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ORIGINAL ARTICLE

Validity and Repeatability of Anterior Chamber Depth Measurements With Pentacam and Orbscan

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ABSTRACT: *Purpose.* The purpose of this study was to determine the validity and repeatability of anterior chamber depth (ACD) measurements obtained with a novel rotating Scheimpflug camera (Pentacam; Oculus Optikgeräte GmbH, Wetzlar, Germany) to scanning slit topography (Orbscan; Bausch & Lomb, Rochester, NY). *Methods.* ACD in 60 healthy eyes was measured twice by two independent observers with each modality in random order. A total of eight measurements was performed on each eye. The mean differences between measurements, between observers, and between modalities were calculated, and 95% limits of agreement (LoA) were given as mean ± 1.96 * standard deviation (SD) of the mean. *Results.* The mean ACD values as determined with the different modalities (± SD) were 3.18 ± 0.38 mm for Pentacam imaging and 3.23 ± 0.40 for Orbscan. The mean difference between the two modalities was 0.047 mm (LoA: 0.176 to -0.081 mm). Within each modality, the limits of agreement of the differences between individual measurements and between different observers were within 0.073 mm or 4% of total ACD. The total variance in the observed data was 0.145. The variance resulting from interindividual differences in ACD was 85%, as a result of the two different modalities 15%, as a result of different observers 0.007%, and as a result of different measurements 0.007%. *Conclusions.* In the assessment of normal eyes, the differences of ACD values measured with Orbscan and Pentacam were within clinically acceptable levels, and inter- and intraobserver variability was considerably below clinically significant levels. Thus, these two modalities can be regarded as interchangeable. (Optom Vis Sci 2005;82:858–861)

Key Words: anterior chamber depth, biometry, Scheimpflug imaging, comparative study, observer variability

Today, intraocular lens (IOL) implantation is facing the challenge to produce perfect results. Patients demand independence of spectacles, and a major reason for IOL explantation is an unsatisfying refractive outcome. Thus, there is an increasing need to accurately predict IOL power required to achieve the intended postoperative refraction. In almost all IOL formulas used today, the assumption is made that the postoperative position of the IOL can be predicted from several biometric parameters such as corneal curvature, anterior chamber depth (ACD), lens thickness, and axial length. Although corneal curvature and axial length can be measured with reasonable accuracy and repeatability,[1,2] no entirely satisfactory method to determine anterior chamber depth exists today. Traditional A-scan methods in the form of applanation and immersion ultrasonography have shown considerable variability between measurements,[3] between observers,[1] and between manufacturers.[4] Consequently, errors in effective lens position after IOL implantation are believed to account for up to 40% of residual refractive errors.[5,6]

Several noncontact methods to determine ACD have been recently used as alternatives to ultrasound measurements, including preliminary studies comparing ultrasound-based and optical coherence-based methods (IOL Master; Zeiss, Oberkochen, Germany).[7] Other recent technologies that have been adapted for anterior segment measurements are the Orbscan Topography System (Bausch & Lomb, Rochester, NY) and the Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany). The Orbscan has been evaluated and is claimed to provide accurate measurements of ACD.[8] However, the variability of ACD between measurements and between observers has not been quantified, and no evaluation of the Pentacam in assessing ACD exists.

The purpose of the present study was to compare ACD measurements obtained with the Orbscan and the Pentacam. Estimates for the error between measurements with different modalities and for the reproducibility of measurements within and between observers within a single modality should be provided.

METHODS

Thirty healthy volunteers (16 women and 14 men with a mean age of 31.5 years; standard deviation [SD] 3.8; range, 26.5–44.5 years) were recruited for the study. The study was performed in compliance with all applicable institutional and legal requirements. Informed consent was obtained in writing from all participants. All subjects had normal eyes without corneal abnormalities as verified by slit lamp examination. The refractive error was measured with an autorefractometer (model 597; Humphrey Systems, Dublin, CA). Mean spherical refraction was −1.7 D (SD 1.9); mean astigmatism was 0.4 D (SD 0.4). Measurements were taken on both eyes.

Anterior chamber depth was defined as the distance from the posterior vertex of the corneal endothelium to the anterior surface of the crystalline lens along the optical axis. It was measured with two different modalities: 1) with a novel rotating Scheimpflug camera (Pentacam 70,700; Oculus, Wetzlar, Germany), and 2) with scanning slit topography (Orbscan, B&L, software version 4.00; Orbtek Inc., Salt Lake City, UT).

Each modality was carried out by two independent observers (BL, GS) blinded to the previous measurements of the study. The order of the examiners and of the modalities were randomly assigned to each eye.

Rotating Scheimpflug Imaging (Pentacam)

Rotating Scheimpflug imaging was performed with the patient seated using a chinrest and forehead strap. The patient was asked to keep both eyes open and to fixate on a blinking fixation target.

The system uses a rotating Scheimpflug camera and a monochromatic slit light source (blue LED at 475 nm) that rotate together around the optical axis of the eye. During 2 s, the system rotates 180° and acquires 25 images that contain 500 measurement points on the front and back corneal surface to draw a true elevation map. The software acquires the images as volume data, thus multiplanar reformations allow the creation of axial and tangential maps. Patient eye movement was constantly monitored by the system, and only measurements with less then 0.6 mm decentration were included.

Scanning-Slit Topography (Orbscan)

A noncontact topography system (Orbscan) was used. Subjects were seated in typical position using the chinrest; the instrument was aligned and scanned the cornea. The system software automatically detects the corneal endothelial surface and anterior surface of the crystalline lens on the acquired images, compensates for differences in refraction from the corneal anterior surface using a ray trace algorithm, and calculates ACD.

During all measurements, the observer verified that the optical axis of the system and the center of the pupil were within <0.6 mm of each other. The effect of decentration on ACD measurements was assessed using a model eye adopted from Hecht[9] assuming a posterior corneal curvature of 5.685 mm and anterior lenticular curvature of 8.672 mm. Changes in ACD are given as a function of lateral decentration of the axis of measurement.

Statistical Analysis

The dependent variable was ACD. It was measured twice by two observers and with two modalities. Thus, eight values for ACD were obtained on each eye. Agreement between measurements, between observers, and between modalities was expressed by calculating 95% limits of agreement (as mean difference between measurements ± 1.96 * SD of the mean difference). Data were graphically displayed in Bland-Altman plots as difference between two measurements over a mean of two measurements.[10,11] Multifactor repeated measurements analysis of variance (RM-ANOVA) was used to determine the components of the observed variance in ACD resulting from: 1) different measurements by one observer, 2) different observers, and 3) different modalities to measure ACD. The residual variance in the data can largely be attributed to the interindividual variance in ACD.[12]

RESULTS

Difference Between Devices

Mean ACD for all eyes was 3.18 ± 0.38 mm measured with Pentacam and 3.23 ± 0.40 mm measured with Orbscan. Measurements with Orbscan were on the average 0.046 mm longer than with Pentacam ($p < 0.0005$). The 95% limits of agreement (LoA) between the two modalities were -0.08 mm to 0.18 mm, i.e., if the two modalities were to assess a single eye, there is a 95% chance that Orbscan will measure ACD between 0.18 mm longer and 0.08 mm shorter than Pentacam (Table 1). In relative terms, this error range corresponds to +5.6%–−2.5% of the mean ACD in this study. A graphic illustration of the repeatability between the

TABLE 1.

Mean differences, standard deviation (SD) of the differences, and limits of agreement (LoA) that occurred when measuring anterior chamber depth between measurements of a single observer (first and second rows), between two observers (third and fourth row), and between the two modalities (Orbscan and Pentacam, fifth row)[a]

	Mean difference (mm)	SD of difference (mm)	95% LoA (mm)
Orbscan within observer	0.001	0.052	0.102 to −0.100
Pentacam within observer	0.005	0.039	0.081 to −0.070
Orbscan between observers	0.001	0.040	0.073 to −0.071
Pentcam between observers	0.002	0.037	0.074 to −0.069
Orbscan versus Pentacam	0.047	0.066	0.176 to −0.081

[a] The mean difference indicates the magnitude of a systemic error; the limits of agreement indicate the error range in which two measurements on a single eye can be expected, depending whether they are performed by a single observer, by two observers, or with two different modalities.

two modalities is given in Figure 1A. If the previously suggested "acoustic correction factor" was applied to the Orbscan measurements, the systematic error between the devices grew to 0.21 mm (LoA: 0.09 to 0.33 mm) (Fig. 1B).

Decentration caused only a modest influence on ACD measurements. The calculations using Hecht's eye model showed that a decentration of 0.6 mm led to an underestimation of ACD of 0.01 mm. A decentration of 1.8 mm would be required to create an ACD error of −0.1 mm. The effect of decentration in other eye models would not be substantially larger.

Variability In and Between Observers

The variance in ACD between measurements and between observers was similar and smaller than the variance of ACD between eyes and between the two devices. Table 1 shows the standard deviation of the difference in ACD measurement between individual measurements of a single observer and between measurements of two different observers. For both modalities, the limits of agreement of the measurement differences are within 0.073 mm or 4% of total ACD. Figure 1C–D shows the interobserver repeatability of ACD measurements with the two modalities. The application of the components of variance model showed that total variance in the observed data was 0.145. It consisted of the following components: Variance as a result of interindividual differences in ACD was 0.123 (85%), as a result of the two different modalities 0.022 (15%), as a result of different observers 0.00,001 (0.01%), and as a result of different measurements 0.00,001 (0.007%).

DISCUSSION

The data of the present study show that ACD in normal eyes tends to be measured shorter with Pentacam than with Orbscan. The mean difference between these modalities, however, was only 1.4% of the mean ACD in the collective.

Most formulas for the calculation of IOL power rely on an accurate estimate of the distance between the IOL and the retina.[13] One way to calculate this distance is from the difference between ocular length and ACD.[14] Errors in ACD measurement therefore indirectly affect IOL power calculation. However, because ocular length is approximately five times larger than ACD, errors in ACD influence IOL power to a lesser extent. The observed mean error between the two modalities, more so the error between observers, is too small to create any noticeable difference in refractive outcome (e.g., in the Nuvita Nomogram, the required IOL power varies by 0.1 D for each 0.2 mm of ACD).

Traditionally, ACD was measured with ultrasound biometry. However, an increasing number of studies found high variability of the results between observers, between measurements, and compared with other modalities to determine ACD.[15] This has led some researchers to recommend the additional use of other modalities for ACD determination.[4,16]

Other studies have assessed agreement of ACD measured with ultrasound versus Orbscan. Vetrugno et al. report a mean difference below 5% between (applanation) ultrasound and Orbscan;[17] Auffarth et al. report a mean difference of 1.2% using immersion ultrasound.[18] Reddy et al. tested agreement among ultrasound, Orbscan, and IOL Master, and found that ultrasound measured ACD 13% shorter, whereas the other two modalities showed good

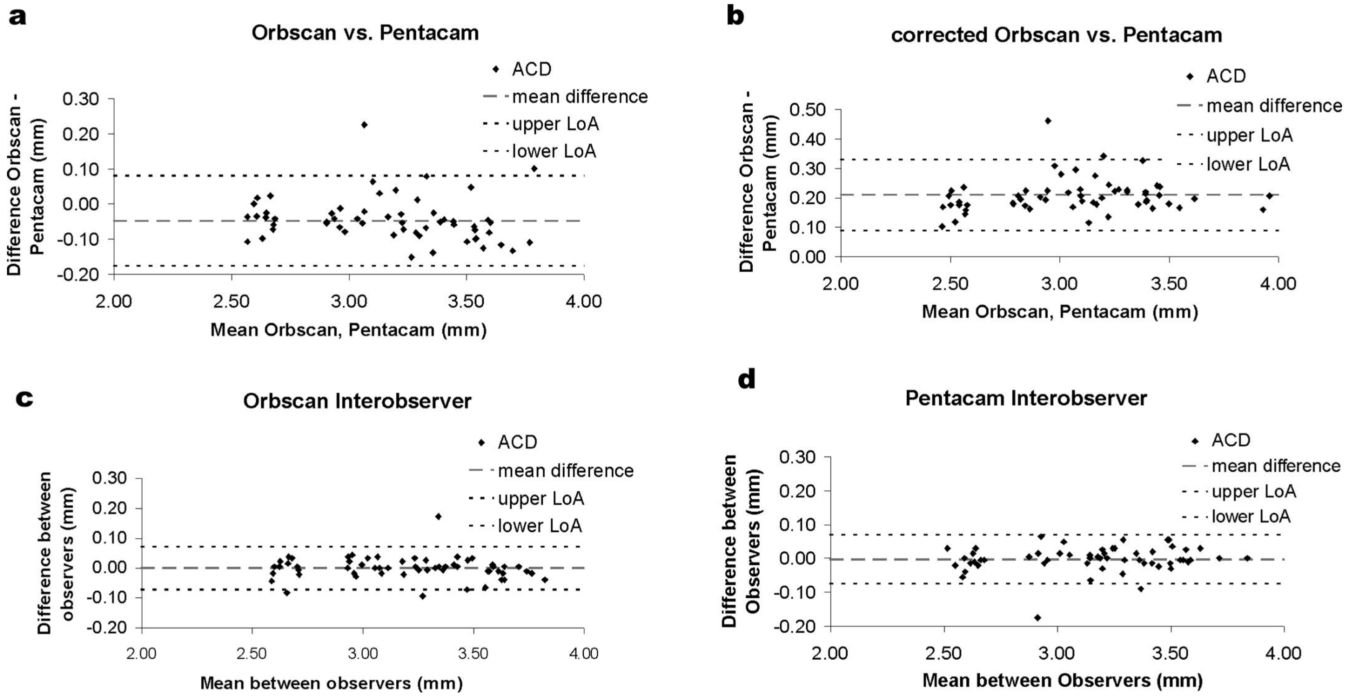

FIGURE 1.

Agreement of anterior chamber depth measured with Pentacam versus Orbscan (a), with Pentacam versus Orbscan corrected with the "acoustic correction factor" (b), and measures by two independent observers on the same device (c, d). Bland-Altman plots represent the difference between two measurements over the mean between these measurements.

correlation. They attributed this difference to applanation effects of the handheld ultrasound probe.[19] Excellent correlation between three optical modalities (Orbscan, conventional nonrotating Scheimpflug camera, and optical pachymetry) to determine ACD were reported by Koranyi et al. with mean differences of approximately 1.5%, whereas ultrasound measured ACD markedly shorter.[16]

In method comparison studies, assessment of repeatability of each method is highly relevant because the repeatability of either method of measurement limits the amount of agreement that is possible.[11,12] High tolerances in repeatability can interfere with the comparison of two methods because if one method has poor repeatability (i.e., considerable variation in repeated measurements on the same subject), the agreement between the two methods is bound to be poor.[10]

Both ultrasound and optical methods to determine ACD have certain technical limitations. The application of ultrasound requires the selection of a predefined value for ultrasound propagation speed to calculate the various distances, which may not accurately match the true propagation speed. Furthermore, although optical methods allow for the quantification and documentation of centration (i.e., the distance between the actual point of measurement and the eye's optical axis), ultrasound measurements using a handheld probe are more operator-dependent. Optical methods to determine ACD, on the other hand, suffered from systematic errors as a result of distortion effects in optical media with different refractive indices, but this has been largely compensated for in both machines used in this study by applying ray-tracing algorithms. Both optical pachymetry devices used in this study require clear reflections on the epithelial and endothelial corneal surfaces and homogeneous composition of the diverse optical media to obtain precise measurements.[20] As such, their use is limited to eyes that are free of sources of light-scattering or distortion such as opacities, scarring, deposits, or edema. However, ultrasound propagation may also be altered in the presence of edema. The data from this study can therefore not necessarily be translated to postoperative measurements.

The lack of a standard value for ACD has certain implications on the interpretation of the results of this study. Ultrasound measurements cannot serve as reliable "gold standards" for reasons mentioned here, because their variability between individual measurements and between observers is considerably greater than with the optical methods described here. Therefore, the different modalities for preoperative biometry need to be compared in randomized studies assessing refractive outcome after IOL implantation.

CONCLUSION

Both Orbscan and Pentacam can be used for ACD measurements with clinically acceptable intra- and interobserver variation in normal eyes. The difference between the two modalities lies within a clinically insignificant error range, which suggests their comparability and interchangeability. Further studies are needed to demonstrate their accuracy in eyes with substantial refractive errors and in postoperative conditions.

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