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Comparison of anterior chamber depth measurements taken with the Pentacam, Orbscan IIz and IOLMaster in myopic and emmetropic eyes

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ABSTRACT.
Purpose: **This study determined to assess the degree of agreement between anterior chamber depth (ACD) measurements obtained using three different devices and to analyse the relationship between ACD and spherical equivalent (SE) refraction.**
Methods: **In this cross-sectional study, 42 eyes of 42 patients with a mean SE of − 4.69 ± 4.61 D (range 0.00 D to − 14.88 D) were analysed. Measurements of ACD between the corneal epithelium and the anterior surface of the crystalline lens, obtained using the Pentacam, Orbscan IIz and IOLMaster, were compared. The relationships between SE and ACD measurements obtained with different devices were also investigated. The results were analysed using Bland−Altman analyses, single-sample *t*-test and Pearson's correlation test.**
Results: **Orbscan ACD measurements were an average of 0.05 mm less than Pentacam measurements ($p = 0.01$). IOLMaster measurements were an average of 0.06 mm less than Orbscan measurements ($p < 0.001$). None of the ACD values measured by any of the devices were correlated with increasing SE ($p > 0.05$ for all). There was a weak positive correlation between SE and the difference in ACD measurements with Pentacam and Orbscan ($p = 0.04$); however, the differences between Pentacam and IOLMaster ACD measurements and Orbscan and IOLMaster ACD measurements seemed to be independent of SE ($p = 0.17$ and $p = 0.54$, respectively).**
Conclusions: **The ACD in clinically normal eyes is measured differently by various non-ultrasonic devices. However, the observed mean error between these modalities is too small to create any noticeable difference in refractive outcome. No significant relationship was found between SE and ACD measurements obtained by Pentacam, Orbscan or IOLMaster.**

Key words: anterior chamber depth – IOLMaster – Orbscan – Pentacam

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Introduction

The anterior chamber depth (ACD) measurement provides valuable information in different fields in ophthalmology. Firstly, it is important for the new theoretical biometric formulas used to calculate the power of intraocular lenses (IOLs) (Olsen 1992; Holladay 1997). Secondly, phakic IOL implantation requires precise ACD measurement for both surgical planning and IOL power calculation (Fechner 1990). Thirdly, the ACD is also implicated as a screening risk factor for glaucoma (Congdon et al. 1997; Devereux et al. 2000). Additionally, precise ACD measurement is thought to be important to the accurate determination of the optic zone ablation diameter for keratorefractive surgery, as well as for the analysis of postoperative ACD changes (Rosa et al. 2006).

Several methods for measuring the ACD are available. They include ultrasonic (based on reflected sound waves), optical (based on the Jaeger principle) and photographic (based on the Scheimpflug principle) techniques (Barrett et al. 1996).

The aim of this study was to assess the agreements between ACD measurements obtained using the Pentacam, Orbscan IIz and IOLMaster. Previous reports have studied the agreements between ACD measurements obtained with these devices (Rabsilber et al. 2003; Reddy et al. 2004; Hashemi et al. 2005; Lackner et al. 2005). However, to the best of our knowledge, this is the first study to compare measurements obtained with these devices in eyes with different refractive errors.

Materials and Methods

Forty-two eyes of 42 volunteers (29 women, 13 men) were included in the study. The right or left eye of each patient was randomly selected to include 21 right and 21 left eyes.

The study was performed in compliance with the tenets of the Helsinki Declaration. Informed consent was obtained in writing from all participants prior to their participation.

All subjects had normal eyes without corneal abnormalities as verified by slit-lamp examination, except in terms of refractive error. All subjects had been free of contact lens wear for ≥ 2 weeks before the study. Refractive error was measured with the Topcon KR-7100 autorefractometer (Topcon Corp. Tokyo, Japan). Manifest refractive spherical equivalent (SE) and best corrected visual acuity (BCVA) were also recorded.

Measurements were obtained using three different modalities:

(1) a novel rotating Scheimpflug camera (Pentacam comprehensive eye scanner type 70.700, Version 1.09; Oculus Optikgeräte GmbH, Wetzlar, Germany);
(2) scanning slit topography (Orbscan IIz, B&L, Version 3.00; Orbtek Inc., Salt Lake City, UT, USA), and
(3) the IOLMaster (Version 3.02; Carl Zeiss Meditec, Jena, Germany).

Measurements of the ACD from the corneal epithelium to the anterior surface of the lens were compared between different devices.

Measurements were taken in identical physical environments and in the same order in each patient (Pentacam, Orbscan IIz, IOLMaster), with intervals of ≥ 10 mins between measurements to allow for relaxation of the patients and restoration of ocular tear film. Subjects were seated in a typical position using the chinrest and were asked to keep both eyes open and to fixate on a fixation target. The instrument was then aligned and the cornea scanned.

Pentacam imaging

The Pentacam uses a rotating Scheimpflug camera to provide 2- and 3-dimensional anterior segment imaging, anterior/posterior corneal elevation topography, tangential and axial maps, a corneal pachymetry map, ACD measurement and densitometry of lens opacities in a single scan. The device defines the ACD as the distance along the optical axis between the anterior or posterior surface of the cornea and the anterior surface of the lens (Oculus Optikgeräte GmbH, 2005).

Orbscan imaging

The Orbscan IIz is a computerized slit scanning topography system. It quantifies elevation differences between the anterior and posterior corneal surfaces, the anterior surfaces of the iris and the lens, and automatically compensates for differences in refraction from the corneal endothelial surface using a ray trace algorithm, to provide accurate and reproducible measurements of ACD from both surfaces of the cornea to the anterior surface of the crystalline lens along the optical axis (Auffarth et al. 1997; Vinciguerra et al. 1998).

IOLMaster imaging

The IOLMaster uses the partial coherence interferometry principle for axial length measurement. Corneal power is measured by conventional keratometry, which should be performed first because the system requires the input of the corneal radii to calculate the ACD. The ACD is determined by calculating the distance along the visual axis between the corneal epithelium and lens using lateral slit illumination, with high resolution (± 0.01 mm) (Santodomingo-Rubido et al. 2002), high precision (≤ 5 μm) and good reliability (Findl et al. 1998; Haigis et al. 2000; Meyer et al. 2001).

Statistical analysis

Statistical analysis was performed using Microsoft Excel 2003 and Analyse-It® software, Ltd., Leeds, UK. Data for Orbscan, Pentacam and IOLMaster measurements were tested with respect to normality with the Shapiro–Wilks test. Data were graphically displayed in Bland–Altman plots as the differences between two techniques against the averages of the two different techniques (Bland & Altman 1986, 1995). This method reveals a relationship between the difference and averages, identifies any system bias, and identifies possible outliers. The systematic bias and the 95% limits of agreement were evaluated. Student's *t*-test was used to analyse the difference in mean ACD measurements between the instruments. A value of $p < 0.05$ was considered significant.

Results

The mean SE of refraction was − 4.69 ± 4.61 D (range 0.00 D to − 14.88 D). Patient demographics are shown in Table 1 and Fig. 1.

IOLMaster measurements were an average of 0.06 mm less than Orbscan measurements ($p < 0.001$). The mean difference between IOLMaster and Orbscan measurements was only 1.65% of the mean ACD calculated across all measurements (Fig. 2).

Orbscan ACD measurements were an average of 0.05 mm less than

Table 1. Demographic properties of subjects in emmetropic and myopic groups.

	Mean	Median	SD	Range
Age, years	30.31	29	10.02	13–55
SE, D	− 4.69	− 4.94	4.61	− 14.88 to 0.00
BCVA	0.70	0.9	0.35	0.03–1.0
ACD by Orbscan, mm	3.49	3.52	0.30	2.75–4.18
ACD by Pentacam, mm	3.54	3.56	0.31	2.79–4.2
ACD by IOLMaster, mm	3.43	3.47	0.29	2.71–4.04

SD = standard deviation; SE = spherical equivalent; BCVA = best corrected visual acuity; ACD = anterior chamber depth.

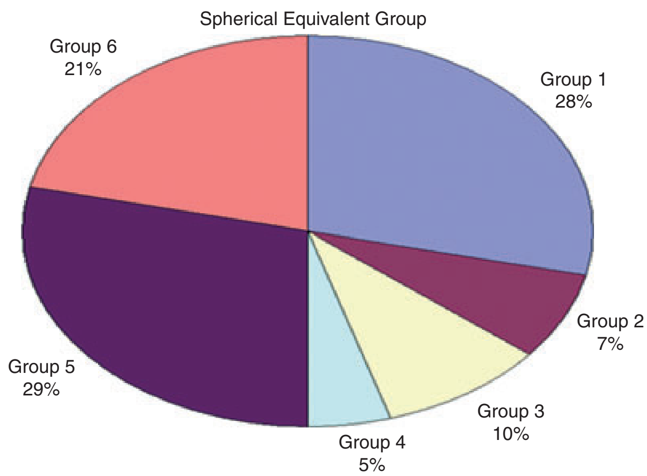

Fig. 1. Distribution of study eyes according to spherical equivalent. Group 1: 0.00 D; group 2: < 0.00 D to − 1.00 D; group 3: < − 1.00 D to − 3.00 D; group 4: < − 3.00 D to − 5.00 D; group 5: < − 5.00 D to − 10.00 D; group 6: < − 10.00 D to − 14.88 D.

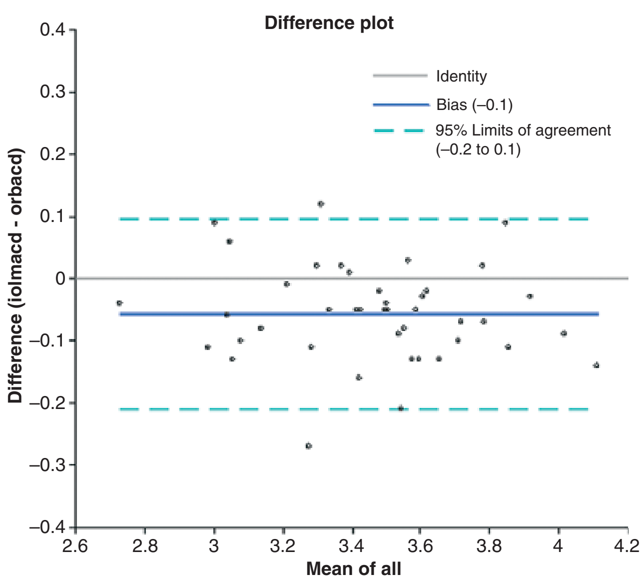

Fig. 2. Bland−Altman analysis of anterior chamber depth (ACD) measurements obtained with the Orbscan and IOLMaster.

Pentacam measurements ($p = 0.01$). The mean difference between Orbscan and Pentacam measurements was only 1.44% of the mean ACD calculated across all measurements (Fig. 3).

IOLMaster ACD measurements were an average of 0.11 mm less than Pentacam measurements ($p < 0.001$). The mean difference between IOLMaster and Pentacam measurements was 3.16% of the mean ACD calculated across all measurements (Fig. 4).

None of the ACD values measured by any of the three devices were correlated with refraction SE ($p > 0.05$ for all). There was a weak positive correlation between the difference in ACD measurements obtained with Orbscan and Pentacam and refraction SE ($R^2 = 0.10$, adjusted $R^2 = 0.08$, $p = 0.04$). However, the difference between ACD measurements obtained with Pentacam and IOLMaster, and Orbscan and IOLMaster seemed to be independent of refraction SE ($p = 0.17$, $p = 0.53$, respectively) (Table 2).

The difference between the agreement between Orbscan and IOLMaster measurements and the agreement between Orbscan and Pentacam measurements was not statistically significant, as determined by comparison of the squared differences between the measurements of the various devices ($p = 0.19$). However, the difference between Pentacam and IOLMaster measurements was significantly greater than the difference between Pentacam and Orbscan measurements ($p = 0.01$).

Discussion

Accurate measurement of the ACD has many theoretical and practical applications in different fields of ophthalmology. In modern cataract surgery, a major reason for IOL explantation is an unwanted refractive outcome derived from inaccurate biometry (Mamalis 2000). Recently derived biometric formulas (Haigis, Holladay 2) use the preoperatively measured ACD to predict effective lens positioning in IOL power calculations (Holladay 1997; Haigis 2002). More precise preoperative ACD measurement is needed to predict the exact postoperative IOL position (Olsen et al. 1995). It has been shown that errors in prediction of effective lens position (ELP) may account for 20–40% of total refractive prediction error (Olsen 1992; Holladay 1997). In phakic IOL implantation, precise ACD measurements are required not only to determine IOL power and ELP, but also to prevent endothelial cell damage (Barrett & McGraw 1998; Koranyi et al. 2002; Rabsilber et al. 2003). In glaucoma studies, the ACD provides an indicator of glaucoma, with the ACD being shallower in patients at risk (Barrett & McGraw 1998; Devereux et al. 2000; Friedman et al. 2003). In keratorefractive surgery the ACD is important to the setting of a correct optical zone ablation diameter because deeper anterior chambers require larger ablation areas (Vinciguerra et al. 1998). Additionally, in pseudophakic eyes, measuring ACD is a common method of evaluating possible IOL movement during accommodation (Lewiewska-Junk & Kalzuny 2000; Findl et al. 2003; Langenbucher et al. 2003).

Several methods are available for measuring the ACD. They can be classified as ultrasonic, optical and photographic (Barrett et al. 1996). Another method of estimating ACD uses the slit-lamp but does not require an attachment (Osuobeni et al. 2000).

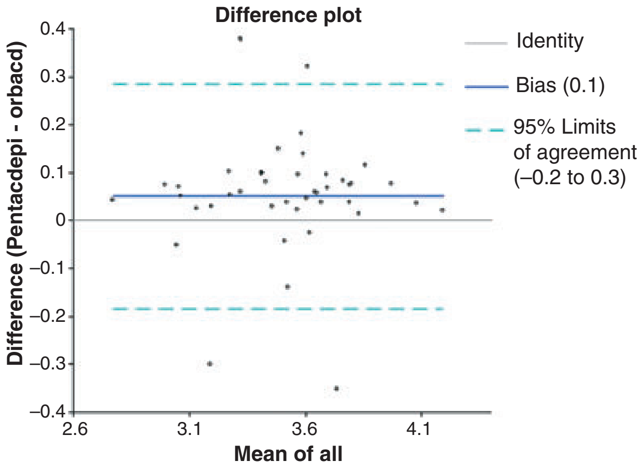

Fig. 3. Bland–Altman analysis of anterior chamber depth (ACD) measurements obtained with the Orbscan and Pentacam.

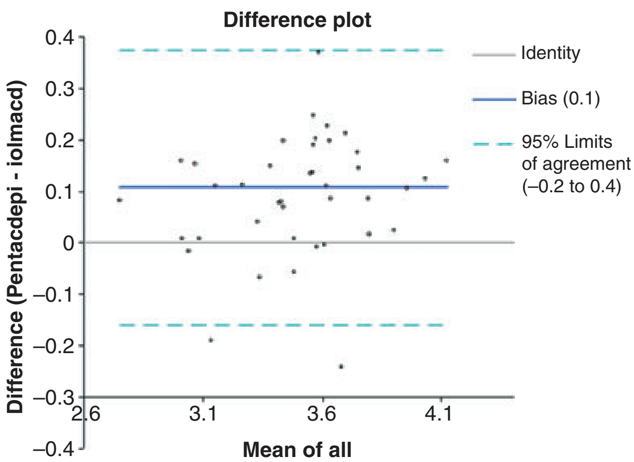

Fig. 4. Bland–Altman analysis of anterior chamber depth (ACD) measurements obtained with the Pentacam and IOLMaster.

Table 2. Correlation between the refraction spherical equivalent and mean ACD values measured by different devices.

	Pearson correlation coefficient/p value
SE and ACD by Orbscan	−0.25 / 0.12
SE and ACD by Pentacam	−0.13 / 0.42
SE and ACD by IOLMaster	−0.23 / 0.15
SE and the difference of ACD measurements by Orbscan and IOLMaster	−0.10 / 0.53
SE and the difference of ACD measurements by Orbscan and Pentacam	**0.32 / 0.04**
SE and the difference of ACD measurements by IOLMaster and Pentacam	0.22 / 0.17

SE: Spherical equivalent
ACD: Anterior chamber depth

Ultrasound ACD measurement has been considered as the gold standard. However, ultrasound measurements using a hand-held operator are operator-dependent, unlike optical methods, which allow for the quantification and documentation of centration (i.e. the distance between the actual point of measurement and the centre of the pupil). However, for optical devices, a 1.0-mm error in centering is considered highly unlikely in everyday practice, whereas 0.5-mm centering errors are considered to be commonplace and acceptable and to give an underevaluation of the ACD of 20 μm, which probably has no practical impact because it represents a relative error of < 6–8% (Baikoff et al. 2005).

By contrast, optical methods that determine the ACD could suffer from systematic errors as a result of distortion effects in optical media with different refractive indices. This effect has been largely compensated for in both Pentacam and Orbscan using ray tracing algorithms. The optical devices require clear reflections on the epithelial and endothelial corneal surfaces and homogeneous composition of the diverse optical media to obtain precise measurements (Boscia et al. 2002). However, ultrasound propagation may also be altered in the presence of oedema, opacities, scarring or deposits in the optical media.

This study attempted to assess central ACD in normal and myopic eyes with three non-ultrasonic devices: the Pentacam, Orbscan and IOLMaster. All three systems provide non-contact measurements and their use is reported to require minimal training compared with other methods such as ultrasound (Marsich & Bullimore 2000). Measurements can be taken quickly if patients can sit and fixate on the fixating light during the entire process. This requirement can be a major problem in children and elderly patients (Cho et al. 2002). Measuring with these devices can be complicated if there are severe tear film problems, corneal scars or nystagmus.

An important source of error that can arise during ACD evaluation is off-axis measurement. Correct alignment of the beam is important because only a minor deviation of the correct direction (perpendicular to the four major surfaces in the optical axis of the eye) affects the results of the ACD measurement (Giers & Epple 1990). Therefore, patient alignment is of maximum importance. The slight offset in measurement results obtained by the different devices in this study may be explained by different axes of measurement.

In the present study, good agreement between measurements obtained with the three devices was detected. The greatest difference between ACD measurements obtained with different devices was noted between Pentacam and IOLMaster measurements. IOLMaster ACD measurements tend to be shorter than Pentacam measurements; however, the mean difference between these modalities was 3.16% of the mean ACD calculated across all measurements. The observed mean error of 0.11 mm between these modalities is too small to create any noticeable difference in refractive outcome (e.g. with the Nuvita Nomogram, the required IOL power varies by 0.1 D for each 0.2 mm of ACD [Lackner et al. 2005]). Considering the similarities between the measurements and basic measurement principles of the instruments, we believe they provide correct results.

Hashemi et al. (2005) conducted a comparison of ACD measurements in myopic eyes, with A-scan ultrasonography, Orbscan II and IOLMaster. They reported that ACD measurement differences may be clinically negligible, although statistically significant. Likewise, Rabsilber et al. (2003) and Reddy et al. (2004) found no statistically significant difference between Orbscan II and IOLMaster ACD values. Lackner et al. (2005) reported that ACD measurements taken with Pentacam were shorter than those taken with Orbscan in normal eyes, but the mean error observed between the two devices was small enough not to create a significant change in the refractive error.

In high hyperopic eyes, the anterior chamber is often shallower than in emmetropic eyes, even taking racial differences into account. By contrast, in high myopic eyes, there is no direct relationship between ACD and refraction, which is more related to axial length elongation (Vetrugno et al. 2000). Rabsilber et al. (2003) found ACD in emmetropic eyes to be only 0.1 mm less than in myopic eyes, and increasing myopia was correlated only with increasing axial length. Our results also failed to demonstrate any significant relationship between ACD and SE, by Pentacam, Orbscan or IOLMaster, although the difference in the ACD measurements obtained with Orbscan and IOLMaster seemed to rise slightly with increasing SE. There have been no previous reports comparing measurements obtained with these devices in eyes with different refractive errors.

In conclusion, the ACD in clinically normal eyes is measured differently by various non-ultrasonic devices. However, the observed mean error between these modalities is too small to create any noticeable difference in refractive outcome.

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