Comparison of Anterior Chamber Depth Measurements by the Galilei Dual-Scheimpflug Analyzer and Conventional A-Scan Ultrasound

Galilei Dual-Scheimpflug Analyzer ve Konvansiyonel A-Tarayıcı Ultrason ile Elde Edilen Ön Kamara Derinlik Ölçümlerinin Karşılaştırılması

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ABSTARCT

Purpose: To compare the anterior chamber depth measurements (ACD) obtained by the Galilei Dual-Scheimpflug Analyzer (GSA) and conventional A-scan ultrasound in healthy subjects.

Materials and Methods: In this prospective study, ACD measurements of 80 eyes of 43 healthy subjects (30 adults and 13 children; 21 females and 22 males; mean age: 27.86±15.32 years) were respectively measured by GSA (Ziemer Group, Switzerland) and ultrasound. The data was analyzed statistically by the Paired-T test, Bland-Altman plot, and Pearson correlation test to assess the agreement of the measurements.

Results: The mean ACD values obtained by GSA and ultrasound were 3.58±0.29 mm and 3.47±0.33 mm, respectively. The mean difference between the ACD measurements obtained by ultrasound and GSA (GSA minus Ultrasound) was 0.11±0.14 mm and the difference between the ACD measurements of these devices was statistically significant ($p<0.001$). There was high correlation between the ACD measurements of GSA and those of ultrasound ($r=0.90$; $p<0.001$).

Conclusions: The ACD measurements of GSA and conventional A-scan ultrasound are highly correlated. GSA measures the ACD on average 0.11 mm longer than conventional ultrasound and this difference may be regarded as clinically insignificant.

Key Words: Anterior chamber depth, dual-Scheimpflug, ultrasound.

ÖZ

Amaç: Galilei Dual-Scheimpflug Analyzer (GSA) ve konvansiyonel A-Tarayıcı ultrason ile sağlıklı bireylerde elde edilen ön kamara derinlik ölçümlerinin karşılaştırılması.

Gereç ve Yöntem: Bu prospektif çalışmada, 43 sağlıklı bireyin 80 gözü (30'u yetişkin ve 13'ü çocuk; 21'i kız ve 22'si erkek; ortalama yaş: 27.86±15.32 yıl) sırasıyla GSA (Ziemer Group, İsviçre) ve ultrason ile ön kamara derinliği için ölçüldü. Ölçümler arasındaki uyumluluk için; veriler Paired-T test, Bland-Altman plot, and Pearson korelasyon testi ile incelendi.

Bulgular: GSA ve ultrason ile elde edilen ön kamara derinliği sırasıyla 3.58±0.29 mm and 3.47±0.33 mm idi. Ultrason ve GSA ile elde edilen ön kamara derinlik ölçümleri arasındaki fark (Ultrason eksi GSA) 0.11±0.14 mm iken; bu fark istatistiksel olarak anlamlıydı ($p<0.001$). GSA ve ultrason ile elde edilen ön kamara derinlik ölçümleri arasında yüksek korelasyon mevcuttu($r=0.90$; $p<0.001$).

Sonuç: GSA ve ultrason ile elde edilen ön kamara derinlik ölçümleri birbirleriyle yüksek düzeyde koreledir. GSA ön kamara derinliğini, konvansiyonel ultrasondan ortalama 0.11 mm daha uzun ölçmektedir ve bu fark klinik olarak anlamsız sayılabilir.

Anahtar Kelimeler: Ön kamara derinliği, dual-Scheimpflug, ultrason.

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Geliş Tarihi - Received: 14.06.2012
Kabul Tarihi - Accepted: 30.10.2012
Glo-Kat 2012;7: 209-214

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INTRODUCTION

Precise and accurate measurement of anterior chamber depth is important for cataract and refractive surgery. Ocular biometry is critical for obtaining the desired postoperative refractive outcome.[1-3] The determination of ACD is vital in theoretical biometric formulas for routine intraocular lens power calculation[3] and for the implantation of phakic, and accommodative intraocular lenses.[4] The association of a shallow anterior chamber and angle closure glaucoma has been shown in most racial groups and the measurement of ACD may have potential in screening angle closure glaucoma.[5] Although conventional ultrasound biometry is widely used for the evaluation of ACD, this technique is not regarded as the gold standard method. Recently, several non-contact devices have been developed for the assessment of ACD such as partial coherence interferometry,[6-8] scanning-slit topography,[9,10] anterior segment optical coherence tomography,[7,11] and Scheimpflug imaging techniques.[8,10,12] The Scheimpflug imaging technique provides a three-dimensional scan of the anterior segment of the eye by using one or two rotating cameras. These systems are fast and non-contact methods of measuring the cornea and anterior chamber. Although there are many studies which have previously compared the Scheimpflug system with a single camera and other optic or ultrasonic devices for ACD,[8,10-15] there was no study comparing the Dual-Scheimpflug technique and an acoustic device for ACD measurement.

In our prospective study, we compared the ACD measurements obtained by GSA and conventional A-scan ultrasound and assessed the agreement of the ACD measurements of these devices.

MATERIALS AND METHODS

One hundred and six eyes of 30 healthy adults and 28 healthy children, who were examined in our clinic between January 2011 and March 2011, were measured in this study after obtaining informed consent from adult subjects and the parents of the children. The study was approved by the Human Research Ethics Committee and it was conducted in accordance with the tenets of the Declaration of Helsinki.

Participants with any history of ocular surgery, ocular trauma or disease and with refractive error more than ±1 Dioptre (D) were excluded. The measurements of ACD were taken consecutively by the Galilei Dual-Scheimpflug Analyzer (Ziemer Group, Switzerland) and conventional ultrasonic biometry from all eyes by the same experienced ophthalmic technician. All measurements were taken without pupil dilation. The direct contact of the ultrasound probe to the cornea may influence the measurements of ACD obtained by the Scheimpflug camera, and we therefore took the measurements by GSA before performing ultrasonic measurements. The participant was comfortably seated with the chin placed on the chin rest and forehead against the strap. While he or she was looking forward to the fixation target of the GSA, the operator manually focused and aligned the image. One of the indicators of device must be located manually to the corneal apex of the Scheimfplug slit image by using the joystick when the other one is at the center of the pupil at the screen for appropriate alignment of the instrument in the horizontal, vertical, and anterior-posterior axes. When the indicators of device were at the most appropriate position according to the manufacturer's guidelines, the participant was asked to blink once and open the eye widely without moving the eye anymore and a whole scan was performed.

The time taken for the each scan was nearly 2 seconds. Scans with an overall quality over 85% were assumed to be 'reliable'. When an unreliable scan had been taken, it was repeated until a reliable one was obtained. The values of ACD and central corneal thickness (CCT) that the software of GSA automatically determined were used for the analysis. During the measurement, GSA computes the anterior chamber depth as the largest distance between the crystalline lens and the posterior cornea. The final ACD value is automatically determined by the average of valid measurements for all 16 Scheimpflug images at the different angles. Forty-six eyes of 28 healthy children aged between 3 and 7 years (both eyes of 18 children and a single eye in 10 children) were scanned by the GSA for a screening program and 20 eyes of 13 healthy children with reliable measurements of the anterior eye segment were included in the study. We excluded the 26 eyes of the children with low compliance as these measurements were not available for the comparison.

For A-scan ultrasound (Pacscan 300 A A-scan ultrasound, Sonomed Inc., NY, USA), the cornea was anesthetized topically by one drop of Alcaine (Proparacaine Hydrochloride 0.5% , Alcon, Fort Worth, Texas, USA) and five minutes later a complete ocular biometric measurement was performed with the participant seated upright while looking the fingertip located 30 cm apart from the eye in order to provide a similar accommodative condition with GSA. The ultrasonic velocity was set at 1532 m/s and the frequency of the ultrasound probe was 20 MHz. A handheld straight probe was aligned as perpendicular as possible on the central cornea by the same technician, while taking measurements. The mean of at least three consecutive ACD measurements with the lowest standard deviation (SD<0.05) was used for the analysis.

GSA measures the anterior chamber depth as the distance from the corneal endothelium to the anterior surface of lens, whereas ultrasound measures ACD from the anterior corneal surface. Therefore, the central corneal thickness obtained by GSA was added to the ACD measurement of GSA.

Statistical Analysis

The data on the age and sex of the patients, spherical equivalent and the ACD values taken by both devices were recorded and statistical analysis was performed by SPSS 16 (SPSS Inc, Chicago, Illinois, USA) for Windows and MedCalc version 11.2. The Paired -T test was used to compare the means of the two dependent groups and the Pearson correlation test was used to investigate the relationship and correlation between the ACD readings by ultrasound versus those by GSA. For the statistical tests, a P-value of less than 0.05 indicated statistical significance. The agreement between the two methods was also investigated by using the Bland-Altman plot and the mountain plot. Sample size and power calculations were performed by the PS- Power and Sample Size Calculator (Version 3, January 2009, by Dupont and Plummer). For the sample size of 80 eyes, the power of the study was calculated as 87.1% to detect a difference in mean ACD measurement of 0.1 mm at a significance level of 5% with an estimated standard deviation of 0.2 mm.

RESULTS

Eighty eyes of 43 healthy persons (30 adults and 13 children) were evaluated in our study; 48.8 percent of the patients were female and the rest (51.2%) were male (21 female, 22 male) and the mean age was 27.86±15.32 (range in adults: 19-59 years; range in children: 3-7 years). The mean spherical equivalent of the participants was -0.06±0.50 D (range:-1.00 D to +1.00 D). The mean ACD values obtained by GSA and UP were found to be 3.58±0.29 mm and 3.47±0.33 mm, respectively and the difference was statistically significant ($p<0.001$).

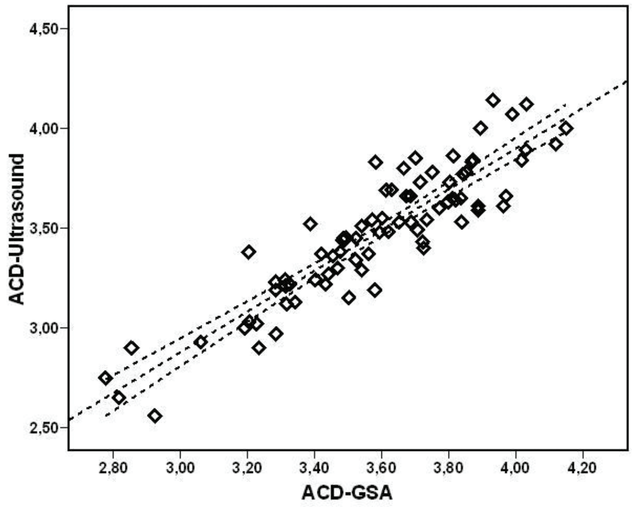

Figure 1: *A scattergraph of ACD as measured by ultrasound versus GSA shows a high correlation between the devices.*

The mean difference of ACD measurements between these devices (GSA minus Ultrasound) was 0.11±0.14 mm. There was high correlation between ultrasound and GSA for the ACD measurement ($r=0.90$, $p<0.001$; Pearson's correlation coefficient). In figure 1, the correlation between the ACD values obtained by the two devices are shown in a graph. The distribution of the difference between the ACD measurements of the devices is shown in Figure 2 (Ultrasound minus GSA). The Bland-Altman plot (Figure 2) showed that most of plotted points of Ultrasound-GSA differences were within the 95% confidence limits for the mean difference. A total of 76/80 (95%) UP-GSA differences were within the 95% confidence interval for the mean difference and 95% of the differences between ultrasound and GSA were between 0.17 mm and -0.39 mm. Figure 3 shows a mountain plot analysis demonstrating percentiles of the differences in the distribution of the ultrasound minus GSA values. It appears that the median of the differences is close to -0.1 mm. The ACD measurements obtained by GSA and those taken by ultrasound were negatively correlated with age (r=-0.38, p=0.001 and r=-0,558, p<0.001, respectively).

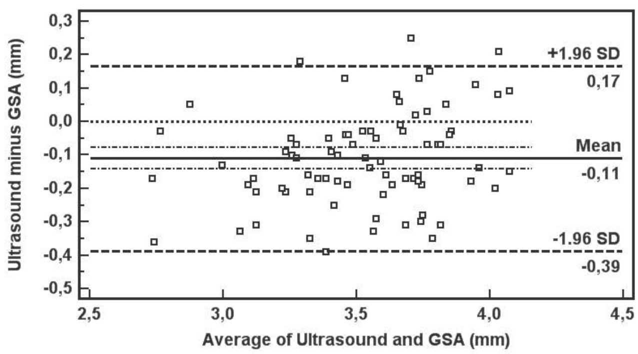

Figure 2: *A Bland-Altman plot shows the difference between ultrasound and GSA (Ultrasound minus GSA) for the measurement of ACD.*

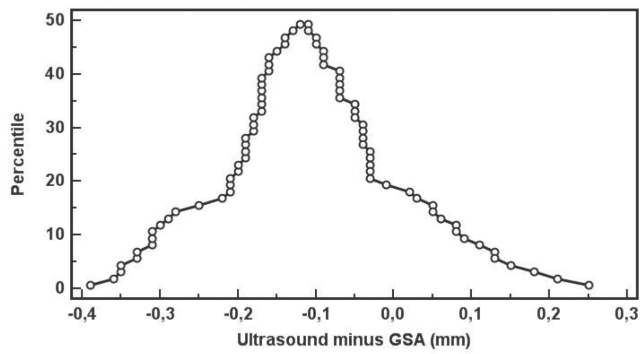

Figure 3: *A Mountain plot demonstrating the percentiles of differences in the distribution of Ultrasound minus GSA values.*

While there was no significant correlation between spherical equivalent and the measurements of ACD ($p>0.05$) because of limited refractive range, the ACD measurements taken by GSA and ultrasound were positively correlated with the axial length of the eyes ($r=0.536$; $p<0.001$; $r=0.415$; $p<0.001$, respectively). The mean central corneal thickness was 566±34.26 µm. The mean ACD measurements in children obtained by GSA and ultrasound were 3.72±0.20 mm and 3.76±0.20 mm, respectively and in adults they were 3.53±0.30 mm and 3.37±0.31 mm, respectively. Children had deeper anterior chamber than the adults and this difference was statistically significant ($p<0.001$).

DISCUSSION

Intraocular lens power (IOL) calculation is one of the most important steps for acquiring best refractive outcome in cataract surgery. After the surgery, the position of the IOL relative to the cornea has a major effect on the refractive status of the patient.[3,16] Some formulas of IOL power calculation have therefore been developed and used for this reason.

The determination of ACD is also necessary for the phakic or accommodative IOL implantations and excimer laser photorefractive keratectomy.[4] As larger ablation areas may be required with a deep anterior chamber, ACD can be important to set a correct optical zone ablation diameter in laser refractive surgery.[17] The measurement of ACD also has potential in screening for primary angle closure glaucoma.[5,18]

Although conventional A-scan ultrasound is known as the most popular method for measuring the depth of the anterior chamber,[19] some non-contact methods and devices have begun to be widely used for this purpose. Partial coherence interferometry (IOLMaster; Carl Zeiss Meditec, CA, USA), scanning slit topography (Orbscan; Bausch&Lomb, Rochester, NY, USA), anterior segment optical coherence tomography (AS-OCT; Visante, Carl Zeiss Meditec, CA, USA) and the Sheimpflug imaging systems (Pentacam; Oculus, Wetzlar, Germany and Galilei Dual-Scheimpflug analyzer; Ziemer Group, Switzerland) are commonly used as non-contact methods in clinical practice. There is no gold standard method for the measurement of ACD, and many studies comparing these different methods have previously been performed.

Table: *Comparison of ACD measurements by Scheimpflug imaging systems and those by other devices.*

Authors	Scheimpflug Device	Other Device	ACD Difference (mm)	P
Reuland et al.[14]	Pentacam	IOLMaster	0.05	0.01
Su et al.[15]	Pentacam	IOLMaster	0.06	<0.001
Meinhardt et al.[25]	Pentacam	IOLMaster	0.285	<0.05
Elbaz et al.[13]	Pentacam	IOLMaster	0.099	<0.01
Savant et al.[26]	Pentacam	IOLMaster	-0.02	0.29
Nemeth et al.[8]	Pentacam HR	IOLMaster	0.06	0.29
*Savini et al.[27]	Pentacam	Ultrasound- Immersion	0.43	<0.001
**Szalai et al.[12]	Pentacam HR	Ultrasound-Contact	-0.11 &-0.19	<0.001
Nemeth et al.[30]	Pentacam	Ultrasound-Contact	-0.02	0.84
Liang et al.[28]	Pentacam	Ultrasound- Immersion	0.08	<0.001
Utine et al.[20]	Pentacam Pentacam	Orbscan IOLMaster	0.05 0.11	0.01 <0.001
Doors et al.[11]	Pentacam Pentacam	Orbscan AS-OCT	0.08 -0.07	<0.001 <0.001
Salouti et al.[10]	Pentacam HR Pentacam HR GSA	GSA Orbscan Orbscan	0.03 -0.29 -0.32	0.013 <0.001 <0.001
Patel and Pandit [29]	GSA	IOLMaster	0.12	<0.001

** The study was performed only in pseudophakic eyes.*
*** In this study interoperator reliability was investigated so it has two quantitative results belonging to two different operators.*
ACD Difference (mm): The difference between the means of anterior chamber depth measurements of the devices.
Pentacam HR is the latest version of Pentacam device.
AS-OCT: Anterior Segment Optical Coherence Tomography.
GSA: Galilei Dual-Scheimpflug Analyzer.

It was reported that the anterior chamber depth is underestimated[20] or overestimated[21] when comparing the measurements taken by the IOL Master with those by Orbscan although they were highly correlated. Frisch et al.,[22] found that there was no significant difference between these devices for ACD; however, these devices use a different technology. Lee et al.,[9] compared Orbscan IIz and ultrasound biomicroscopy (UBM) in phakic eyes and they found that the mean ACD with the Orbscan IIz was less than that with UBM and this difference was statistically significant. It was previously reported that the values of ACD obtained by conventional A-scan ultrasound are generally less than those by the IOL Master or Orbscan.[6,21] The applanation effect of the ultrasound probe may result in shorter ACD measurements than those obtained by non-contact methods.

The ACD values taken by AS-OCT are generally higher than the IOL Master[6,7,23] and immersion ultrasound biometry.[24] AS-OCT, Pentacam, and Orbscan II were compared in healthy phakics and in patients with phakic IOL by Doors et al. and they found that Orbscan II underestimated ACD compared to AS-OCT and Pentacam measurements, and AS-OCT overestimated ACD when compared to Pentacam measurements in both groups.[11]

Pentacam is the first commercially available Scheimpflug system and it provides three dimensional imaging of the anterior segment. Several studies were performed for comparing the ACD measurement of Pentacam with other devices (Table). It was shown that Pentacam generally overestimated ACD compared to the measurements of the IOL Master[13-15,25] and this difference between these devices was statistically significant. Savant et al. compared the ACD by Pentacam and those by IOL Master in 50 eyes of 25 healthy volunteers and they found that the Pentacam minimally underestimated ACD in contrast to other studies although there was no statistically significance.[26] Recently, Nemeth et al.[8] reported that there was no statistically significant difference between Pentacam HR, the latest version of Pentacam that provides high quality images and more accurate measurements of anterior segment, and IOL Master for ACD measurement. However, the ACD values of Pentacam HR were minimally higher than the values of the IOL Master. The Pentacam produces generally larger ACD values than ultrasound biometry in phakic and pseudophakic eyes.[13,15,27,28] Szalai et al.[12] recently compared the ACD measurements of Pentacam HR and those of conventional A-scan ultrasound in healthy phakic subjects. While they showed a high correlation between the devices for ACD, there was a statistically significant difference between the ACD measurements of these devices ($p<0.001$). Utine et al.[20] measured the ACD in 42 myopic and emmetropic eyes of 42 patients by Orbscan IIz and Pentacam and found that Orbscan ACD measurements were an average of 0.05 mm less than Pentacam measurements ($p=0.01$). GSA is the dual-Scheimpflug imaging system that has two rotating Scheimpflug cameras instead of one, in contrast to Pentacam, and these oppositely located cameras provide an improvement of the image and the accuracy of the measurements even when the camera is decentered due to micromovements of the eye. Salouti et al.[10] compared GSA, Pentacam HR, and Orbscan II for ACD in 74 eyes of 37 healthy subjects, and in contrast to the study results of Utine et al.[20] they reported that Orbscan measurements were larger than the measurements of both devices ($p<0.001$) and they found no significant difference between the GSA and Pentacam HR (Table).

Recently, Patel and Pandit assessed the agreement of GSA and IOL Master for ACD measurement and found that these devices were highly correlated for ACD measurement, and the GSA measured on average 0.12 mm longer than the IOL Master.[29] To the best of our knowledge, this is the first study to compare the ACD measured by the Scheimpflug system with double cameras and those by the ultrasonic method and assess the agreement of the ACD measurements of these devices in healthy subjects. In our prospective study, we found the mean difference of ACD values obtained by GSA and UP to be 0.11±0.14 mm and the difference was statistically significant ($p<0.001$) with high correlation between ultrasound and GSA for the ACD measurement ($r=0.90$, $p<0.001$; Pearson's correlation coefficient). Nearly all measurements between the two devices were within 95% limit of agreement in our study. The small difference of the measurements between the devices may have resulted from the indentation effect of the ultrasound probe and the effect of the difference in central corneal thickness. A good correlation between the CCT measurements of GSA and ultrasound in healthy subjects was previously reported[31] and the possible difference between the CCT measurements of these devices may have a clinically unimportant effect on the measurements of ACD. Ultrasound with immersion is generally used to eliminate the effects of probe applanation and central corneal thickness. Giers and Epple[32] reported that ACD measured by contact A-scan ultrasound was 0.3 mm less than those by ultrasound with immersion.

GSA measures the ACD on average 0.11 mm longer than ultrasound and this small difference would result in an alteration of less than 0.1 Dioptre for target refractive error when performing an implantation of posterior chamber IOL. The difference between the ACD measurements of GSA and ultrasound is similar to the differences between Pentacam and the other devices (Table).

GSA is non-contact method that can also take precise measurements of ACD in preschoolers but the cooperation of the child is an important factor to get a reliable measurement. The ACD measurements of GSA and conventional A-scan ultrasound were highly correlated in our study though they are technically different devices and the difference between the ACD measurements of the devices may be regarded as clinically unimportant although it is statistically significant.

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