Central Corneal Thickness, Anterior Chamber Depth, and Pupil Diameter Measurements Using Visante OCT, Orbscan, and Pentacam

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ABSTRACT

PURPOSE: To evaluate the agreement among three different optical methods in measuring anterior chamber depth (ACD), central corneal thickness (CCT), and pupil diameter.

METHODS: One hundred eyes of 50 healthy patients (25 men, 25 women) were enrolled in the study. Mean patient age was 25 years (range: 21 to 32 years). Exclusion criteria were history of any intraocular or corneal surgery, contact lens wear, corneal anomalies, and spherical refraction greater than 5.00 diopters (D) or cylindrical refraction greater than 2.00 D. All measurements were done by the same operator under mesopic light conditions and repeated using three different optical methods: Visante optical coherence tomography (OCT) (Carl Zeiss Meditec), Orbscan (Bausch & Lomb), and Pentacam (Oculus Optikgeräte GmbH).

RESULTS: Mean CCT as measured by Visante OCT, Orbscan, and Pentacam was 529 ± 30.5 µm, 554 ± 32.7 µm, and 552 ± 29.3 µm, respectively. Mean ACD values were 2.94 ± 0.34 mm, 2.84 ± 0.33 mm, and 2.98 ± 0.33 mm, respectively. Mean pupil diameter measurements were 4.87 ± 1.09 mm, 4.0 ± 0.67 mm, and 3.05 ± 0.59 mm, respectively. The Visante OCT measured CCT thinner and Orbscan measured ACD shallower than the other two methods. All three methods measured pupil diameters significantly different.

CONCLUSIONS: This study found some statistically significant but clinically insignificant differences among the optical methods assessed. The differences are small and do not influence decisions for refractive surgery in clinical practice. [J Refract Surg. 2010;26:127-133.] doi:10.3928/1081597X-20100121-08

With the development of cataract and refractive surgery, precision of ocular measurements has gained importance. An exact measurement of anterior chamber depth (ACD) is important in intraocular lens (IOL) power calculation and phakic IOL implantation. Corneal thickness and pupil diameter in LASIK surgery determine the outcome and success of the surgery. Until recently, ultrasonic biometry has been the most commonly used method for ACD and corneal thickness measurements. However, in addition to the risk of creating corneal epithelial defects, great variability of the results due to indentation of the probe and off-the-axis measurements are main disadvantages of this technique.1,2 Because of these issues, non-contact methods are preferred today.3,4 Visante optical coherence tomography (OCT; Carl Zeiss Meditec, Dublin, Calif), Orbscan (Bausch & Lomb, Rochester, NY), Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany), IOLMaster (Carl Zeiss Meditec), specular microscopy, and ultrasonic biomicroscopy are some of the non-contact devices currently available.

Visante OCT is a newly developed, optically based, high resolution tomographic and biomicroscopic device designed for anterior segment imaging and measurement. The principle of imaging is based on low coherence interferometry using a 1310-nm superluminescent light-emitting diode as the light source. Low coherence interferometry measures the delay and intensity of backscattered light by comparing it to light that has traveled a known reference path length and time delay. Visante OCT can be used to measure corneal thickness, angle-to-angle distances, anterior chamber dimensions, and crystalline lens thickness.

An established method for anterior segment evaluation is the Orbscan. It uses two different techniques—the Placido...
One hundred eyes of 50 healthy patients (25 men, 25 women) were enrolled in the study. Mean age was 25 years (range: 21 to 32 years). The exclusion criteria were history of any intraocular or corneal surgery, contact lens wear, corneal anomalies, spherical refraction >5.00 diopters (D) or cylindrical refraction >2.00 D. All patients had been previously informed about the study.

In Visante OCT, the patient was instructed to sit in front of the device and place his chin on a chin rest. After the real-time image was optimally aligned, the scan was performed. For proper alignment, the optically produced corneal reflex became visible as a vertical white line along the center of the cornea. Pupil diameter and ACD measurements were manually done and CCT was noted from the corneal thickness map.

Orbscan scanning slit imaging was performed in the same chin rest and forehead position. The screen image of the eye was centered and aligned manually. The patient was asked to keep his eyes open and not to move. Corneal measurements were done with an acoustic correction factor of 0.94.

Pentacam mapping was performed with the patient seated in the same position described above. The patient was asked to fixate on a target in the center of the camera. The real-time image on the computer screen was adjusted manually by moving the joystick in the directions indicated on the screen. As the image was aligned, the scan was performed automatically. Central corneal thickness, ACD, and pupil diameter values for each patient were noted.

The ACD was defined as the distance from the posterior surface of the cornea (endothelium) to the anterior surface of the lens. In all techniques, horizontal pupil diameter values were recorded. The measurements were performed under mesopic conditions, without any cycloplegic medication and by the same operator.

**STATISTICS**

Parameters were assessed using SPSS 11.5 software (SPSS Inc, Chicago, Ill). All measurements were compared using repeated measures analysis of variance (ANOVA) and Tukey multiple comparison tests. The correlation between each method was assessed using Pearson’s correlation analysis. A P value <.05 was regarded as statistically significant.

To show the differences between individual measurements for each device, Bland-Altman plots were composed. The difference between the two methods compared was set in the perpendicular line, with the mean value of the methods in the horizontal line. The mean difference and 95% limits of agreement (±1.96 standard deviation) were also displayed.

**RESULTS**

The mean spherical refraction of the patients was
-0.44 D (range: -4.00 to +2.75 D), cylindrical refraction was -0.10 D (range: -2.00 to 0.00 D), and spherical equivalence was -0.48 D (range: -5.00 to +2.25).

The highest mean CCT value was obtained with the Orbscan, the highest mean ACD was with the Pentacam, and the highest mean pupil diameter was with Visante OCT. Mean CCT, ACD, and pupil diameter results are shown in Table 1.

The mean CCT measurements of the Pentacam and Orbscan were similar, whereas Visante OCT measured CCT significantly thinner. The greatest difference was found between the Orbscan and Visante OCT, which was computed to be 4.4% (Table 2).

Mean ACD measurements, on the other hand, were similar between Visante OCT and the Pentacam, and Orbscan measured ACD significantly shallower. The greatest difference between mean values was 4.8% between Orbscan and Pentacam (Table 2).

All three methods measured pupil diameter significantly different. Under mesopic light conditions, the highest pupil diameter values were obtained by Visante OCT (Table 1).

High correlation was present among all three methods in ACD and CCT measurements (Table 3).

Bland-Altman plots were composed to show the individual differences (Figs 1 and 2).

**DISCUSSION**

Until recently, ultrasonic biometry has been regarded as the gold standard for evaluating and measuring anterior segment structures. However, as a contact device it possesses some disadvantages; therefore, non-contact methods are more preferred today. In addition, ultrasound measurements may be influenced by the experience of the operator. Probe indentation on the cornea results in lower ACD values, whereas decentration and off-the-axis measurements lead to higher corneal pachymetric and variable ACD readings. In fact, considerable variability has been described with ultrasound measurements.

In studies evaluating the accuracy of and agreement between different methods, the repeatability and reproducibility of each method should be high.
If the results of repeated measurements by the same or different operators, using the same technique on the same case are too varied, comparing that technique to others will not give reliable results. For this reason, repeatability and reproducibility should be investigated first. Many studies demonstrating high repeatability and reproducibility of CCT and ACD measurements using Visante OCT, Orbscan, and Pentacam are reported.14-18

### CENTRAL CORNEAL THICKNESS

In this study, CCT values of the Pentacam and Orbscan were found to be similar ($P=.86$), whereas Visante OCT measured CCT thinner than the other two methods (both $P<.001$). However, for CCT measurements, none of the mean differences were higher than 5% of the mean CCT (Table 2).

In studies with healthy patients, mean CCT values measured with Visante OCT were 510 to 538 µm,17,19,20 with Orbscan 530 to 553 µm,15,19-21 and with Pentacam 542 to 561 µm.15,21,22 Central corneal thickness values obtained using ultrasound pachymeters were 540 to 553 µm.15,19-22 The results of our study are consistent with previous studies where Visante OCT measured thinner CCT.19,20 Pentacam and Orbscan gave more similar results that were also consistent with ultrasound pachymetry measurements. However, the advantages of the former two methods compared to ultrasound are the convenience of a non-contact procedure and less dependency on operator experience.

### ANTERIOR CHAMBER DEPTH

Anterior chamber depth measurement studies comparing optical and ultrasonic methods showed that optical methods had acceptable results with small (<5%) differences, whereas ultrasound values for ACD were much lower (10% to 15%) than all other optical methods.23,24

In the present study, mean ACD values for the Pentacam and Visante OCT were found to be similar whereas Orbscan measured ACD shallower than the other two methods. The only significant difference was between Orbscan and Pentacam ($P=.009$). None of the mean differences were higher than 5% (Table 2).

It is well known that ACD changes according to the accommodative status of the eye. Baikoff et al25 showed a 300-µm decrease in ACD when the curvature of the lens increased after +10.00 D of accommodation. The accommodation process is the result of the ciliary muscular contraction that can be induced by near fixation.26 Because there is no system to block this accommodation in the Pentacam and Orbscan, shallowing of ACD as a result of accommodation is expected. In Visante OCT, however, there is a distant fixation target to impede the accommodation. In the current study, all measurements were done in the same room under mesopic conditions and without cycloplegic medication. The mean ACD result of the Pentacam was simi-
lar to that of Visante OCT, and Orbscan values were apparently lower.

In Pentacam and Orbscan, ACD measurement is automatically acquired by the device, whereas in Visante OCT the vertex point is marked by the operator and the measurements are done manually. This presumably may prevent errors due to fixation loss of the patient. A half-millimeter deviation from the corneal vertex results in a 20-µm decrease in ACD and a 1-mm deviation results in a 63-µm decrease.27 Although the fully automatic methods are less dependent on operator experience, errors such as fixation loss may occur during the measurements.

In previous studies that evaluated ACD in healthy patients, mean values for Visante OCT were 3.12 to 3.64 mm,18,27,28 Orbscan 3.23 to 3.35 mm,24,29,30 and Pentacam 3.37 to 3.93 mm.23,31,32 Although in clinical practice the distance from anterior cornea to anterior lens (as in the IOL power calculation) is typically used, in this study ACD does not include corneal thickness to eliminate corneal differences from interfering with actual results.

Overall, our results are similar to other studies. Orbscan measurements were found to be lower than with the other two methods. Excluding corneal thickness, Lee et al14 measured a mean ACD of 2.91 mm using Orbscan, which was found to be similar to ultrasonic biomicroscopy readings for the same patients. The great variability of ACD values in different studies is possibly related to the age of participants and cases selected for the study. It is known that ACD decreases with age.25

**PUPIL DIAMETER**

Because pupil diameter is influenced by the light of the media and reduces in size with accommodation, the Pentacam and Orbscan cannot provide clinically useful information prior to refractive surgery. As previously mentioned, visible light is utilized by these two devices, which may explain the reason why pupil diameters are measured smaller (Table 1). The use of an infrared light source and a mechanism to fixate on a distant subject may keep pupil size unaltered in Visante OCT.

The Orbscan is not a preferred tool for estimating mesopic pupil size.33,34 To our knowledge, there are no studies comparing mesopic pupil size measurements of Pentacam or Visante OCT to infrared pupillometers. Mean pupil diameter was estimated to be 3.04±0.45 mm in a study assessing the reliability of Pentacam anterior segment measurements of volunteers where the pupil diameter measurement showed poor reliability.35

We believe that prior to refractive surgery, more useful pupil diameter measurements can be obtained by Visante OCT compared to the methods using visible light. However, further studies are needed to evaluate
the agreement between the device and other infrared light-using reference methods. Anterior segment measurements are the cut-off point in surgical method decision and appropriate patient selection in various ocular surgeries. For this reason, the reliability of the method is important. In the present study, the greatest differences among the mean measurements of three different optically based devices was found to be 4.4% in CCT and 4.8% in ACD measurements, which account for differences of 25 µm and 0.1 mm, respectively.

This study found some statistically significant but clinically insignificant differences among the optical methods assessed. The differences are so small that they do not influence decisions for refractive surgery in clinical practice.

**AUTHOR CONTRIBUTIONS**

Study concept and design (A.T.Y., E.B., O.F.Y.); data collection (C.A., V.K., G.P.); analysis and interpretation of data (C.A., N.A.); drafting of the manuscript (A.T.Y., N.A., G.P.); critical revision of the manuscript (A.T.Y., E.B., V.K., O.F.Y.); statistical expertise (A.T.Y.);

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