Preoperative Anatomy Parameters in Implantable Collamer Lenses

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Research Article

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Abstract

**Purpose:** To determine patient preoperative anatomical features and the parameters of implantable collamer lenses (ICLs) relevant in explaining vault variability.

**Setting:** Ophthalmology Xi’an Aier Gucheng Eye hospital, Xi’an China.

**Design:** Retrospective case series.

**Methods:**

This study comprised 88 eyes of 45 patients implanted with myopic or toric ICLs between May 2021 and August 2021. Pentacam imaging was used for assessing white-to-white (WTW) diameter, central keratometry, anterior chamber depth (ACD), central corneal thickness and vault. Anterior-segment optical coherence tomography (AS-OCT) was used to measure the horizontal anterior chamber angle distance (ATA). Ultrasound biomicroscopy (UBM) was used to measure horizontal and vertical sulcus to sulcus (vSTS). According to different ACD, we divide ACD into shallow group (2.8 to 3.2 mm), medium group (3.2 to 3.5 mm), and deep group (3.5 mm).

**Results:** Linear regression analysis found significant correlation between WTW diameters and ATA diameters ($y = 0.9605x + 0.1491$, $R^2 = 0.9148$), with a coefficient of determinant of 0.9148 ($P < 0.01$). Linear regression analysis found significant correlation between hSTS and vSTS ($y = 0.9855x - 0.0178$, $R^2 = 0.1979$), with a coefficient of determinant of 0.1979 ($P < 0.01$). WTW diameters showed statistically significant difference in shallow and medium ACD ($t = -3.28, P < 0.01$), significant difference in shallow and deep ACD ($t = -4.69, P < 0.01$), there was no correlation in medium and deep ACD ($t = -1.41, P < 0.05$). There was a statistically significant correlation between WTW diameters and hSTS diameters when the ACD was less than 3.5 mm ($t = -0.451, P = 0.000$) ($t = 1.406, P = 0.026$), but weak correlation when the ACD was bigger than 3.5 mm ($t = 1.594, P = 0.051$). ATA and WTW with a mean difference close to zero (-0.66 mm). Despite the relatively high correlation (intraclass correlation coefficient = 0.689), the range of agreement is quite broad (1.33 mm).

**Conclusions:**

ATA measured with AS-OCT cannot be used interchangeably with WTW obtained with Pentacam. WTW diameters and hSTS diameters have a statistically significant correlation when the ACD was less than 3.5 mm. WTW, ATA, hSTS, and vSTS all should be considered during design the size of lens and regulating the vault after surgery.

**Background**

In recent years ICL surgery has already been proved for its safe, stable and effective for correction of high myopia. With the advantage of reversibility, fast visual recovery, no flap-related complications compared with corneal laser surgery, it has been demonstrated the importance in refractive surgeries. As a posterior
chamber phakic intraocular lens, considering that the ICL haptics is placed in the ciliary sulcus of the posterior chamber, it's significant to assess the biometric data of the anterior segment before surgery. In order to reduce the postoperative complications and improve the results, it's necessary to evaluate the biometric data of the anterior segment such as internal anterior chamber depth, white to white, angle to angle distance, sulcus to sulcus diameters.

As we know, in clinical surgery there are still some complications related with vault which just defined as the distance between the ICL and the anterior crystalline lens surface. Low vault may lead to cataract, toric lens rotation, high vault may produce anterior chamber angle closure, or even develop glaucoma.

Most doctors now choose the ICL lens size by imputing the parameters like WTW, ACD, using the online calculation provided by manufacturer (STAAR Surgical Co.) to calculate. When using WTW diameter to calculate the lens size, high vault (750 mm) accounts for 17.6%, low vault (250 mm) accounts for 23.5%. Parker tried using STS diameter to calculate the lens size since the ICL haptics were placed in the ciliary sulcus.

we speculated that the large difference between WTW-STS distance is a risk factor which directly lead to inappropriate vault. So alternative methods using STS diameters or ATA diameters have been proposed to calculate. UBM is the only direct sulcus measurement method. AS-OCT is an alternative technique for assessing the transverse size of the eye. It's assessment is more convenient for the patient and less operator-dependent compared to UBM. Yabo Yang mentioned different devices judge different results of anterior segment.

At present, there is no established gold-standard method of the accuracy of anterior segment parameter measurement with different devices. In this study, we aim to study and the relationship between WTW and ATA, and the variance between WTW-STS distance in different ACD groups.

Materials And Methods

This single-center, retrospective cohort study was approved by the institutional review board of Xi’an Gucheng Aier Eye hospital followed the tenets of the Declaration of Helsinki. Prior informed consent was obtained from the subjects. Patients who did phakic intraocular lens surgery during May 2021 to August 2021 in Xi’an Gucheng Aier Eye hospital were enrolled in this study. Subjects with cataract, infectious diseases and glaucoma were excluded.

Examination

The patients were examined on Scheimpflug camera (Pentacam HR; Oculus Optikgeräte GmbH, Germany), UBM (MD-300L, Tianjin, China) and anterior segment OCT (slit-lamp adapted OCT, SL-OCT, Heidelberg, Germany). Examinations like WTW were automatically evaluated on Scheimpflug camera,
ATA evaluated from AS-OCT, STS measured from UBM. Using the online Calculation and Ordering System (OCOS) provided by the manufacture to order lens.

**UBM (MD-300L, Tianjin, China)** All patients were detected with UBM for preoperative STS in horizontal and vertical position. Exams were performed by an experienced technician. The patient was in supine position, fully anesthetized and conjunctival place a suitable eye cup in the capsule and drip 0.1 ml of corneal protective agent (Xiaolai Wei, aierjian company), and then inject distilled water contact agent. A full view scan of the anterior segment was obtained at the 3- to 9-o'clock and 6- to 12-o'clock positions with the probe held perpendicular to the eyes, when the STS was captured clearly, the end of the high reflective line on the back surface of the iris was defined as the ciliary sulcus. It was measured manually using a digital caliper. After 3 times measurements, the mean STS value was recorded.

**Anterior segment parameters measurement AS-OCT (slit-lamp adapted OCT, SL-OCT, Heidelberg, Germany)** is used to check that the light source is 1300nm infrared diode laser. The imaging resolution is 10 μm, the scanning speed is 1 frame/s, the scanning area width is 15mm and the depth is 7mm. During the examination, the patient take the sitting position, place the lower jaw on the lower jaw support, and adjust the eye position. The patient looks at the scanning direction of the aiming light, and the examiner ensures that the scanning site is in cornea center through the video monitor. The angle-to-angle (ATA) diameter was defined as the distance between the angle recesses on the nasal and temporal sides. ATA were measured by drawing calipers. After 3 times measurements, the average value was calculated.

**Pentacam HR (Oculus; GmbH, Germany)**

The Pentacam HR three-dimensional anterior segment panoramic analyzer of oculus company in Germany is used to measure the WTW and ACD. All examinations are completed by the same examiner. During the measurement, take the sitting position, fix the subject's head position, keep the horizontal position of both eyes on the same straight line, ask him to look at the black circle in the center of the blue light band in front, and focus accurately with the joystick. The instrument automatically starts and completes 360 scanning within 2s. The results only used when quality standard shows "OK", after 3 measurements, select the horizontal section, record the ACD and the WTW. According to different ACD, we divide ACD into shallow group (2.8 to 3.2 mm), medium group (3.2 to 3.5 mm), and deep group (≥3.5 mm).

**Statistical analysis**

IBM SPSS23.0 software was applied to perform statistical analysis. Normal distribution of all data sets was evaluated with the Kolmogorov–Smirnov test. Differences of the two devices were evaluated with a paired sample t-test. It was considered to be statistically significant when p < 0.05. Bland–Altman plots were used to evaluate the agreement between two devices. Intraclass correlation co-efficients were calculated. Statistical significance of inter-device differences between measurements was evaluated by one-way analysis of variance (ANOVA). Data were analyzed using SPSS software (version 16.0, SPSS, Inc.).
Results

This study enrolled 88 eyes of 45 patients, the mean age of the patients was 28.49 ± 5.48 years (range 17–42 years). The preoperative manifest refraction spherical equivalent was −8.07 ± 2.76 diopters (range: 0 to−17D).

Table 1. shows descriptive statistics for WTW obtained with Pentacam, ATA obtained with Ag-OCT, hSTS and vSTS obtained with UBM.

Table 2 shows the difference between WTW diameters, ATA diameters, horizontal and vertical STS diameters in different ACD. All parameters examined three times, the average value were taken. According to different ACD, 39 eyes in shallow ACD group A (2.8≤ACD<3.2mm), 27 eyes in medium ACD group B (3.2≤ACD<3.5mm), 22 eyes in deep ACD group C (ACD≥3.5mm). WTW showed

11.37±0.26mm, 11.61±0.34mm, 11.76±0.39mm in group A, B and C. The relationship between group AB showed (t=-3.28, P<0.01), group AC showed (t=-4.69, P<0.01), and group BC showed (t=-1.41, P>0.05). There were no significant changes in ATA, hSTS, vSTS among different ACD groups (P>0.05). (Figure 1) shows a comparison of WTW diameters and ATA diameters. Statistically significant correlation was found between WTW diameters and ATA diameters, there was a Linear regression equation (y=0.9605x±0.1491, R² = 0.9148), with a coefficient of determinant of 0.9148 (P<0.01). (Figure 2) shows a comparison of horizontal and vertical STS diameters. There was a linear regression equation between hSTS and vSTS diameters (y=0.9855x-0.0178, R²=0.1979), with a coefficient of determinant of 0.1979 (P<0.01). WTW diameters showed statistically significant difference in shallow and medium ACD (t=-3.28, P<0.01), significant difference in shallow and deep ACD (t=-4.69, P<0.01), there was no correlation in medium and deep ACD. In different ACD, no correlation was found between the ATA diameters, hSTS, vSTS diameters.

Different ACD Groups

In shallow ACD group, significant difference was found between WTW diameters and hSTS (t=-0.451, P=0.000) (Table 3). There was a linear regression analysis between WTW diameters and hSTS, with a coefficient of determinant of 0.0007 (P<0.001). (Figure 3). In medium ACD group, the difference between WTW diameters and hSTS was statistically significant (t=1.406, P=0.026) (Table 3). Linear regression analysis found a statistically significant correlation between WTW diameters and hSTS, with a coefficient of determinant of 0.0007 (P<0.001) (Figure 4). In deep ACD group, the difference between WTW diameters and hSTS was not significant (t=1.594, P=0.051) (Table 3). Linear regression analysis found the correlation between WTW diameters and hSTS diameters with a coefficient of determinant of 0.0007 (P<0.001) (Figure 5).

(Figure 6). Bland Altman analysis showed a mean difference of 0.66mm and the limits of agreement of -1.27 to -0.26 between WTW distance measured by Pentacam and ATA measured by AS-OCT.
Table 1
Comparision of anterior segment parameters by different instruments

| Device(parameter)     | Mean+SD(mm) | Range(mm) |
|----------------------|-------------|-----------|
| AS-OCT(STS)          | 11.75+1.31  | 10.80~12.70 |
| AS-OCT(ATA)          | 11.60+0.42  | 11.10~13.20 |
| Pentacam WTW         | 11.54+0.36  | 10.80~12.30 |
| Pentacam ACD         | 3.30+0.274  | 2.80~4.04   |
| UBM(hSTS)            | 11.37+0.76  | 7.78~12.70  |
| UBM(vSTS)            | 11.90+0.53  | 10.28~13.10 |

WTW=WTW white to white,STS= sulcus to sulcus,ACA =angle to angle,ACD anterior chamber depth

Table 2
Anterior segment parameters in different ACD groups

| Mean(mm)±SD          | Group    | Eyes | WTW(mm) | ACA(mm) | hSTS(mm) | vSTS(mm) |
|----------------------|----------|------|---------|---------|----------|----------|
|                      | Shallow  | 39   | 11.37±0.26 | 12.13±0.50 | 11.19±0.98 | 11.85±0.50 |
|                      | Medium   | 27   | 11.61±0.34 | 12.31±0.30 | 11.44±0.52 | 11.88±0.51 |
|                      | Deep     | 22   | 11.76±0.39 | 12.29±0.44 | 11.60±0.43 | 12.03±0.61 |
| t                    |          |      | t AB-3.28 | t AB-1.68 | t AB-1.19 | t AB-0.26 |
|                      |          |      | t AC-4.69 | t AC-1.23 | t AC-1.89 | t AC-1.26 |
|                      |          |      | t BC-1.41 | t BC 0.24 | t BC-1.21 | t BC-0.94 |
| P Value              |          |      | PAB<0.01* | PAB>0.05 | PAB>0.05 | PAB>0.05 |
|                      |          |      | PAC<0.01* | PAC>0.05 | PAC>0.05 | PAC>0.05 |
|                      |          |      | PBC>0.05  | PBC>0.05 | PBC>0.05 | PBC>0.05 |

Shallow (2.8mm≤ACD<3.2mm), Medium (3.2mm≤ACD<3.5mm),Deep(ACD≥3.5mm),Note:WTW=white to white,STS sulcus to sulcus,h=horizontal,v=vertical,ACA angle to angle,all parameters showed Mean± SD,Paried t test
Table 3. Comparison of WTW diameters and horizontal sulcus to sulcus diameters.

|                  | Mean (mm) ±SD | hSTS | P Value |
|------------------|---------------|------|---------|
| **Group**        | **WTW**       | **hSTS** |         |
| Shallow ACD      | 11.38±0.25    | 11.20±0.96 | 0.000*  |
| Medium ACD       | 11.64±0.32    | 11.70±0.66 | 0.026*  |
| Deep ACD         | 11.75±0.39    | 11.60±0.43 | 0.051   |

hSTS = horizontal sulcus to sulcus, ACD = anterior chamber depth, WTW = white to white

Discussion

Analysing anterior segment parameters plays a significant role in choosing the appropriate PIOL size.[8–13]. As we know, now most doctors choose lens size using WTW through online calculation system. The ICL lens size usually by adding the WTW distance with 0.5 to 1.0 mm[14]. It may lead to cataract when choosing a smaller lens[15], and increase the risk of angle-closure glaucoma when choosing a bigger lens[16]. Inappropriate size can lead to toric lens instability, develop ocular hypertension, iritis, or lesions in the corneal endothelium[17, 18]. Theoretically more parameters like the ATA distance and ciliary STS diameter play a great role in the design the size of lens. Many studies compared the horizontal WTW and vertical WTW values using different devices, the average values of the two were 11.5 ~12.5 mm[19–23] and 10.6 mm.[24, 25]

Our study showed that the horizontal WTW values of between 10.8 mm and 12.3 mm which just similar as previous studies[26, 27]. Baikoff et al[28] found that in 74% of eyes, vertical ATA distance was at least 100 mm greater than the horizontal ATA distance, 50% of eyes was greater more than 300 mm, but still controversial and need proved in further studies. In our study, we found that vertical STS distances to be higher than the horizontal values which also proved in previous studies[29]. Oh et al[30] found the ciliary sulcus shape was vertically ovoid, which makes the issue more complicated. We found there was also a significant relationship between horizontal and vertical STS measured by UBM(y=0.9855x-0.0178, R² = 0.1979). This finding just suggest that the position of different implant lens in horizontal and vertical can be affected by the shape of sulcus, so we could regulate the vault by adjust the position of lens.

Unfortunately, we did not use UBM to measure the position of the ICL haptic in the current study, which will need to be done in the future to confirm the possible relationship between the position of the ICL haptic and the shape affecting the vault.

Comparing WTW and ATA, Pinero et al[31] found that the WTW distance was bigger than the ATA distance, Baikoff[28] found the WTW distance similar to ATA distance, Reinstein et al[32] found the WTW
distance to be smaller. Our data agree with the results of Reinstein et al.\textsuperscript{[32]} Anterior segment parameters measured by different machines and different method of measurement all affect much to the results. In our study significant correlation was found between the WTW distance and the horizontal ATA distance (\( y = 0.9605x \pm 0.1491, R^2 = 0.9148 \)), similar to results of Reinstein et al.

Different results for the relationship between ATA and WTW also been studied, Dinc et al\textsuperscript{[33]} found that WTW measured by IOLMaster 500 and WTW measured by Scheimpflug camera showed significant difference. But insignificant difference were found between ATA obtained from anterior segment OCT among WTW obtained by IOLMaster 500 or WTW measured by Scheimpflug camera. Dinc concluded that ATA can be used interchangeably with WTW. Nemeth et al\textsuperscript{[34]} found that WTW and ATA measured by partial coherence interferometry biometer had a quite weak correlation (\( r = 0.51 \)). He demonstrated that ATA cannot be used interchangeably with WTW. In our study, we agree with Nemeth since our results proved that Bland-Altman plots show statistically significant differences between AS-OCT ATA and Pentacam WTW with a mean difference close to zero (-0.66 mm). Despite the relatively high correlation (intraclass correlation co-efficient = 0.689), the range of agreement is quite broad (1.33 mm). It was not clinically acceptable for designing the size of lens. (Figure 6). This indicates that ATA measured by AS-OCT and WTW measured by Pentacam cannot be used interchangeably.

Our study found that although there was a significant correlation between ACD the WTW distance, there was no correlation between ACD with hSTS and vSTS measured with the UBM device, no correlation between the ACD and the ATA distance measured with the AS-OCT device, just because the reproducibility of UBM is not very good, and all measured manually except WTW measured by the system automatically.

The results showed in our study, only when ACD was less than 3.5 mm there was a significant correlation between WTW and hSTS diameters. So when using WTW diameters to predict sulcus sizes may not be accurate especially ACD greater than 3.5 mm. The ICL lens size are currently sized to the nearest 0.5 mm, with increasing ACDs, the potential error lead to lens size related complication such as cataract, glaucoma, or iris pigment dispersion also increase. Considerable variation between WTW diameter and ciliary STS diameter were also found in many studies\textsuperscript{[35–37]}. They concluded the reason for this variation is unclear, it may be affected by the light conditions may be related to the basic information (age, refraction, eg), or the variation between WTW and ACD diameters.

There are several limitations. Firstly, UBM has poor repeatability and relies heavily on inspectors. So even experienced inspector might affect the result. Secondly, when the Scheimpflug camera automatically obtains the WTW value. The different light condition has an impact on the system measurement especially WTW defined as grey-scale photography of the eye and sclera-cornea boundary (limbus), the reflectivity of the tissue might affect results. Thirdly, samples were small, further studies still need to confirm our data.

\textbf{Conclusion}
In conclusion, ATA measured with AS-OCT can not be used interchangeably with WTW obtained with Pentacam. Significant correlation was found between WTW diameters and horizontal sulcus diameters when the ACD was less than 3.5 mm. The accurate realization of the internal dimensions like WTW, ATA, hSTS, and vSTS are essential for the implantation of an appropriately sized phakic IOL, providing additional safety to the patients and decreasing the rate of postoperative complications.

**Abbreviations**

ICL
- implantable collamer lenses

IOL
- Phakic intraocular lens

WTW
- white-to-white diameter

ACD
- anterior chamber depth

AS-OCT
- Anterior-segment optical coherence tomography

UBM
- Ultrasound biomicroscopy

hSTS
- horizontal sulcus to sulcus

vSTS
- vertical sulcus to sulcus

ATA
- horizontal anterior chamber angle to angle distance

**Declarations**

**Ethics approval and consent to participate**

Written informed consent was obtained from all individual participants included in the study. Ethical approval by Xi’an Gucheng Aier Eye hospital.

**Consent for publication**

Not applicable (no identifying patient data).

**Availability of data and material**

The datasets used and/or analyzed during the current study are available from the first author upon reasonable request.
Competing interests Not applicable

Funding Not applicable

Authors' contributions

Yanzhen Xue contributed to the manuscript as the first authors. Yonghong Guo contributed to the manuscript as the corresponding author. Ruibo Zhao designed the study and provided the required clinical data. Yanzhen Xue collected and analyzed the clinical data. Yanzhen Xue reviewed the design and wrote the draft paper, Yonghong Guo reviewed and edited the final paper. All authors read and approved the final manuscript.

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References

1. Reinstein D Z, Lovisolo C F, Archer T J, et al. Comparison of postoperative vault height predictability using white-to-white or sulcus diameter-based sizing for the visian implantable collamer lens[J]. J Refract Surg, 2013,29(1):30–35.

2. Kato S, Shimizu K, Igarashi A. Assessment of low-vault cases with an implantable collamer lens[J]. PLoS One, 2020,15(11):e241814.

3. Yang W, Zhao J, Zhao J, et al. Changes in anterior lens density after Implantable Collamer Lens V4c implantation: a 4-year prospective observational study[J]. Acta Ophthalmol, 2021,99(3):326–333.

4. Strungaru M H, Gonzalez R J, Weisbrod D J, et al. Acute Angle Closure Following Implantable Collamer Lens for Myopia[J]. J Glaucoma, 2020,29(7):e74-e76.

5. Choi K H, Chung S E, Chung T Y, et al. Ultrasound biomicroscopy for determining visian implantable contact lens length in phakic IOL implantation[J]. J Refract Surg, 2007,23(4):362–367.

6. Reinstein D Z, Lovisolo C F, Archer T J, et al. Comparison of postoperative vault height predictability using white-to-white or sulcus diameter-based sizing for the visian implantable collamer lens[J]. J Refract Surg, 2013,29(1):30–35.

7. Wan T, Yin H, Yang Y, et al. Comparative study of anterior segment measurements using 3 different instruments in myopic patients after ICL implantation[J]. BMC Ophthalmol, 2019,19(1):182.

8. Nakamura T, Isogai N, Kojima T, et al. Implantable Collamer Lens Sizing Method Based on Swept-Source Anterior Segment Optical Coherence Tomography[J]. Am J Ophthalmol, 2018,187:99–107.

9. Allemann N, Chamon W, Tanaka H M, et al. Myopic angle-supported intraocular lenses: two-year follow-up[J]. Ophthalmology, 2000,107(8):1549–1554.

10. Price F W, Parker D A. Horizontal corneal diameter and its implications for implanting sulcus-fixated lenses[J]. J Cataract Refract Surg, 1997,23(8):1131–1132.
11. Rosen E, Gore C. Staar Collamer posterior chamber phakic intraocular lens to correct myopia and hyperopia[J]. J Cataract Refract Surg, 1998,24(5):596–606.

12. Reinstein D Z, Lovisolo C F, Archer T J, et al. Comparison of postoperative vault height predictability using white-to-white or sulcus diameter-based sizing for the visian implantable collamer lens[J]. J Refract Surg, 2013,29(1):30–35.

13. Jonker S, Berendschot T, Saelens I, et al. Phakic intraocular lenses: An overview[J]. Indian J Ophthalmol, 2020,68(12):2779–2796.

14. Sanders D R, Vukich J A, Doney K, et al. U.S. Food and Drug Administration clinical trial of the Implantable Contact Lens for moderate to high myopia[J]. Ophthalmology, 2003,110(2):255–266.

15. Yang W, Zhao J, Zhao J, et al. Changes in anterior lens density after Implantable Collamer Lens V4c implantation: a 4-year prospective observational study[J]. Acta Ophthalmol, 2021,99(3):326–333.

16. Strungaru M H, Gonzalez R J, Weisbrod D J, et al. Acute Angle Closure Following Implantable Collamer Lens for Myopia[J]. J Glaucoma, 2020,29(7):e74-e76.

17. Chaitanya S R, Anitha V, Ravindran M, et al. Safety and efficacy of toric implantable collamer lens V4c model - A retrospective South Indian study[J]. Indian J Ophthalmol, 2020,68(12):3006–3011.

18. Packer M. The Implantable Collamer Lens with a central port: review of the literature[J]. Clin Ophthalmol, 2018,12:2427–2438.

19. Reinstein D Z, Lovisolo C F, Archer T J, et al. Comparison of postoperative vault height predictability using white-to-white or sulcus diameter-based sizing for the visian implantable collamer lens[J]. J Refract Surg, 2013,29(1):30–35.

20. Pop M, Payette Y, Mansour M. Predicting sulcus size using ocular measurements[J]. J Cataract Refract Surg, 2001,27(7):1033–1038.

21. Hashemi H, Khabazkhoob M, Emamian M H, et al. White-to-white corneal diameter distribution in an adult population[J]. J Curr Ophthalmol, 2015,27(1-2):21–24.

22. Singh K, Gupta S, Moulick P S, et al. Study of distribution of white-to-white corneal diameter and anterior chamber depth in study population obtained with optical biometry using intraocular lens (IOL) master[J]. Med J Armed Forces India, 2019,75(4):400–405.

23. Martin R, Ortiz S, Rio-Cristobal A. White-to-white corneal diameter differences in moderately and highly myopic eyes: partial coherence interferometry versus scanning-slit topography[J]. J Cataract Refract Surg, 2013,39(4):585–589.

24. Gharaeae H, Abrishami M, Shafiee M, et al. White-to-white corneal diameter: normal values in healthy Iranian population obtained with the Orbscan II[J]. Int J Ophthalmol, 2014,7(2):309–312.

25. Sanchis-Gimeno J A, Sanchez-Zuriaga D, Martinez-Soriano F. White-to-white corneal diameter, pupil diameter, central corneal thickness and thinnest corneal thickness values of emmetropic subjects[J]. Surg Radiol Anat, 2012,34(2):167–170.

26. Khng C, Osher R H. Evaluation of the relationship between corneal diameter and lens diameter[J]. J Cataract Refract Surg, 2008,34(3):475–479.
27. Werner L, Izak A M, Pandey S K, et al. Correlation between different measurements within the eye relative to phakic intraocular lens implantation[J]. J Cataract Refract Surg, 2004,30(9):1982–1988.
28. Baikoff G, Jitsuo J H, Bourgeon G. Measurement of the internal diameter and depth of the anterior chamber: IOLMaster versus anterior chamber optical coherence tomographer[J]. J Cataract Refract Surg, 2005,31(9):1722–1728.
29. Petermeier K, Suesskind D, Altpeter E, et al. Sulcus anatomy and diameter in pseudophakic eyes and correlation with biometric data: evaluation with a 50 MHz ultrasound biomicroscope[J]. J Cataract Refract Surg, 2012,38(6):986–991.
30. Oh J, Shin H H, Kim J H, et al. Direct measurement of the ciliary sulcus diameter by 35-megahertz ultrasound biomicroscopy[J]. Ophthalmology, 2007,114(9):1685–1688.
31. Pinero D P, Plaza P A, Alio J L. Corneal diameter measurements by corneal topography and angle-to-angle measurements by optical coherence tomography: evaluation of equivalence[J]. J Cataract Refract Surg, 2008,34(1):126–131.
32. Reinstein D Z, Archer T J, Silverman R H, et al. Correlation of anterior chamber angle and ciliary sulcus diameters with white-to-white corneal diameter in high myopes using artemis VHF digital ultrasound[J]. J Refract Surg, 2009,25(2):185–194.
33. Kucumen R B, Yenerel N M, Gorgun E, et al. Anterior segment optical coherence tomography measurement of anterior chamber depth and angle changes after phacoemulsification and intraocular lens implantation[J]. J Cataract Refract Surg, 2008,34(10):1694–1698.
34. Nemeth G, Hassan Z, Szalai E, et al. Comparative analysis of white-to-white and angle-to-angle distance measurements with partial coherence interferometry and optical coherence tomography[J]. J Cataract Refract Surg, 2010,36(11):1862–1866.
35. Pinero D P, Plaza P A, Alio J L. Corneal diameter measurements by corneal topography and angle-to-angle measurements by optical coherence tomography: evaluation of equivalence[J]. J Cataract Refract Surg, 2008,34(1):126–131.
36. Reinstein D Z, Archer T J, Silverman R H, et al. Correlation of anterior chamber angle and ciliary sulcus diameters with white-to-white corneal diameter in high myopes using artemis VHF digital ultrasound[J]. J Refract Surg, 2009,25(2):185–194.
37. Fea A M, Annetta F, Cirillo S, et al. Magnetic resonance imaging and Orbscan assessment of the anterior chamber[J]. J Cataract Refract Surg, 2005,31(9):1713–1718.

Figures
Figure 1

Relationship between white to white and anterior chamber angle measured by anterior segment OCT

\[ y = 0.9605x + 0.1491 \]

\[ R^2 = 0.9148 \]
Figure 2

Relationship between horizontal and vertical sulcus to sulcus measured by UBM
Figure 3

White-to-white against horizontal sulcus diameters in the shallow ACD group. The regression line is plotted as a continuous blue line, and the regression equation and coefficient of determinant are presented.

\[ y = 2.362x - 15.7 \]
\[ R^2 = 0.3486 \]
Figure 4

White-to-white against horizontal sulcus diameters in the medium ACD group. The regression line is plotted as a continuous blue line, and the regression equation and coefficient of determinant are presented.
Figure 5

White-to-white against horizontal sulcus diameters in the deep ACD group. The regression line is plotted as a continuous blue line, and the regression equation and coefficient of determinant are presented.
**Figure 6**

Bland–Altman analysis of differences between Pentacam white to-white (WTW) and anterior segment optical coherence tomography (AS-OCT) angle to-angle (ATA). The solid lines represent the mean difference and the 95% LoA.