

Comparison of the biometric measurements obtained using the Lenstar, Pentacam and ultrasound pachymetry methods in cataract patients

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Lenstar 及 Pentacam 与 A 超测量白内障患者眼生物参数的比较

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摘要

目的: 比较光学相干生物测量仪(Lenstar)、三维眼前节分析仪(Pentacam)和A型超声测量仪(A-scan)在白内障患者中测量角膜中央厚度、角膜曲率、前房深度和眼轴长度结果的差异。

方法: 分别用3种仪器对158例(158眼)白内障患者进行眼部生物测量, 比较角膜中央厚度、角膜曲率、前房深度和眼轴长度的结果, 采用重复测量的方差分析及Pearson相关分析, 一致性比较采用Bland-Altman统计分析法。

结果: Lenstar和Pentacam测得的角膜中央厚度分别为 $536.54 \pm 27.90 \mu\text{m}$ 和 $541.46 \pm 29.85 \mu\text{m}$, 两者差异有统计学意义($t = -5.439; P < 0.001$); K值分别为 $43.87 \pm 1.45\text{D}$ 和 $43.86 \pm 1.44\text{D}$, 两者差异无明显统计学意义($t = -0.348, P > 0.05$)。Pentacam、Lenstar和A超测量的前房深度分别是 $2.73 \pm 0.38\text{mm}$ 、 $2.71 \pm 0.38\text{mm}$ 和 $2.85 \pm 0.40\text{mm}$, 三者差异均有统计学意义($F = 309.94, P < 0.001$), Pearson相关分析显示三者呈正相关($r = 0.989, 0.978, \text{and } 0.977; P < 0.001$), 但变异系数较小($CV = 3.12\%$)。A超和Lenstar测量的眼轴长度分别是 $24.28 \pm 1.70\text{mm}$ 和 $24.52 \pm$

1.73mm , 两者差异有统计学意义($t = -19.482, P < 0.001, r = 0.996; P < 0.001$)。Bland-Altman分析显示, 对于这几种眼前节参数, 三种方法测量的一致性较好。

结论: 三种仪器测量的结果尽管有一定差异, 但Lenstar和Pentacam的生物测量可重复性好, 操作简便更易于白内障患者的检查。

关键词: 生物测量; Lenstar; Pentacam; A型超声; 一致性

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Abstract

• **AIM:** To compare the central corneal thickness (CCT), keratometry (K) reading, anterior chamber depth (ACD), and axial length (AL) measured with Lenstar and Pentacam with those obtained with the ultrasound (US) pachymetry in the cataract patients.

• **METHODS:** A total of 158 eyes of 158 patients were examined in this study. The CCT, average K, ACD and AL obtained by Lenstar and/or Pentacam were compared with those obtained from US pachymetry using repeated-measures analysis of variance, Pearson correlation coefficients and Bland-Altman analyses.

• **RESULTS:** The mean CCT obtained using Lenstar and Pentacam were $536.54 \pm 27.90 \mu\text{m}$ and $541.46 \pm 29.85 \mu\text{m}$ ($t = -5.439; P < 0.001$). The mean Km obtained using Lenstar and Pentacam methods were $43.87 \pm 1.45\text{D}$ and $43.86 \pm 1.44\text{D}$ ($t = -0.348, P > 0.05$). The mean ACD measured using the Pentacam, Lenstar, and US pachymetry were $2.73 \pm 0.38\text{mm}$, $2.71 \pm 0.38\text{mm}$, and $2.85 \pm 0.40\text{mm}$, respectively ($F = 309.94, P < 0.001$), and they were positively correlated ($r = 0.989, 0.978, \text{and } 0.977; P < 0.001$) and the coefficient of variation was small (3.12%). The mean AL obtained by US pachymetry and Lenstar were $24.28 \pm 1.70\text{mm}$ and $24.52 \pm 1.73\text{mm}$, respectively ($t = -19.482, P < 0.001, r = 0.996; P < 0.001$). The Bland-Altman analysis showed that the three methods were comparable for CCT, Km, ACD and AL.

• **CONCLUSION:** Although there were statistically significant differences, the measurements obtained by the Lenstar and the Pentacam were highly repeatable and the instruments easy to use.

• **KEYWORDS:** biometry; Lenstar; Pentacam; ultrasound pachymetry; agreement

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INTRODUCTION

Ocular biometry can be measured using a variety of techniques. Optical and ultrasonic pachymetry are the most widely used techniques, and are based on different physical principles. One common issue with new instrumentation or clinical tests is agreement with the existing instruments or test. In clinical applications requiring accurate and repeatable measurements of biometry, ultrasonic pachymetry is currently seen as the gold standard^[1-2]. However, ultrasound biometry is operator dependent, requires corneal contact, and the perpendicularity of the probe with respect to the cornea is often difficult to ascertain.

The Oculus Pentacam (Oculus, Germany) is a non-invasive anterior segment tomographer utilizing a rotating Scheimpflug camera. It is capable of imaging the cornea, the anterior chamber, and the lens, providing a plethora of measurements across the anterior segment.

The Lenstar (LS900, Switzerland) which uses optical low coherence reflectometry to provide more information on ocular biometry, such as corneal thickness (CCT), anterior chamber depth (ACD), axial length (AL), keratometry (K) readings, crystalline or intraocular lens thickness is also used clinically^[3-4].

Both devices use light instead of sound to perform ocular biometry and are non-contact systems. These features may lead to their widespread use. When different ways of measuring the same variable are available, it is of interest to ascertain how well they agree, as strong agreement implies that they can be used interchangeably.

The purpose of this study was to evaluate the agreement of ocular biometry with optical and ultrasonic pachymetry and to address these gaps by comparing the agreements among the three methods in terms of CCT, average K, ACD and AL using a coherent statistical approach.

SUBJECTS AND METHODS

The present study was performed at the Cataract Surgery Center of the New Vision Eye Hospital, Shanghai, China. We certify that the study was approved by our local Ethics Committee and was performed in accordance with the Declaration of Helsinki after all participants provided written informed consent. Initially, 175 cataract patients with varying degrees of cataract in both eyes were included. The patients underwent measurement of ocular biometry on a single day using the three methods; Pentacam (Oculus, Germany), Lenstar (LS900, Switzerland), and ultrasonic (US) pachymetry (SP-3000, Tomey, Japan). One eye from each patient was selected, randomizing between right and left eyes, and the data were collected from Jan. to May 2014. Measurements using the Lenstar methods were obtained in 158 of the 175 (90.3%) patients, whereas the Pentacam and US

pachymetry methods were performed in 168 (96%) and 172 (98.2%) of the 175 patients, respectively. Dense opacities and macular disease were the causes of measurement failure. Finally, a total of 158 eyes of 158 patients (63 males and 95 females), with a mean age of 72.6 (8.4) y (range from 52-91y) were included in this chart review. The mean spherical equivalent of the eyes was -3.45 ± 1.78 D (+3.00 to -10.50 D). All measurements on a given subject were performed during the same session by a single trained examiner. The order of measurement was: Pentacam; Lenstar; and US pachymetry (which was always performed last to avoid any influence of corneal flattening on the other two measurements). All patients were examined without dilation, in the dark.

For measurements using the Pentacam and the Lenstar methods, each subject sat in front of the machines with their chin on a chin rest and their forehead against a headband. During the examination, patients were asked to fixate on the light of the device and the instrument was focused using the image of the eye on the monitor. Patient blinking and loss of fixation were monitored and only non-contaminated measurements were used for the analysis. Before each measurement, patients were asked to perform a complete blink to obtain an optically smooth tear film over the cornea. The two devices were both operated in automatic mode to reduce operator subjectivity, requiring only one alignment, obtaining all measurements in a single take.

For measurements using the US pachymetry method, each subject lay supine after the cornea was anesthetized with 0.4% (w/v) oxybuprocaine hydrochloride. The subject was asked to look straight ahead and the probe was placed perpendicularly on the central corneal surface. Ten consecutive measurements were taken, and the means AL and ACD value were calculated automatically.

Statistical Analysis Data analyses were analyzed using Microsoft Excel 2003 (Microsoft Corp., WA, USA) and SPSS software (version 16.0, SPSS Inc., USA). For the CCT and mean K (Km) variable $(K1+K2)/2$, the Lenstar and the Pentacam methods were compared, while one comparison of AL between the US and the Lenstar was conducted. The paired *t*-test was used to determine whether the differences in means between data pairs were significant. The strength of association between data pairs was evaluated by calculation of Pearson's correlation coefficient. Correlation coefficients were also calculated. The ACD measurements using the three methods were compared using repeated-measures analysis of variance and the Scheffé multiple comparison. Agreement between the devices was evaluated using Bland-Altman analysis^[5]. The differences between measurements from each pair of instruments were plotted against the means. The 95% limits of agreement (LoA) was calculated using the mean difference ± 1.96 standard deviations (SD). Data were expressed as means \pm SD. A *P* value of less than 0.05 was considered to indicate statistical significance.

Table 1 Mean values obtained using the three instruments

Biometry	US pachymetry	Lenstar	Pentacam	P
CCT (μm)	-	536.54 \pm 27.90	541.46 \pm 29.85	<0.001
K(D)	-	43.86 \pm 1.44	43.87 \pm 1.45	>0.001
ACD (mm)	2.85 \pm 0.40	2.71 \pm 0.38	2.73 \pm 0.38	<0.001
AL (mm)	24.28 \pm 1.70	24.52 \pm 1.73	-	<0.001

The paired samples *t* test was used to obtain. *P* values and *P*<0.05 indicated significance. CCT: Central corneal thickness; K: Keratometry readings; ACD: Anterior chamber depth; AL: Axial length.

Table 2 Pearson's correlation coefficients(*r*) for the biometry obtained using the three methods

Biometry	Instru vs Instru	<i>r</i>	<i>P</i>	Precision	Repeatability	CV
CCT (μm)	Lenstar-Pentacam	0.925	<0.001	17.12	24.19	1.04%
K(D)	Lenstar-Pentacam	0.980	<0.001	0.39	0.56	0.30%
ACD (mm)	US-Lenstar	0.977	<0.001			
	US-Pentacam	0.978	<0.001	0.18	0.26	3.12%
	Lenstar-Pentacam	0.989	<0.001			
AL (mm)	US-Lenstar	0.996	<0.001	0.39	0.55	0.74%

The repeated-measures ANOVA and the Scheffé multiple comparison; *P*<0.05 was significant; CV: Coefficient of variance. CCT: Central corneal thickness; K: Keratometry readings; ACD: Anterior chamber depth; AL: Axial length.

RESULTS

For all five Bland-Altman plots (Figure 1 to 4), the 95% LoA (mean difference 1.96 SD), which defines the range that encompassed most differences between the measurements with the two methods, was calculated.

The CCT obtained using the Lenstar method tended to be smaller than that obtained using the Pentacam method (4.92 \pm 11.37 μm), with a 95% LoA ranging from -27.19 to 17.36 μm (Table 1; Figure 1).

The average K as assessed by the Lenstar method was similar to that with the Pentacam method (about 0.01 \pm 0.29), with a 95% LoA from -0.56 to 0.55 (Table 1; Figure 2).

The mean ACD values yielded by the Pentacam, the Lenstar, and the US pachymetry methods were 2.73 \pm 0.38, 2.71 \pm 0.38, and 2.85 \pm 0.40mm, respectively, and these differences were statistically significant (*F* = 309.941, *P* < 0.001) (Table 1). Significant linear correlations were evident between the US pachymetry and the Lenstar data (*r* = 0.977, *P* < 0.001), between the US pachymetry and the Pentacam data (*r* = 0.978, *P* < 0.001), and the Lenstar and the Pentacam data (*r* = 0.989, *P* < 0.001). The among-method coefficient of variance (CV) was small (3.12%) with little variation (Table 2). Bland-Altman analysis showed that all the ACD values obtained were in strong agreement. On average, the US pachymetry method gave a greater ACD (by 0.14 mm) compared with the Lenstar method, with a 95% LoA, ranging from -0.03 to 0.31 mm. The US pachymetry method also had a greater ACD (by 0.12 mm) compared with the Pentacam method, with a 95% LoA, ranging from -0.05 to 0.29 mm. The Lenstar method gave a lower ACD (by 0.02 mm) compared with the Pentacam method, with a 95% LoA, ranging from -0.13 to 0.09 mm (Figure 3). Nearly all the data lie within the 95% LoA and were evenly distributed, indicating that no relationship existed between the average ACD and any interdevice difference.

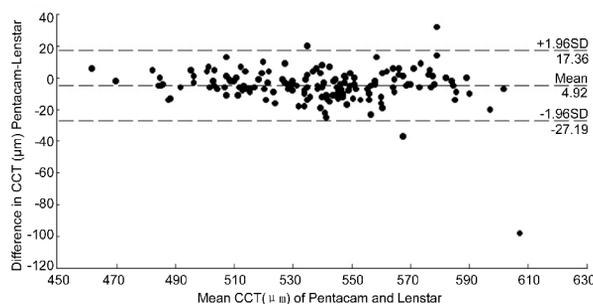


Figure 1 On average, the Lenstar method measured smaller CCT values compared with the Pentacam method by 4.92 μm , with a 95% LoA from -27.19 to 17.36 μm . Nearly all data lie within the 95% LoA and are evenly distributed, indicating no relationship between average CCT and interdevice difference.

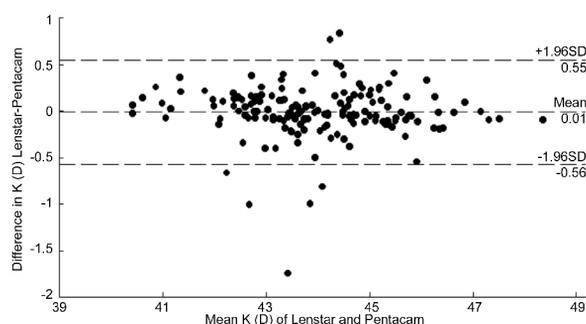


Figure 2 On average, the Lenstar method measured bigger K values compared with the Pentacam method by 0.01 D, with a 95% LoA from -0.56 to 0.55 D. Nearly all data lie within the 95% LoA and are evenly distributed, indicating no relationship between average K values and interdevice difference.

The mean difference \pm SD in AL between the US pachymetry and the Lenstar methods was 0.24 \pm 0.15 mm; the 95% LoA was moderate, ranging from -0.54 to 0.06 mm (Table 1; Figure 4). The Pearson's correlation coefficient test disclosed a statistically significant correlation (*P*<0.001) between the

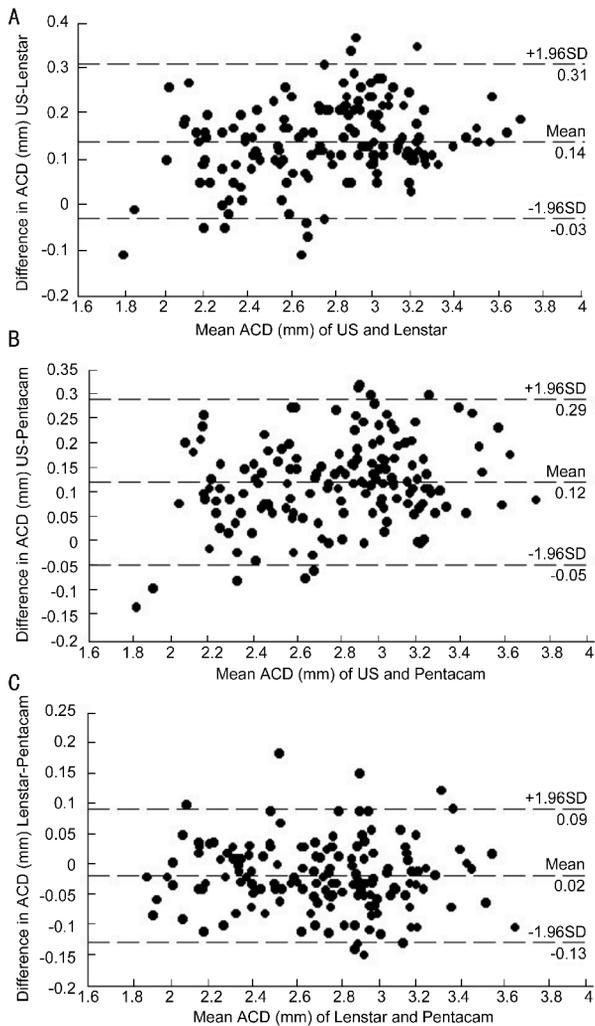


Figure 3 Bland-Altman plots of the differences between US and Lenstar of ACDs A: US and Pentacam; B: Lenstar and Pentacam; C: Measurements in the 175 cataract patients. It shows that all ACDs obtained with 3 devices were in good agreement (A: CoA 0.14 mm, LoA -0.03-0.31 mm; B: CoA 0.12 mm, LoA -0.05-0.29 mm; C: CoA 0.02 mm, LoA -0.13-0.09 mm). Nearly all data lie within the 95% LoA and were evenly distributed, indicating that no relationship existed between the average ACD and any interdevice difference.

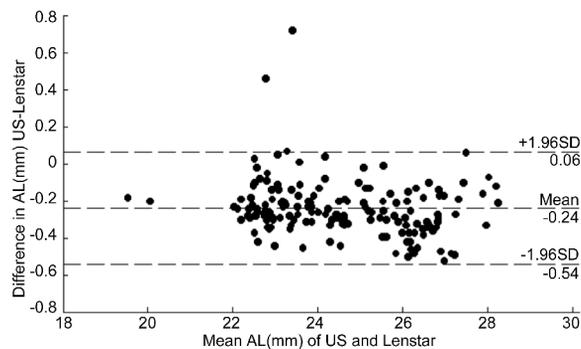


Figure 4 On average, the Lenstar method gave longer AL values than US pachymetry by 0.24 mm, with a 95% LoA from -0.54 to 0.06 mm. Nearly all data lie within the 95% LoA and are evenly distributed, indicating no relationship between average AL and interdevice difference.

US pachymetry and the Lenstar ($r = 0.996$). The among-method CV was small (0.74%); there was good precision

(0.39) and repeatability (0.55) in measuring the AL between the Lenstar and the US pachymetry methods (Table 2).

DISCUSSION

With the rapidly increasing popularity of corneal refractive surgery and the implantation of intraocular lenses, accurate measurement of ocular biometry has gained in importance. The CCT, K readings, ACD and AL are important factors contributing to the accuracy of the IOL power calculations and the safety of refractive surgery^[6-7]. In this study we compared the performance of three different biometry devices used in cataract patients to assess the interchangeability of these methods.

The US pachymetry method used in this report could not take measurements for CCT and K values. Therefore, we compared the Lenstar method with the Pentacam method for the CCT and K values. The mean±SDs of the CCT measurements obtained by these methods were 536.54 ± 27.90 and 541.46 ± 29.85 μm , respectively. The differences were statistically significant ($P < 0.001$), and were within clinically acceptable levels. Tai *et al*^[8] reported that Lenstar and Pentacam provide comparable results. Similar results between Lenstar and US were also reported^[9]. Our results demonstrated that the CCT measurements with Lenstar are comparable to and have good correlation with Pentacam, indicating that the two noncontact methods can be used interchangeably for CCT measurements. The optical method measures the thickness between the air-tear film interface and the posterior corneal surface, which include the tear film in CCT measurements, so the reproducibility in CCT measurements depends largely on fixation of the examinee and the condition of the dry eye. Differences in fixation lights and the manner in which measuring light beams move may affect the reproducibility of noncontact pachymetric measurements. Though good repeatability has been showed on Lenstar and Pentacam using a single examiner^[8], interobserver variability has not been addressed in this study, which still was a weakness. Furthermore, agreement with ultrasound was not performed, and therefore comments on accuracy of CCT data from the two devices can only be interpreted relative to each other.

The Km values obtained by the Pentacam and the Lenstar methods were similar, and no statistically significant difference was observed ($P > 0.05$). The Bland-Altman analysis showed that virtually all measurements from the Pentacam and Lenstar methods were within the 95% LoA range. Previous studies reported strong agreement between the Lenstar and the IOLMaster methods in average K^[10]. An exception is a recent study^[11] that reported less satisfactory average K agreement between the IOLMaster and the Lenstar methods; the mean difference being 0.67 D, with 95% LoA (0.07, 1.20). The poor precision found with front meridional and axial maps may be the main reason for small eye movements, where the repeated measure may not be an exact corresponding point on the anterior corneal surface. The second explanation is that the position of the pupil center changed between measurements. However, the good,

repeatable results with the Pentacam and Lenstar in present study may be due to improvements over the basic and classic model. The new model is capable of capturing more than five times the number of data points than the original model. In addition, the good fixation and rapid inspection also contributed to the repeatability in K readings with two devices.

For ACD measurements, earlier studies reported mixed results^[12-13]. Elbaz *et al*^[14] reported that ACD measurements obtained using the Pentacam method were significantly greater than those yielded by the IOLMaster or ultrasound. There was poor consistency in the among - method data and the two methods could not be used interchangeably. Reuland *et al*^[15] showed that the data from the Pentacam and IOLMaster methods were similar, and Németh *et al*^[16] considered these procedures comparable. Savini *et al*^[17] reported that the Pentacam and the US pachymetry ACD data were comparable, showing no significant difference, and could be used interchangeably.

In the present study, we found that the mean ACDs obtained using the US pachymetry, the Pentacam, and the Lenstar methods were 2.85 ± 0.40 , 2.73 ± 0.38 , and 2.71 ± 0.38 mm, respectively. There was a significant difference between the US pachymetry and the Pentacam data, and between the US pachymetry and the Lenstar data. Although the means differed significantly among the three measurements, and the ACD means of the Pentacam and the Lenstar methods were lower than that of the US pachymetry method, the mean differences (0.12 and 0.14 mm) were small, and possibly not clinically significant. Bland-Altman analysis showed that almost all of the Pentacam and Lenstar measurements were within the 95% LoA range, which was in agreement with the results of prior studies^[18-19]. The mean difference between the Pentacam and US pachymetry data, although significant, was very small. Applying the Haigis formula, in an eye with normal axial length and exhibiting average keratometry, an ACD difference of 0.08 mm would change the target refractive error by less than 0.05 D upon placement of a common posterior chamber IOL. Hence, we consider that the observed differences were clinically acceptable. Chen *et al*^[20] assessed the repeatability of common measurements with the Sirius Scheimpflug-Placido topographer and the Lenstar methods and found that both optical devices had excellent repeatability for all parameters, the former also based on Scheimpflug imaging, was consistent with our results.

The AL could not be obtained using the Pentacam method; thus, we compared the AL using only the US pachymetry and the Lenstar methods. The mean \pm SDs of the AL obtained by the US pachymetry and the Lenstar methods were 24.28 ± 1.70 and 24.52 ± 1.73 mm, respectively. In general, measurements of length were larger as measured by the Lenstar method compared with the US pachymetry method. Despite the several statistically significant differences between the Pentacam and the US pachymetry methods, they were not considered to be clinically significant. The clinical

significance of these effects are minor, with the 0.01 mm difference in axial length equating to <0.03 D^[21-22]. Our results reinforced earlier studies^[23-25] reporting the strong agreement found between the Lenstar and US pachymetry methods in AL. Previous studies reported greater variability when comparing the Lenstar method with US pachymetry method, possibly because laser light is reflected from the retinal pigment epithelium, in contrast to ultrasound waves, which are reflected from the internal limiting membrane^[26]. As the AL obtained by the US pachymetry method is slightly shorter than that obtained by the Lenstar method, another explanation is that the former is a contact form of measurement; the ultrasonic probe must be manually placed on the corneal surface, and may slightly damage the tear film, thus underestimating the AL. The reproducibility of the data from the US pachymetry method depends on the expertise of the examiner.

In the present study, all three sets of measurements showed significant linear correlations, and all methods exhibited very satisfactory repeatability. The CV (also termed the dispersion coefficient) was very small (3.12%, 0.74%, 0.30%, 1.04%), showing that the three methods of measuring ocular biometry were consistent and the data repeatable. The coefficients of variation for ACD, AL, CCT and Km obtained with the Lenstar method by Rohrer *et al*^[27-28] were comparable with our results.

Each device has inherent advantages and disadvantages in terms of obtaining precise measurements. The Lenstar and Pentacam methods require the examinee to fixate for only 1.0 to 2.0s, and the ocular biometry is performed automatically and quickly. However, the measurement by US pachymeter is manual and slow, and would be appropriate for patients with dense cataracts. Owing to tight clinic schedules, we did not restrict comparisons using only patients with the same degree of cataract severity; neither did we control for potential effects of age, gender, or ethnicity.

In conclusion, the ocular biometry obtained using the three devices were slightly different. However, the difference, although statistically significant, was clinically acceptable. Measurements taken using the three instruments exhibited significant linear correlations, and all methods were highly reproducible. Taking previous and the present findings into account, we believe that the Lenstar and Pentacam methods could be used routinely for preoperative checks in cataract patients as replacements for the ultrasonic pachymeter method.

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