· Original article ·

Comparison of anterior chamber depths measured using the Pentacam, the IOLMaster, and ultrasound pachymetry

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Received: 2013-12-14 Accepted: 2015-05-14

Pentacam、IOLmaster 和 A 型超声测量仪测量前房深度的比较

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摘要

目的:比较 Pentacam、IOLMaster 和 A 型超声测量仪测量前房深度(anterior chamber depth, ACD)的准确性。

方法:观察性对照研究。对 69 例(138 眼)近视患者由同一操作者分别使用 Pentacam、IOLMaster 和 A 型超声测量仪进行 ACD 测量,并对所得数据进行统计学分析。3 种仪器的测量值一致性比较采用 Bland-Altman 检验,且用组内标准差及计算重复性系数来评价 3 种方法的重复性。

结果: Pentacam, IOLMaster 和 A 型超声测量仪测得 ACD 值分别为(3.77±0.24)、(3.73±0.23)、(3.69±0.22)mm。Bland-Altman 分析显示,3 种方法测量 ACD 的平均值一致性较好(Pentacam *vs* IOLMaster:CoA 0.04mm, LoA -0.05~0.13mm;A 超 *vs* IOLMaster:CoA 0.04mm, LoA -0.17~0.08mm;Pentacam *vs* A 超:CoA 0.08mm, LoA -0.06~0.22mm)。组内标准差及计算重复性系数显示 3 种方法测量 ACD 的重复性好(S_w=0.03、0.02、0.03;2.77 S_w=0.08、0.06、0.08)。3 种仪器测量 ACD 值相互正相关(r=0.946, 0.987, 0.951, P<0.001)。

结论: Pentacam、IOLMaster 和 A 型超声 3 种方法测量 ACD 的可重复性均很好、变异小、高度相关。Pentacam 测得的 ACD 值稍大于 A 型超声,但由于 3 组数据可重复性好,变异系数小,故此差异没有重要的临床意义。

关键词:前房深度;Pentacam;IOLMaster;A 型超声

引用:张静,张士胜,于青,吴江秀,廉井财. Pentacam、IOLMaster 和 A 型超声测量仪测量前房深度的比较. 国际眼科杂志 2015;15(8):1313-1318

Abstract

• AIM: To investigate and compare anterior chamber depths (ACDs) measured using the Pentacam, the IOLMaster, and ultrasound pachymetry (US).

• METHODS: The present study was observational in nature. ACDs were measured in 138 eyes of 69 myopic patients, by the same operator, using the Pentacam, the IOLMaster, and US. We assessed the agreement among the three methods using Bland - Altman plots. The repeatability among the three methods was evaluated by within-subject standard deviation.

• RESULTS: The means±SDs of ACDs measured using the Pentacam, the IOLMaster, and US were 3.77±0.24, 3.73±0.23, and 3.69±0.22mm respectively. Bland - Altman analysis showed that Pentacam and IOLMaster data were in good agreement (CoA, 0.04mm; LoA, 0.05 to 0.13mm), as were US and IOLMaster data (CoA, 0.04mm; LoA, 0.17 to 0.08mm), but the Pentacam ACD values were slightly greater than the US figures (CoA, 0.08mm; LoA, 0.06 to 0.22mm). Measurements of the ACD with the three devices also showed high repeatability (S_w=0.03, 0.02, and 0.03; 2.77 S_w=0.08, 0.06, and 0.08, respectively). The three depth estimates were positively correlated (r=0.946, 0.987, and 0.951; P<0.001).

• CONCLUSION: Measurement of ACDs using the Pentacam, the IOLMaster, and US showed good agreement and repeatability. The Pentacam and IOLMaster ACDs, and the IOLMaster and US ACDs, agreed reasonably well, but agreement between the Pentacam and US data was poorer. However, both the absolute differences and the coefficients of variation were small, and the observed variability was likely not clinically significant.

• KEYWORDS: anterior chamber depth; Pentacam; IOLMaster; ultrasound pachymetry

DOI:10.3980/j.issn.1672-5123.2015.8.03

Citation: Zhang J, Zhang SS, Yu Q, Wu JX, Lian JC. Comparison of anterior chamber depths measured using the Pentacam, the IOLMaster, and ultrasound pachymetry. *Guoji Yanke Zazhi*(*Int Eye Sci*) 2015;15(8):1313-1318

INTRODUCTION

Intraocular lens (IOL) implantation surgery has been developed extensively, and accurate evaluation of the anterior chamber depth (ACD; the distance from the anterior surface of the cornea to the anterior surface of the lens) is becoming increasingly critical, which can be used in the IOL power calculation formulas. Olsen[1] reported the contribution to error from ACD, axial length (AL), and corneal power is 42%, 36%, and 22%, respectively. Thus, one of the main causes of residual refractive error with IOL formulas is neglecting the role of the ACD. Especially for the implantation of multifocal intraocular lenses that provide simultaneous distance and near vision[2,3], it is key to provide accurate ocular biometry to calculate the power of the intraocular lenses. Additionally, phakic intraocular lenses (PIOLs) are generally accepted as an alternative treatment for ametropia correction in various refractive ranges, and more accurate ACD measurements can reduce postoperative complications.

ACD can be measured by both contact and non-contact methods. A variety of ACD-measuring instruments are available, employing different principles. Although ultrasound (US) pachymetry is used widely, the technique requires cornea-probe contact, possibly yielding slightly thinner measurements than other methods because of corneal indentation. Also, US is associated with a possible risk of epithelial erosion and iatrogenic infection[4-6]. Nevertheless, ophthalmologists with poorly resourced clinics continue to rely on ultrasound biometry in clinical consultations.

The Pentacam and IOLMaster are both non-contact instruments, which are becoming increasingly popular because of their speed of operation, relative ease of use, avoidance of any need for topical anesthesia, and lack of corneal indentation. The Pentacam uses a rotating Scheimpflug camera to provide a three-dimensional scan of the anterior segment of the eye. From the images acquired, information on ACD, keratometry readings, corneal thickness, and the horizontal corneal diameter can be determined[7,8]. The other optical biometry device, the IOLMaster, can also provide valid anterior segment measurements[9].

The repeatability and reproducibility of non-contact instruments has not been ideal for all parameters, so the use of non-contact devices versus US pachymetry in measuring the ACD remains open to debate[10]. When different methods of measuring the same variable are available, it is valuable to determine how well the different methods agree, because strong agreement indicates that they can be used interchangeably. The purposes of the present study were to compare ACD measurements obtained using the three instruments, and to evaluate the agreement and repeatability of the two optical biometry techniques and ultrasound biometry for use in important clinical applications.

SUBJECTS AND METHODS

Subjects Prior approval by ethic committee of Ruijin Hospital (Shanghai Jiaotong University School of Medicine) was obtained according to the Declaration of Helsinki. All participants were informed about the purpose of the study and provided written informed consent before inclusion.

Data collection was ended when 69 consecutive patients who came for refractive surgery had been sampled. We queried 100 patients, with a 69% response rate. Reasons for declining to participate in the study include dry eye, lack of time, and unwillingness to undergo three biometry sessions in a setting. The sampling period was from May to July 2013.

Subjects underwent measurement of ACD on a single day using the three methods: the Pentacam (Oculus, Germany), the IOLMaster (Carl Zeiss, Germany), and US (SP-3000, Tomey, Japan). All subjects, with no ocular abnormalities, were scheduled for refractive surgery. In total, 138 eyes in 69 subjects met the inclusion criteria. We collected data on 39 males and 30 females of mean age 25±3.6 (range, 19-32) y. The refractive spherical equivalents were 1.50 to 12.50D. All subjects were told to stop wearing contact lenses for at least 1wk prior to ACD measurement, and had no ocular abnormality other than myopia. All measurements on a given subject were made during the same session by a single trained examiner. The order of measurement was: Pentacam, IOLMaster, and US (which was always performed last to avoid any influence of corneal flattening on the other two measurements). All pupils were examined without dilation in the dark.

Methods For Pentacam and IOLMaster measurements, each subject sat in front of the machines with the chin on a chin rest and the forehead against a headband. During the Pentacam check, each patient was instructed to fixate on a blue light source in the center of the rotating camera and the operator examined a real-time image of the eye on a computer screen; the machine marked the edge and center of the pupil, and the corneal apex. The Pentacam was operated in automatic mode to reduce operator subjectivity. In this mode, the instrument automatically determines when the focus is correct and when alignment with the corneal apex has been achieved, and next, in less than 2s, measures the eye three times, recording an average ACD value that includes corneal thickness. IOLMaster data were acquired similarly. Measurement was automatic and the average of three ACD values was calculated.

For US measurement, each subject lay supine after the cornea was anesthetized with 0.4% (w/v) oxybuprocaine hydrochloride. The subject was told to look straight ahead and the probe was placed perpendicularly on the central corneal surface. Ten consecutive measurements were taken, and a mean ACD value calculated automatically. ACD was measured from the apex of the anterior corneal surface to that of the distant anterior lens capsule with the three devices, respectively.

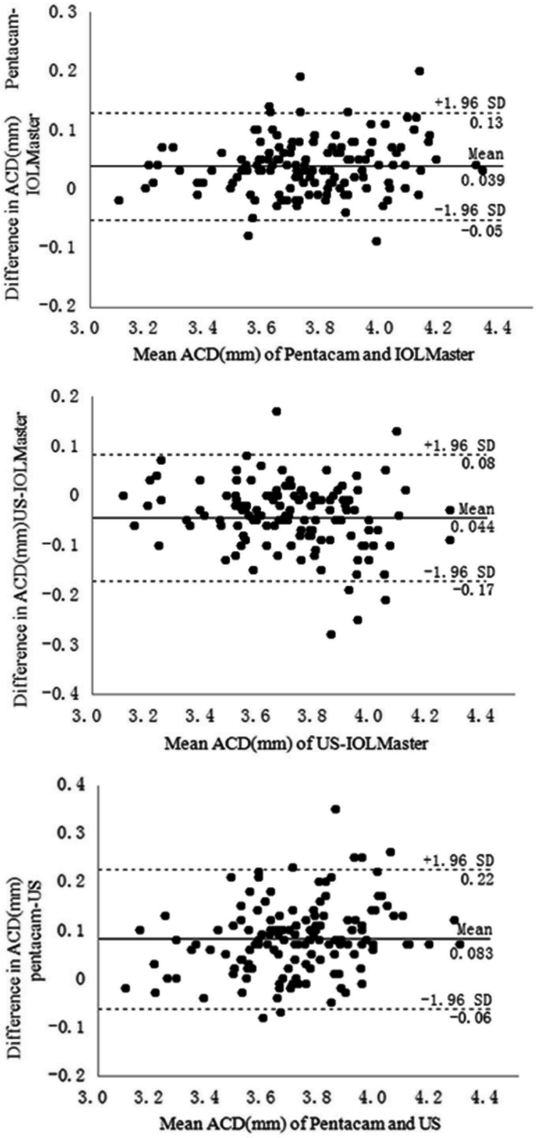

Figure 1 The Bland–Altman plot shows that all ACDs obtained were in good agreement (Pentacam *vs* IOLMaster: CoA 0.04mm, LoA −0.05 to 0.13mm; US *vs* IOLMaster: CoA 0.04mm, LoA −0.17 to 0.08mm; Pentacam *vs* US: CoA 0.08mm, LoA −0.06 to 0.22mm). Nearly all data lie within the 95% LoA and were evenly distributed, indicating that no relationship existed between the average ACD and any interdevice difference.

Statistical Analysis Data analyses were performed using Microsoft Excel 2003 (Microsoft Corp., WA) and StatView (ver. 13; SAS Institute, NC). The repeatability of the three ACD values obtained with the three instruments was assessed by determining the within-subject standard deviation (S_w) and test-retest repeatability ($2.77S_w$). The test-retest, calculated by multiplying the S_w value by 2.77, represents the interval within which 95% of the differences in measurements are expected to lie[11]. Bland-Altman plots[11] were prepared to facilitate inter-method comparisons of ACD measurements. The differences between measurements from each pair of instruments were plotted against means. A 95% limit of agreement (LoA) was defined as the mean difference between the data of two instruments, plus-or-minus 1.96-fold the standard deviation (SD), calculated using the Bland and Altman[12] approach. Data were expressed as means±SD. A *P* value of less than 0.05 was considered to reflect statistical significance. Among the data of three instruments, the correlation coefficients were established by Spearman.

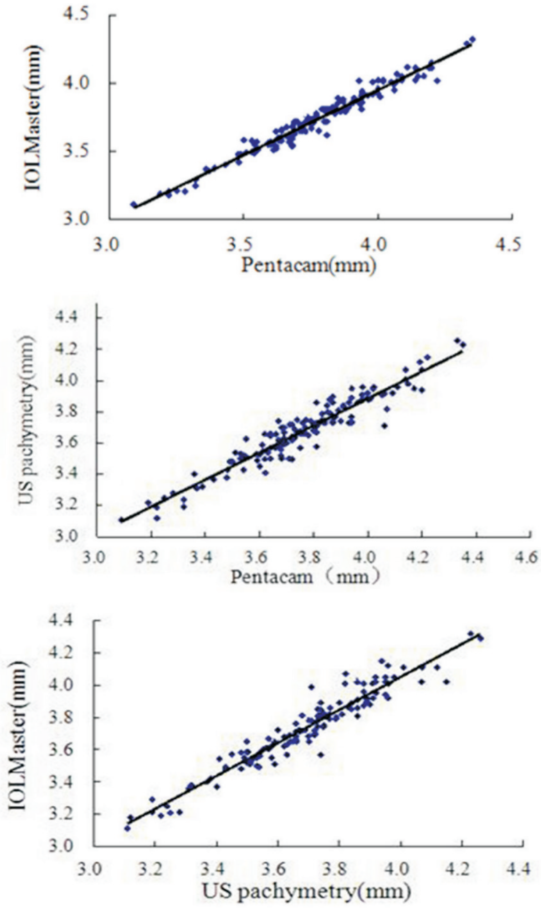

Figure 2 Three significant linear correlation were evident respectively A: Pentacam and IOLMaster data (r=0.946, P<0.001); B: IOLMaster and US data (r=0.987, P<0.001); C: Pentacam and US data (r=0.951, P<0.001).

Table 1 The repeatability of the ACD measurements with the three instruments

Instrument	Mean±SD (μm)	S_w	$2.77S_w$
Pentacam	3.77±0.24	0.03	0.08
IOLMaster	3.73±0.23	0.02	0.06
US	3.69±0.22	0.03	0.08

Statistical analysis: within subject standard deviation (S_w).

RESULTS

The mean ACD values yielded by the Pentacam, the IOLMaster, and US pachymetry were 3.77±0.24, 3.73±0.23, and 3.69±0.22mm, respectively. The repeatability of the ACD values obtained using the three instruments was assessed by the within-subject standard deviation (Table 1). Bland-Altman analysis showed that all ACD values obtained were in good agreement (Table 2). On average, the Pentacam measured a greater ACD (by 0.04mm) than the IOLMaster, with a 95% limit of agreement (LoA) ranging from −0.05 to 0.13mm. The Pentacam measured a greater

Table 2 The agreement of ACD measurements with the three instruments $\bar{x}\pm s$

Pairwise comparison	Mean paired difference (μm)	P	95% LoA
Pentacam-IOLMaster	0.039±0.046	<0.001	-0.05, 0.13
US-IOLMaster	0.044±0.065	<0.001	-0.17, 0.08
Pentacam-US	0.083±0.073	<0.001	-0.06, 0.22

Bland-Altman analysis: 95% limit of agreement (LoA) for each comparison (mean differences±1.96×SD).

ACD (by 0.08mm) than did US, with a 95% LoA from -0.06 to 0.22mm. The US measured a lower ACD (by 0.04mm) than the IOLMaster, with a 95% LoA from -0.17 to 0.18mm (Figure 1). Nearly all the data points were within the 95% LoA and were evenly distributed, indicating that no relationship existed between the average ACD and any interdevice difference. Significant linear correlations were evident between Pentacam and IOLMaster data ($r=0.946$, $P<0.001$), IOLMaster and US data ($r=0.987$, $P<0.001$), and Pentacam and US data ($r=0.951$, $P<0.001$; Figure 2).

DISCUSSION

It is essential to accurately measure the ACD prior to intraocular refractive surgery and IOL implantation, especially when iris-claw or phakic anterior chamber lenses or multifocal lens are to be fitted[13-15]. ACD measurements using contact and non-contact pachymetry have yielded mixed results[16-19]. In one study, Elbaz *et al*[20] reported that ACD measurements obtained using the Pentacam were significantly greater than those yielded by the IOLMaster and ultrasound. Among-method data were poorly consistent and could not be used interchangeably. Reuland *et al*[21] found that Pentacam and IOLMaster data were similar, and Németh *et al*[22] thought it appropriate to measure ACD using either instrument. Savini *et al*[23] reported that Pentacam and US ACD data were comparable, showing no significant difference, and could be used interchangeably. It has been shown previously that both the Pentacam and IOLMaster have high repeatability and reproducibility[24,25]. Although different versions of essentially the same device, it is not certain whether measurement results will match well and can be used interchangeably. Our study evaluated the repeatability of the three instruments by measuring ACD three times for each patient with a single experienced examiner. Repeatability refers to the variability in repeated measurements by one observer when all other factors are assumed constant[26].

In the present study, we found that the mean ACDs obtained using the Pentacam, the IOLMaster, and US were 3.77±0.24, 3.73±0.23, and 3.69±0.22mm, respectively. Our results showed high repeatability of ACD values obtained by the Pentacam, the IOLMaster, and US: the S_w values were 0.02, 0.03, and 0.03, respectively. No significant difference was evident between Pentacam and IOLMaster data, or between US and the IOLMaster. Although a significant difference was evident between mean Pentacam and US measurements, and the mean IOLMaster ACD value was lower than that of the Pentacam, the mean difference (0.08mm) was small, and likely not clinically significant. Bland-Altman analysis showed that almost all Pentacam and IOLMaster measurements were within the 95% LoA range, which was 0.28mm when mean Pentacam and US data were compared, in agreement with the results of prior studies[27,28]. The mean difference between Pentacam and US data, although significant, was very small, Applying the Haigis formula, in an eye of normal axial length and exhibiting average keratometry, an ACD difference of 0.08mm would change the target refractive error by less than 0.05D upon placement of a common posterior chamber IOL.

Therefore, we consider that the observed differences were clinically acceptable. Other studies have come to the same conclusion. Hashemi *et al*[29] and Utine *et al*[30] found that US and Orbscan II data did not differ significantly. The IOLMaster data did differ, with statistical, but not clinical, significance. Bland-Altman analysis revealed that consistency was good. Savant *et al*[31] measured ACDs using the Pentacam and IOLMaster and found no significant difference. Chen *et al*[32] assessed the repeatability of common measurements with the Sirius Scheimpflug-Placido topographer and Lenstar and found that both optical devices had excellent repeatability for all parameters; the former is based on Scheimpflug imaging and was consistent with our results. Additionally, Huang *et al*[33] evaluated the effect of cycloplegia on ocular biometry measurements and intraocular lens power calculation using the Lenstar and the IOLMaster biometers, and also found that the ACD increased post-cycloplegia. In this study, we obtained the ACD with the natural pupil and assessed the repeatability of the ACD using two non-contact methods in comparison with US pachymetry, which has been considered to be the 'gold standard'[12]. The results were similar in that the ACD measurements were comparable among the rotating Scheimpflug camera, scanning-slit topography, and ultrasonic pachymetry. Although there was no accommodation control, good agreement was demonstrated in our study. Compared with McAlinden *et al*'s study[34], we did not perform each measurement with two or more observers, so lack of a reproducibility tests is a weakness of this study.

The observed consistency may be explained in several ways. US is a contact form of measurement; the ultrasonic probe must be manually placed (perpendicularly) on the center of the cornea, and may slightly damage the tear film, thus underestimating the ACD. The reproducibility of US data depends on the expertise of the examiner. The Pentacam and IOLMaster are non-contact techniques that identify the interface of the air-tear film, and reproducibility depends largely on fixation of the examinee. Differences in fixation lights and the manner in which measuring light beams move may affect the reproducibility of non-contact pachymetric measurements.

It should be noted, however, that the Pentacam software has undergone many upgrades, and use of different software versions may cause differences in measurements. Also, ACD data varied when data obtained using a different Scheimpflug device (EAS-1000; Nidek, Gamagori, Japan) were compared with those derived using US[35].

This study was limited by a single-examiner design and interobserver variability was not addressed. Thus, the assessment of the accuracy of the data from the two devices was not comprehensive. However, the examiner was highly experienced, and all subjects were young and cooperative. These factors will have helped to minimize variability. One of the clearest benefits of the new generation of optical biometry devices, such as Pentacam and IOLMaster, is the potential to minimize measurement variation due to operator experience. Kielhorn *et al*[36] showed that both experienced and inexperienced operators of the IOLMaster returned essentially similar measurements for IOL power. Previous studies[2,37] have reported some other optical instruments, such as aberrometers and optical coherence tomography, also rely less on a sophisticated examiner because there is no touching the eye and data are obtained in a few seconds per measurement. In this study, we also strictly controlled the test order, to prevent contact interference with non-contact measurements. Our results agree with those of previous studies. Non-contact ACD measures do not differ by method, and data obtained using different devices can be used interchangeably[38,39].

Depending on objective or subjective measurements, the correct instrument must be selected because each device has inherent advantages and disadvantages. In the IOLMaster, slit light is projected in a band 0.7mm wide from the temporal side to the visual axis, and measures the distance from the anterior corneal surface to the anterior lens capsule. Therefore, the ACD includes the central corneal thickness. The Pentacam captures 25 slit images on each acquisition, and all images are derived from comprehensive examinations of the anterior segment. The map provides a view of the space from the endothelium to the anterior surface of the crystalline lens and is particularly useful when screening patients for phakic IOL implantation. The map also provides the surgeon a three-dimensional overview of the location and hardness of the lens opacities, and makes it possible to plan a better strategy in cataract surgery. Thus, data are also acquired from opaque tissue; this is not true of the IOLMaster. However, the IOLMaster provides the axial length, which cannot be obtained with the Pentacam, and an accurate axial length value can make a valuable contribution in calculations for IOL implantation. Thus, the both Pentacam and the IOLMaster serve as good reference methods and their measurements are consistent with those from ultrasound. An advantage of ultrasound is that it measures through opaque media, such as the ciliary body and structures behind the iris, which cannot be achieved with either of the optical devices. Ultrasound may be the best method for mapping the area behind the iris, but light is always provides the most precise measurements for structures that can be seen optically, because light's wavelength is so much shorter than that of ultrasound.

In conclusion, the mean ACD values obtained using the Pentacam were slightly greater than those measured by US. However, the difference, although statistically significant, was clinically acceptable. Measurements taken using the three instruments exhibited significant agreement, and all data of the three methods were highly repeatable. Thus, the methods may be used interchangeably.

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