• **Clinical Research** •

# Agreement of corneal curvature and central corneal thickness obtained from a swept-source OCT and Pentacam in ectopia lentis patients

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Received: 2020-02-11 Accepted: 2020-06-04

## Abstract

● **AIM:** To assess the inter-device consistency of corneal curvature and central corneal thickness between Pentacam and a swept-source Fourier-domain anterior segment optical coherence tomography (AS-OCT) in ectopia lentis patients.

● **METHODS:** Totally 72 eyes of ectopia lentis patients were recruited. Central corneal thickness (CCT), corneal curvature values and corneal astigmatism were obtained from both the Pentacam and AS-OCT (CASIA2). Repeatability was evaluated for both devices. The coefficient of repeatability (COR) and the relative COR was calculated. Bland-Altman plots were conducted to evaluate the inter-device agreement of measurement. Orthogonal linear regression was used to examine any proportional bias.

● **RESULTS:** The mean difference of CCT, steep anterior corneal curvature (anterior $K_S$), flat anterior corneal curvature (anterior $K_f$), anterior corneal astigmatism (ACA), steep posterior corneal curvature (posterior $K_S$), flat posterior corneal curvature (posterior $K_f$), posterior corneal astigmatism (PCA), steep true net power (TNP $K_S$), flat true net power (TNP $K_f$) and total corneal astigmatism (TCA) between Pentacam and CASIA2 were 7.03±9.70 μm, -0.19±0.41 D, -0.27±0.35 D, 0.04±0.47 D, -0.17±0.23 D, -0.11±0.11 D, -0.02±1.02 D -0.41±0.43 D, -0.52±0.46 D, and -0.15±0.96 D, respectively. For measurement of TNP $K_f$ with the Pentacam and CASIA2, a mean difference of 0.52 D and COR of 0.90 with $P$=0.02 was detected. There was no significant difference in CCT ($P$=0.393), anterior $K_f$ ($P$=0.107), anterior Ks ($P$=0.414), ACA ($P$=0.131), posterior $K_f$ ($P$=0.286), posterior $K_s$ ($P$=0.418), PCA ($P$=0.105), TNP $K_s$ ($P$=0.054), and TCA ($P$=0.977) between Pentacam and CASIA2.

● **CONCLUSION:** Our study reveals good agreement of CCT, corneal curvature and corneal astigmatism measured by CASIA2 and Pentacam in ectopia lentis patients. However, there was significant difference for CCT and corneal curvature values obtained by the two devices.

● **KEYWORDS:** corneal curvature; Pentacam; swept-source Fourier-domain anterior segment optical coherence tomography; ectopia lentis

**DOI:10.18240/ijo.2020.08.10**

**Citation:** Jin GM, Xiao B, Zhou YJ, Wang YY, Li XP, Zheng DY. Agreement of corneal curvature and central corneal thickness obtained from a swept-source OCT and Pentacam in ectopia lentis patients. *Int J Ophthalmol* 2020;13(8):1244-1249

## INTRODUCTION

The proportion of optical power in cornea accounts for approximately two-thirds of total eye; hence, the precise assessment of corneal thickness, corneal curvature and corneal astigmatism prior to cataract surgery and refractive surgery is important for achieving optimal refractive outcomes[1-3]. Corneal curvature, including anterior corneal curvature, posterior corneal curvature, and true net power (TNP) represents the sum of the anterior and posterior corneal powers. According to a recent study, corneal curvature is vital not only for corneal refractive surgery or intraocular lens power calculation before cataract surgery but also for the diagnose of Marfan syndrome (MFS)[4]. Individuals with MFS usually present with severe tissue weakness, especially in the aorta, heart, skeleton and eyes[5-6]. Considering that ectopia lentis is the most easily found clinical sign of MFS and delayed diagnosis may lead to serious consequences, early diagnosis is especially important for ophthalmologists. Although MFS has been the most common cause of ectopia lentis, it's difficult for ophthalmologists to make a diagnosis because of the complex diagnostic criteria[7]. Recently, Chen *et al*[4] reported that patients with MFS have decreased central corneal thickness

(CCT) and decreased corneal curvature and they suggested that corneal curvature could be a promising index for the diagnosis of MFS, which implies the importance of CCT and corneal curvature.

Corneal thickess, corneal curvature and corneal astigmatism can be measured by many devices, such as the Pentacam. The Pentacam (Pentacam AXL, Oculus, Wetzlar, Germany) which uses a rotating Scheimpflug high-resolution camera to provide cross-sectional scans of images that assess corneal parameters has been widely used in clinical and its accuracy has been verified[8-12].

At present, a new anterior segment optical coherence tomography (AS-OCT; CASIA2, Tomey Corporation, Nagoya, Japan) has been used in anterior segment biometric measurement and may also provide values of CCT, corneal curvature values and corneal astigmatism[13]. CASIA2 has documented specifics that include a faster scanning speed of 50 000 A-scans per second and advanced imaging with 13 mm depth and 16 mm width. The device uses a 1310 nm wavelength light and can produce 128 cross-sectional images that are evenly spaced 1.4 degrees apart. Due to its wide scanning range and deep scanning depth, the CASIA2 can scan the whole locality of the crystalline lens. The CASIA2 can be used to assess the decentration and tilt of the intraocular lens and the crystalline lens[14], and it is of great value for evaluating lens dislocation.

Although both the Pentacam and CASIA2 are specifically designed for measuring CCT, corneal curvature and corneal astigmatism, there is some distinction due to the differences in machine technology[13,15-16]. To date, little is known about the accuracy of corneal curvature obtained by the CASIA2, especially in ectopia lentis patients. Thus, we tried to assess the agreement of the corneal biometric values between the Pentacam and CASIA2 in ectopia lentis subjects.

## SUBJECTS AND METHODS

**Ethical Approval** This research was conducted adhere to the Declaration of Helsinki. Written informed consent was obtained from each subject and patient data were obtained anonymously.

**Subjects** A total of 72 eyes from ectopia lentis patients (aged 16.6±9.14y) from the Zhongshan Ophthalmic Center, Sun Yat-sen University were recruited from January 2018 to April 2019. Inclusion criteria were as follows: 1) diagnosed with ectopia lentis and without corneal diseases; 2) without a history of wearing contact lens; 3) had no previous history of ocular surgery; 5) without symptoms of dry eye. Exclusion criteria were as follows: 1) had ocular trauma history, 2) had history of corneal diseases.

**Measurement** Each subject was measured with the Pentacam and CASIA2 by the same experienced operator. Each eye was measured twice using both Pentacam and CASIA2 with an interval of 30min between different measurements. CCT, anterior corneal astigmatism (ACA), steep anterior corneal curvature (anterior $K_s$), flat anterior corneal curvature (anterior $K_f$), steep posterior corneal curvature (posterior $K_s$), flat posterior corneal curvature (posterior $K_f$), posterior corneal astigmatism (PCA), steep true net power (TNP $K_s$), flat true net power (TNP $K_f$) and total corneal astigmatism (TCA) were obtained both from Pentacam and CASIA2.

**Pentacam** Slit images of the anterior segment with a Scheimpflug high-resolution camera using the Pentacam were obtained for all subjects. According to the manufacturer's instructions, measurements were performed with subjects under nonmydriatic conditions in a sitting position looking at the fixation target. If the output readings were not "OK", the scans were repeated until the device issued a quality image. The Pentacam acquires 50 front and back corneal surface images by rotating 360° within 2s under a monochromatic slit light source with a wavelength of 475 nm. For this study, CCT, anterior $K_s$, anterior $K_f$, ACA, posterior $K_s$, posterior $K_f$, PCA, TNP $K_s$, TNP $K_f$ and TCA were acquired by the Pentacam immediately. The principle of TNP from the Pentacam system used in this study was identical to the conventional method. This value was calculated by the formula as follows: $TNP=(1.376-1)\times1000/r_{anterior\ surface}+(1.336-1.376)\times1000/r_{posterior\ surface}$. TNP represents the sum of the anterior and posterior corneal powers[17]. The TNP $K_f$ and TNP $K_s$ represent the total corneal keratometry readings at the flattest and steepest meridians.

**CASIA2** CASIA2 (Tomey Corporation, Nagoya, Japan) has an auto alignment function and assesses the value quality of the operator during the acquisition. After 5min of adaptation in dark room, all subjects were measured under nonmydriatic conditions. The CASIA2 used a 1310 nm swept-source laser wavelength at a frequency of 0.3s, producing 128 cross-sectional images that were evenly spaced 1.4 degrees apart. CCT, anterior $K_s$, anterior $K_f$, ACA, posterior $K_s$, posterior $K_f$, PCA, TNP $K_s$, TNP $K_f$ and TCA were also documented. For the CASIA2, TNP was calculated by formula as follows: $TNP=K_{anterior}+K_{posterior}-[d/(1.376\times10^6)]\times K_{anterior}\times K_{posterior}$, $K_{anterior}$ and $K_{posterior}$ indicates the refractive power of the anterior and posterior cornea, "d" indicates the cornea thickness (μm).

**Statistical Analyses** The Microsoft Excel randomization function was used for randomly selected measurement values from one eye for each normal subject. All statistical analysis was performed by Stata 14.0 (Stata Corp., College Station, TX, USA). The data obtained from both devices were listed as the mean and standard deviations (SD) for continuous variables. The difference between different measurements was examined by using Bland-Altman plots[18]. In addition, we described the variability of the measured values by calculating the coefficient of repeatability (COR=1.96-fold SD), relative COR

**Table 1 Comparison of CCT, corneal curvature and corneal astigmatism with pentacam and CASIA2**

| Variable | Pentacam | CASIA2 | Mean difference | *P* |
|---|---|---|---|---|
| CCT (μm) | 548.2±28.4 | 541.2±29.4 | 7.03±9.70 | <0.001 |
| Anterior $K_f$ (D) | 40.3±1.88 | 40.6±1.77 | -0.27±0.35 | <0.001 |
| Anterior $K_s$ (D) | 42.2±1.94 | 42.4±1.96 | -0.19±0.41 | 0.002 |
| ACA (D) | 1.93±1.12 | 1.89±1.04 | 0.04±0.47 | 0.429 |
| Posterior $K_f$ (D) | -5.79±0.32 | -5.68±0.28 | -0.11±0.11 | <0.001 |
| Posterior $K_s$ (D) | -6.15±0.41 | -5.98±0.38 | -0.17±0.23 | <0.001 |
| PCA (D) | 0.46±0.82 | 0.48±0.67 | -0.02±1.02 | 0.846 |
| TNP $K_f$ (D) | 39.1±1.83 | 39.6±1.71 | -0.52±0.46 | <0.001 |
| TNP $K_s$ (D) | 41.0±1.81 | 41.4±1.90 | -0.41±0.43 | <0.001 |
| TCA (D) | 1.61±1.00 | 1.76±1.07 | -0.15±0.96 | 0.188 |

CCT: Central corneal thickness; $K_s$: Steep corneal curvature; $K_f$: Flat corneal curvature; TCA: total corneal astigmatism; PCA: Posterior corneal astigmatism; ACA: Anterior corneal astigmatism; TNP: True net power.

**Table 2 Comparison of two measurements of CCT, corneal curvature and corneal astigmatism with Pentacam and CASIA2**

| Variable | COR | Relative COR, % | LLOA | ULOA | LOA range | $R^2$ | *P* |
|---|---|---|---|---|---|---|---|
| CCT (μm) | 19.0 | 0.04 | -12.0 | 26.0 | 38.0 | 0.010 | 0.393 |
| Anterior $K_f$ (D) | 0.69 | 0.02 | -0.96 | 0.43 | 1.39 | 0.037 | 0.107 |
| Anterior $K_s$ (D) | 0.80 | 0.02 | -1.00 | 0.61 | 1.61 | 0.010 | 0.414 |
| ACA (D) | 0.92 | 0.48 | -0.88 | 0.97 | 1.85 | 0.032 | 0.131 |
| Posterior $K_f$ (D) | 0.22 | -0.04 | -0.32 | 0.10 | 0.42 | 0.016 | 0.286 |
| Posterior $K_s$ (D) | 0.45 | -0.07 | -0.62 | 0.28 | 0.90 | 0.009 | 0.418 |
| PCA (D) | 2.00 | 4.25 | -2.02 | 1.98 | 4.00 | 0.037 | 0.105 |
| TNP $K_f$ (D) | 0.90 | 0.02 | -1.43 | 0.38 | 1.81 | 0.075 | 0.020 |
| TNP $K_s$ (D) | 0.84 | 0.02 | -1.24 | 0.43 | 1.67 | 0.052 | 0.054 |
| TCA (D) | 1.88 | 1.12 | -2.03 | 1.73 | 3.76 | 0.008 | 0.977 |

COR: Coefficient of repeatability; ULOA: Upper limit of agreement; LLOA: Lower limit of agreement; CCT: Central corneal thickness; $K_s$: Steep corneal curvature; $K_f$: Flat corneal curvature; PCA: Posterior corneal astigmatism; ACA: Anterior corneal astigmatism; TNP: True net power; TCA: Total corneal astigmatism.

(rCOR=COR/average measurement) and limits of agreement (LOA=mean±COR). The magnitude of these limits with lower values suggest better agreement between the two devices[16]. *P*<0.05 was considered statistically significant.

## RESULTS

Table 1 shows the values and the mean differences of CCT, anterior $K_s$, anterior $K_f$, ACA, posterior $K_s$, posterior $K_f$, PCA, TNP $K_s$, TNP $K_f$, and TCA measured by the Pentacam and CASIA2. There are significant differences in CCT and each of the corneal curvatures between the two different devices.

Table 2 shows the COR, relative COR, the lower and upper LOA for CCT, anterior curvature of cornea, ACA, posterior curvature of cornea, PCA, TNP $K_s$, TNP $K_f$ and TCA for measurements with the CASIA2 and Pentacam.

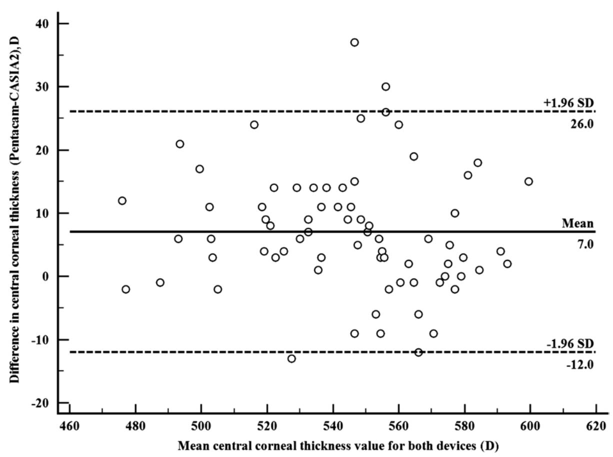

**Figure 1 Bland-Altman plot of CCT with Pentacam and CASIA2.**

The Bland-Altman analysis of CCT, steep corneal curvature, flat corneal curvature and corneal astigmatism measurements with the Pentacam and CASIA2 are shown in Figures 1-4. The Bland-Altman plot of TNP $K_f$ showed a mean difference of 0.52 D for the two devices. Although this difference was very small for clinical significance, the value of TNP $K_f$ obtained from Pentacam and CASIA2 was statistically significant. Further, the measurements indicated a COR of 0.90, relative COR of 0.02, lower limit of agreement of -1.43 and upper limit of agreement of 0.38 with *P*=0.02 (Figure 2).

There was no significant difference in CCT (*P*=0.393), anterior $K_s$ (*P*=0.414), anterior $K_f$ (*P*=0.107), ACA (*P*=0.131), posterior

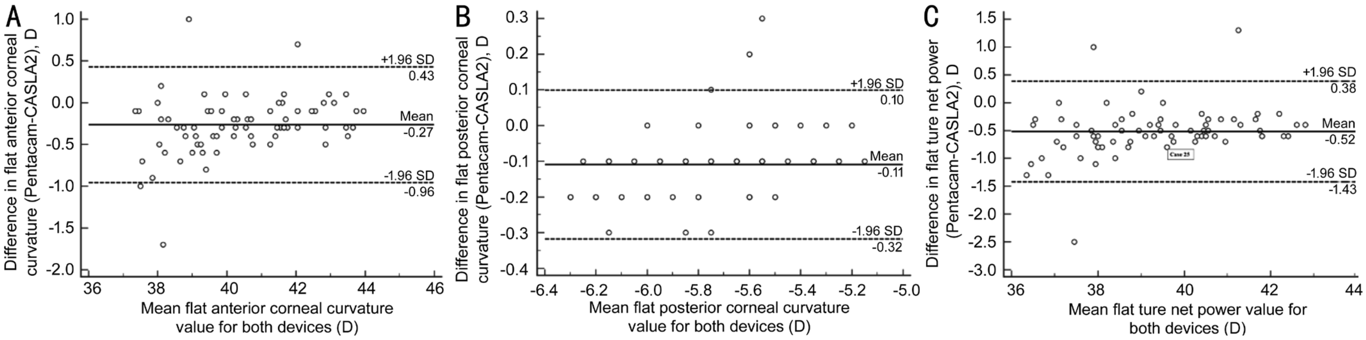


**Figure 2 Bland-Altman plot of flat anterior corneal curvature (A), flat posterior corneal curvature (B) and flat true net power (C) with Pentacam and CASIA2.**

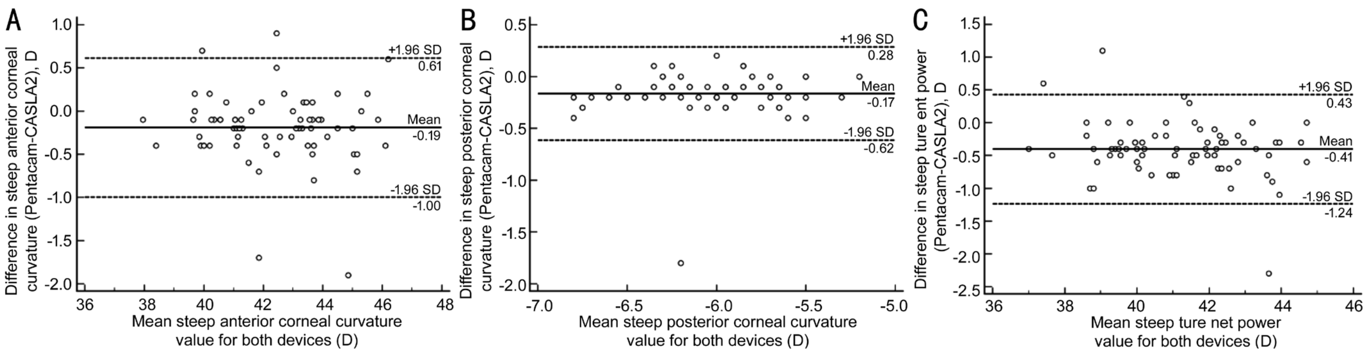


**Figure 3 Bland-Altman plot of steep anterior corneal curvature (A), steep posterior corneal curvature (B) and steep true net power (C) with Pentacam and CASIA2.**

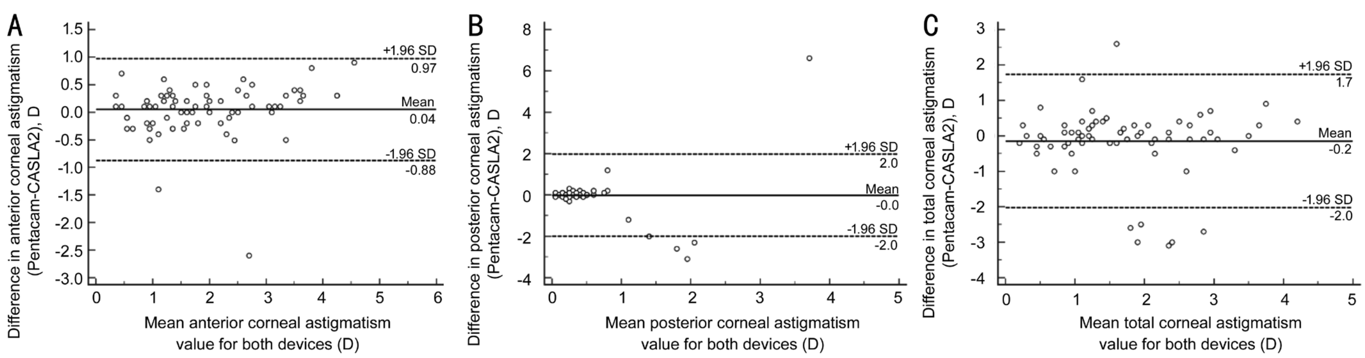


**Figure 4 Bland-Altman plot of anterior corneal astigmatism (A), posterior corneal astigmatism (B) and total corneal astigmatism (C) with Pentacam and CASIA2.**

$K_s$ ($P$=0.418), posterior $K_f$ ($P$=0.286), PCA ($P$=0.105), TNP $K_s$ ($P$=0.054) and TCA ($P$=0.977) between CASIA2 and Pentacam.

## DISCUSSION

Corneal thickness, corneal curvature and corneal astigmatism are of great importance not only for diagnosing corneal diseases but also for cataract or refractive surgery. Moreover, corneal curvature has been suggested as a potential index for diagnosis of MFS through ectopia lentis[4]. In this study, we assessed the agreement of corneal thickness, corneal curvature and corneal astigmatism values in ectopia lentis patients obtained from the Pentacam and CASIA2, and we found favorable LOA. Additionally, no significant difference was found when comparing the agreement of Pentacam and CASIA2 in terms of CCT, anterior $K_s$, anterior $K_f$, ACA, posterior $K_f$, posterior Ks, PCA, TNP $K_s$ and TCA.

We found that TNP $K_f$ had significant discrepancies between the Pentacam and CASIA2. There were several possible explanations. First, there are differences in image acquisition techniques, including image resolution, scanning rate and different acquisition speed. For the Pentacam, the three-dimensional images of the anterior segment comprised 138 000 data points that were recorded by a 1.45-megapixel camera. Then, keratometry could be calculated. One major feature of the Pentacam is that its rotation measurement can obtain more data in the center of the cornea, making the measurements more effective. For the CASIA2, a wavelength of 1310 nm was used which largely enhancing high intensity illumination and increasing penetration of opaque tissue. It could not only provide panoramic scanning of the lens but also multiple corneal curvatures, such as anterior, posterior and true net power corneal curvatures. Second, the two devices utilized different axes for centering the scan. The CASIA2 automatically aligns the scan by finding the vertex of the cornea and captures all meridional scans with the vertex as the center. The differences in capture alignment could certainly have influenced the results. Third, when calculating TNP, the corneal thickness was not taken into account by the Pentacam, while corneal thickness was considered by the CASIA2. In addition, the refractive index of the cornea used by the two devices was different. Forhth, for Pentacam, TNP was calculated by using the ray-tracing method that propagates the parallel rays and uses the Snell law to reflect them through the front and back surfaces of cornea. However, the anterior imaging devices cannot accurately measure the posterior corneal curvature compared with the anterior surface, for the posterior edge of cornea is difficult to be detected and defined accurately[19]. Lastly, the software used to calculate the parameters maybe another factor that influenced the values obtained.

High repeatability and accuracy for corneal curvature measurements by using Pentacam has been reported in previous studies[20-22]. Viswanathan *et al*[12] compared corneal curvature values between Atlas corneal topographer and the Pentacam, and they found that the results obtained by the Pentacam were significantly better than those obtained by the Atlas. However, for CASIA2, a new AS-OCT which showed optimizing image quality of the structure of the anterior segment, although there are several studies have shown good reproducibility in measuring the parameters of the anterior segment[23-24], little is known about the measurement accuracy of corneal parameters by this device especially for special patients such as ectopia lentis patients.

Bland-Altman analysis of TNP $K_f$ between the two devices showed a statistically significant difference, although this difference is very small. This discrepancy has clinical significance because the corneal curvature is one of the main parameters widely used to detect and monitor disease progression, such as keratoconus[25]. Misestimates of corneal curvature may falsely offer reassurance to surgeons, especially for intraocular lens power calculations or for refractive surgery. For ectopia lentis, ophthalmologists may miss the opportunity to diagnose MFS in clinical settings due to misestimates of corneal curvature, as corneal curvature has been suggested as a potential diagnostic tool for MFS[4]. In general, greater LOA usually mean that devices vary significantly in the measurement and thus the values can't be used interchangeable. Ophthalmologists should be careful when using the measurement results of ectopia lentis patients from the two devices interchangeably.

Our study has several limitations. Although ectopia lentis is a rare disease and we have tried our best to include more patients, the study sample size was relatively small. Additionally, our findings are focused on ectopia lentis patients, which limits the generalization of the results to a certain degree.

In conclusion, the corneal parameters measured by Pentacam and the CASIA2 in ectopia lentis patients have generally good agreement. However, there were significant differences for CCT and all corneal curvature values. Among these parameters, the CASIA2 tends to give higher values for corneal curvature. Considering the great importance of corneal curvature for ectopia lentis patients, it is not recommended that the measurement values be used interchangeably across the devices in ectopia lentis patients.

## ACKNOWLEDGEMENTS

Designed the study, initiated the collaborative project, revised the paper: Jin GM and Zheng DY; Monitored data collection, wrote the statistical analysis plan and drafted the paper: Xiao B and Zhou YJ; Cleaned and analysed the data: Xiao B, Wang YY, and Li XP; Administrative, technical or logistic support: Jin GM and Zheng DY.

**Foundations:** Supported by National Natural Science Foundation of China (No.81873673; No.81900841); the Fundamental Research Funds of the State Key Laboratory of Ophthalmology (No.30306020240020212); the Young Teachers Training Program of Sun Yat-sen University (No.20ykpy143).

**Conflicts of Interest: Jin GM,** None; **Xiao B,** None; **Zhou YJ,** None; **Wang YY,** None; **Li XP,** None; **Zheng DY,** None.

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