0.770	0.871 (<0.001)
AL (mm)	23.31±0.71 (22.01-24.98)	23.27±0.71 (22.01-24.98)	0.04±0.25	0.002	0.938 (<0.001)
Kflat (D)	44.09±1.43 (40.53-50.94)	44.08±1.41 (40.02-50.33)	0.01±0.54	0.741	0.929 (<0.001)
Ksteep (D)	45.10±1.55 (41.01-51.77)	45.06±1.52 (40.86-51.13)	0.04±0.61	0.118	0.921 (<0.001)
Kmean (D)	44.59±1.45 (40.77-51.36)	44.57±1.42 (40.62-50.73)	0.03±0.48	0.238	0.944 (<0.001)
WTW (mm)	11.46±0.44 (9.20-12.87)	11.45±0.44 (9.79-12.94)	0.01±0.35	0.745	0.688 (<0.001)
PD (mm)	3.23±0.46 (2.11-4.98)	3.27±0.47 (2.01-5.42)	-0.05±0.32	0.001	0.760 (<0.001)
IOL power (D)	20.96±2.39 (11.0-27.0)	21.14±2.31 (12-27.5)	-0.18±1.01	<0.001	0.908 (<0.001)

CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; Kmean: Mean keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens; OD: Right eye; OS: Left eye; SD: Standard deviation.

Table 3 The difference and correlation between binocular data of long AL eyes mean±SD (range)

Parameters	OD (*n*=170)	OS (*n*=170)	OD-OS	*P*	Correlation (*P*)
CCT (μm)	529.0±32.0 (439.0-601.0)	530.0±33.0 (425.0-606.0)	-0.68±12.0	0.476	0.928 (<0.001)
ACD (mm)	3.53±0.36 (2.52-4.69)	3.53±0.37 (2.54-5.20)	0.01±0.18	0.703	0.878 (<0.001)
LT (mm)	4.14±0.49 (3.13-5.50)	4.17±0.50 (3.12-5.41)	-0.04±0.24	0.058	0.878 (<0.001)
AL (mm)	27.52±1.88 (25.04-32.22)	27.43±1.80 (25.01-32.25)	0.09±0.87	0.180	0.889 (<0.001)
Kflat (D)	43.53±1.82 (38.21-48.02)	43.60±1.77 (38.71-48.29)	-0.07±0.58	0.127	0.948 (<0.001)
Ksteep (D)	44.94±1.81 (39.80-49.82)	44.94±1.91 (39.38-49.84)	0.01±0.63	0.880	0.944 (<0.001)
Kmean (D)	44.24±1.77 (39.01-48.92)	44.27±1.80 (39.05-49.07)	-0.03±0.46	0.393	0.966 (<0.001)
WTW (mm)	11.67±0.55 (9.71-12.96)	11.69±0.53 (9.92-13.05)	-0.02±0.31	0.481	0.830 (<0.001)
PD (mm)	3.52±0.55 (2.27-5.68)	3.54±0.56 (2.23-5.72)	-0.02±0.46	0.508	0.665 (<0.001)
IOL power (D)	8.74±5.53 (-4.5 to 19.5)	8.92±5.55 (-4.0 to 20.5)	-0.18±2.27	0.304	0.916 (<0.001)

CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; Kmean: Mean keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens; OD: Right eye; OS: Left eye; SD: Standard deviation.

0.665 to 0.948 (all P<0.001; Table 3, Figure 5). Moreover, Bland-Altman plots also demonstrated good agreement for all the nine binocular parameters (Figure 6).

Although significant difference in the binocular IOL power was only found in group B, we attempted to find the absolute difference distribution with ±0.5 D and found that only 31

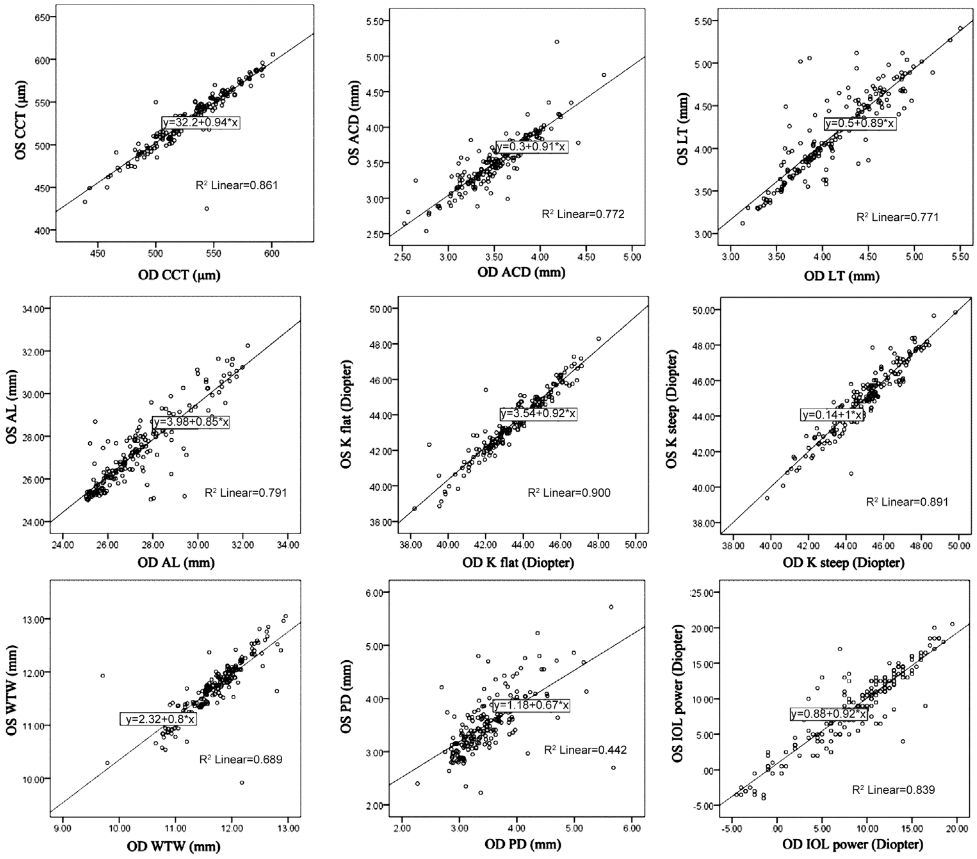

Figure 5 Scatterplots demonstrate the correlation between the CCT, ACD, LT, AL, Kflat, Ksteep, WTW, PD, and IOL power for the binocular parameters in group C The regression equation is demonstrated in the rectangular box (x represents right eye; y represents left eye). CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens.

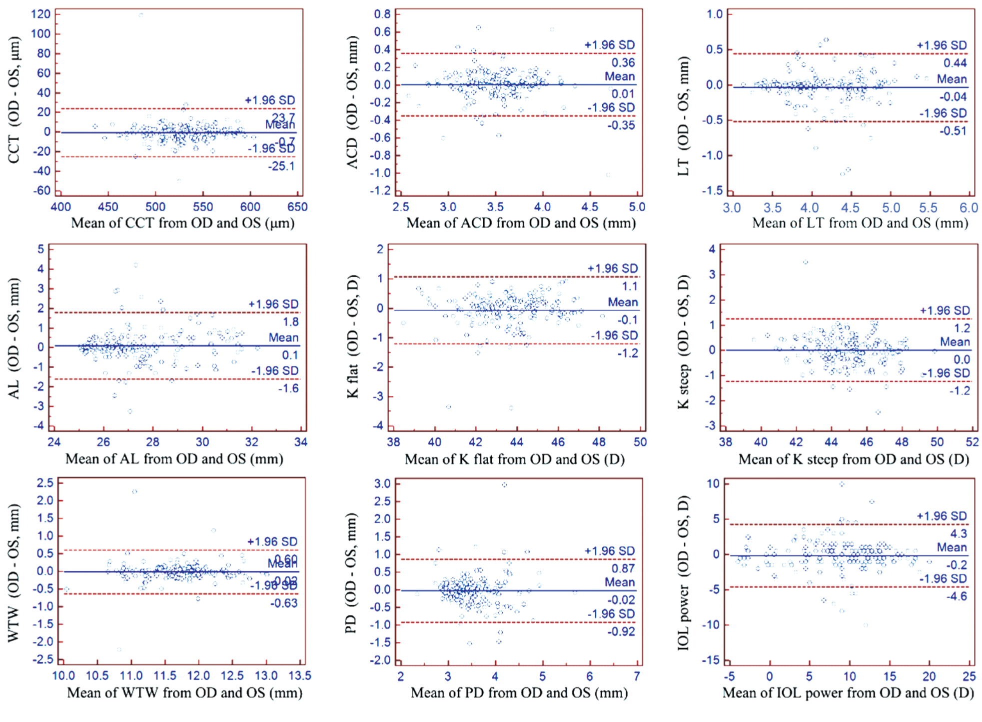

Figure 6 The Bland-Altman plots of CCT, ACD, LT, AL, Kflat, Ksteep, WTW, PD, and IOL power between right and left eyes in group C The mean difference is demonstrated by the continuous line, whereas the 95% limits of agreement are indicated by the dashed lines. CCT: Central corneal thickness; ACD: Anterior chamber depth; LT: Lens thickness; AL: Axial length; Kflat: Flat keratometry; Ksteep: Steep keratometry; WTW: White-to-white distance; PD: Pupil diameter; IOL: Intraocular lens.

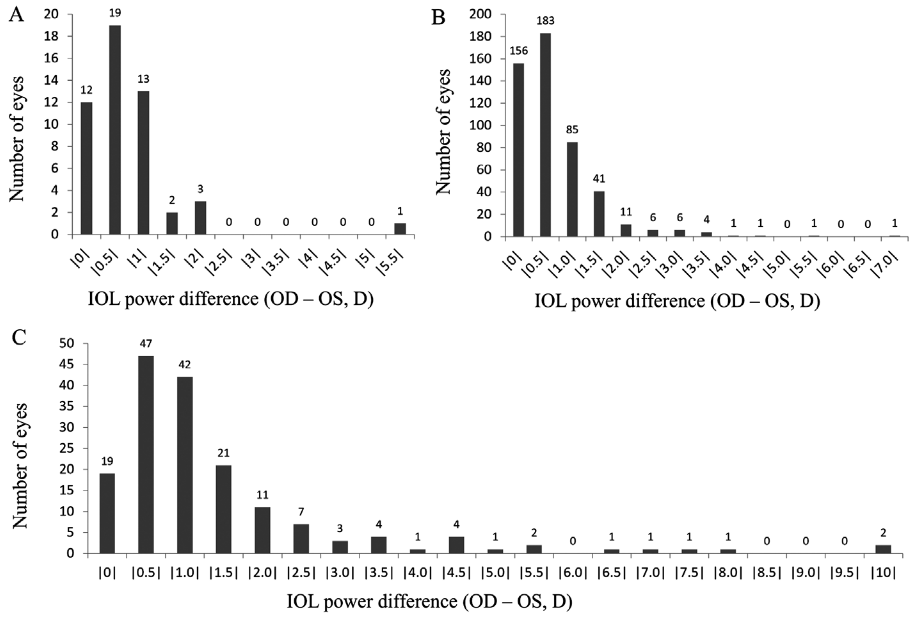

Figure 7 Number of participants of binocular intraocular lens power difference range (absolute value from 0 to 10 D) in groups A, B, and C IOL: Intraocular lens; OD: Right eye; OS: Left eye.

(62%), 339 (68.3%), and 66 (38.8%) participants' binocular IOL power within ±0.5 D in groups A, B, and C, respectively (Figure 7).

DISCUSSION

In the clinic, we always attempt to check the fellow eyes' data when the precision of the first eye biometry values is uncertain, or we cannot obtain the first eyes' measurement values. Moreover, double-checking measured binocular values for cases that difference of AL>0.3 mm, average K>1.0 D, or IOL power >1.0 D for both eyes has been suggested[7,17]. In our study, the major findings were significant correlations exist for the measured binocular parameters in eyes with short, normal, and long axial lengths; a high percentage of binocular IOL power difference ≥1.0 D absolute value, especially in the long axial length group.

Our results demonstrated good binocular correlations for average K and AL in all three groups (group A R^2=0.903, 0.774; group B R^2=0.891, 0.881; group C R^2=0.933, 0.791). The results were comparable with previous three studies on binocular AL and K readings' correlations (de Bernardo *et al*'s[1] study: K readings R^2=0.87, AL R^2=0.80; Covert *et al*'s[5] study: K readings R^2=0.96, AL R^2=0.88; Jabbour *et al*'s[6] study: K readings R^2=0.941, AL R^2=0.941). We should notice that different devices and different sample sizes were used to evaluate the AL and K readings in each study. Covert *et al*[5] and de Bernardo *et al*[1] both used IOLMaster 500; however, the sample size was 206 and 2258 participants, respectively. Jabbour *et al*[6] used an ultrasonic biometer and two calibrated keratometers to measure the AL and corneal power; the sample size was only 121 participants.

Our results also found that good binocular correlation exists for ACD, LT, flat K, steep K, and IOL power (*r* values from 0.871 to 0.974). However, WTW and PD showed relatively lower correlation coefficient values (*r* values from 0.566 to 0.830) in each group. The possible reason could be owing to the difficulties in detecting the gray transition between the cornea and sclera in automated methods, and horizontal WTW could significantly vary even while using automated devices[18-19]; the potential different extent of binocular pupil dynamic contraction during pupil image capturing even in the same illumination condition[20].

Based on de Bernardo *et al*'s[1] study, interocular AL difference ≥0.4 mm or average K difference ≥1.0 D resulted in approximately 1.0 D difference in the IOL power. Our results demonstrated that 1 (2%), 39 (7.8%), and 80 (47.1%) participants showed more than 0.4 mm AL difference in groups A, B, and C, respectively. For average K, 9 (5.3%) participants showed more than 1.0 D difference in group C, but not in group A and B. The higher percentage and case numbers in the long axial length group could indicate that more eye disorders such as anisometropia or amblyopia were prevalent in this group[21].

We used Barrett formula to test the combined effect of input parameters (including AL, ACD, flat K, steep K, LT, and WTW) for binocular IOL power difference. We found that about 19 (38%), 157 (31.7%), 104 (61.2%) participants' binocular IOL power difference was ≥1.0 D in groups A, B, and C, respectively. There was a wide range of IOL power absolute value differences for groups A (0-5.5 D), B (0-7.0 D), and C (0-10.0 D). This finding demonstrated that using biometric values from the fellow eye does not work efficiently to improve the prediction of the second eye, especially for cases of long AL[1].

The higher percentage values also emphasize that the surgeon should consider the combined effect of all related parameters but not only AL, or K values difference when performing IOL power comparison.

Certain limitations of this study should be noted. First, the sample size of the short axial length and the long axial length group was less and should be increased in future studies. Second, participants with anisometropia or amblyopia were not excluded, which could have influenced the correlation values. Moreover, we believe that the inclusion of the participants with anisometropia or amblyopia could better reflect the clinical reality and avoid the introduction of bias.

In conclusion, significant correlations exist for binocular parameters. However, the higher percentage of binocular IOL power difference which was ≥1.0 D should be noted in clinics, especially for AL longer than 25.0 mm.

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