Comparison of Vault Measurements Using a Swept-Source OCT-Based Optical Biometer and Anterior Segment OCT

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Background: To newly describe the vault measurement by using a widely used swept-source OCT-based optical biometer (IOLMaster700) and assessed the accuracy of vault measurement.

Methods: This was a retrospective, cross-sectional study. All patients underwent implantable Collamer lens (ICL) implantation surgery without complications. IOLMaster700 and AS-OCT analyses were conducted for each eye on the same day in the same condition. Measurements of anterior chamber depth (ACD), corneal-ICL (C-ICL), and vault values were made and recorded. The repeatability of the IOL Master700 measurements was quantified based upon intraclass correlation coefficient (ICC) values. Correlations between IOL Master700 and AS-OCT measurements made with these different analytical approaches were assessed. The agreement of instruments was evaluated using Bland-Altman plots.

Results: The IOLMaster700 instrument yielded highly reliable measurements of vault, C-ICL, and ACD (ICC = 0.996, 0.995, 0.995, respectively). Vault, C-ICL and ACD values as measured using the IOLMaster700, was slightly smaller than that measured via AS-OCT, but these differences were not significant (p = 0.652, p = 0.121 and p = 0.091, respectively). The vault, C-ICL, and ACD measurements by these two instruments were strongly correlated (r = 0.971, r = 0.944, and r = 0.963, respectively; all p < 0.001). The 95% limits of agreement for vault, C-ICL, and ACD measurements between the two devices were −0.08 to 0.08 mm, −0.14 to 0.11 mm, and −0.13 to 0.10 mm, respectively.

Conclusions: The IOLMaster700 can measure implanted ICL vault with a high degree of accuracy and repeatability. Good correlations and agreement were observed between IOLMaster700 and AS-OCT in measuring vault, C-ICL, and ACD measurements.

Keywords: IOLMaster700, ICL, vault, AS-OCT, C-ICL, ACD
INTRODUCTION

Implantable Collamer lens (ICL) implantation is increasingly common as a safe and efficacious corrective treatment for myopia (1–4). Achieving success when performing ICL implantation necessitates the accurate prediction of refraction and postoperative ICL lens vault, which correspond to the distance between the crystalline lens anterior surface and the ICL posterior surface. Vault is a critical parameter associated with safety outcomes related to ICL implantation, as insufficient vault can result in negative events including pupillary block, pigment dispersion, cataract development, lens exchange, corneal endothelium cell loss, or increased intraocular pressure (IOP) (5–7).

Broadly speaking, an acceptable vault value is between 250 µm and 1,000 µm (8) (or 750 µm) (9) in some reports. ICL vault measurements are commonly performed via anterior segment optical coherence tomography (AS-OCT), ultrasound biomicroscopy (UBM), or with a Pentacam instrument (Oculus, Germany), but no gold standard measurement strategy exists. Indeed, ICL vault values can differ significantly among these different measurement techniques (10).

The IOLMaster700 instrument (Carl Zeiss Meditec AG, Germany) is a recently developed swept-source OCT-based optical biometer that can measure parameters including axial length (AL), anterior chamber depth (ACD), central corneal thickness (CCT), and lens thickness (LT) with a tunable 1,055 nm laser, in addition to permitting visualization and OCT imaging of the full eye (11, 12). Despite the widespread use of the IOLMaster700, it cannot measure vault after ICL implantation directly. In this article, we employed the ImageJ software to measure ICL vault using an IOLMaster700 instrument and evaluated the accuracy of these measurements.

No prior studies have reported on vault measurements made using the IOLMaster700. Therefore, we used this instrument to scan ICL implantation anterior segment parameters in order to evaluate the accuracy of vault measurement by using this new technology.

METHODS

Subjects and Methods

All patients undergoing ICL (Visian V4c, STAAR Surgical, Switzerland) implantation at Joint Shantou International Eye Center of Shantou University and The Chinese University of Hong Kong (JSIEC) were consecutively recruited from September 2020 to December 2021. The current study was approved by the local clinical research ethics committee (No. EC20200609) and was conducted in accordance with the Declaration of Helsinki. The requirement for informed consent was waived due to the retrospective design of the current study. All patients were evaluated during regularly scheduled follow-up.

ICL Calculation and Size Selection

Horizontal white to white (WTW) and ACD values were measured by corneal topography (Orbscan II; Bausch & Lomb, Rochester, NY, USA). AS-OCT (CASIA 1/CASIA 2, Tomey Corp, Japan) was conducted to measure angle to angle (ATA) and crystalline lens rise (CLR). Chiary sulcus was performed by UBM. Ocular biometric measurements were completed by using the IOLMaster700 instrument. ICL power calculations were completed by STAAR Co using the modified vertex formula, and ICL sizes were chosen as per the NK formula (13).

Surgical Approach

Two experienced surgeons (ZMZ, WG) performed all surgical procedures for each subject. A slit-lamp was used to preoperatively mark the zero horizontal axis for toric ICL implantation. Following the application of topical anesthesia, a viscoelastic substance was applied to the anterior chamber.
An injector cartridge (STAAR Surgical) was then used to insert aV4c ICL via a 3.0 mm clear corneal incision such that the ICL was positioned within the posterior chamber. Following correction of the ICL position, the viscoelastic substance was replaced with a balanced salt solution. No patients experienced any surgery-related complications. Postoperatively, patients were administered 0.5 levofloxacin topically and steroidal medications four times per day over a three-week period, with doses being gradually reduced.

**Postoperative Measurement**

Postoperative anterior segment imaging was performed with both the AS-OCT and IOLMaster700 instruments on the same day under identical lighting conditions in the same room. Anterior chamber depth (ACD), corneal-ICL (C-ICL), and vault were documented for further analysis. Vault was defined as the distance from the crystalline lens anterior surface to the ICL posterior surface. ACD, the distance from the crystalline lens anterior surface to the corneal endothelium, was automatically measured using the built-in software. C-ICL was the distance from the ICL anterior surface to the corneal endothelium.

IOLMaster700 measurements were made using a phakic intraocular lens (P-IOL) pattern and B scans at 0 degrees. The parameters of the IOL Master 700 were measured by the same doctor using the ImageJ software (http://rsb.info.nih.gov/ij; National Institutes of Health, Bethesda, Maryland, USA). First, centering on the pupil axis, the corneal thickness was taken as the benchmark. On the pupil axis, anterior chamber depth (ACD), C-ICL and vault were measured by IOL Master 700 images (Figure 1) and converted pixels to millimeters. To assess the repeatability of measurements, a single doctor measured these parameters three times.

AS-OCT (CASIA 1/CASIA 2, Tomey Corp., Japan) measurements were also conducted, with horizontal median images being captured for subsequent analyses. Measurements were made with an on-screen calibration system.

**Statistical Analysis**

Based on a previous study that employed an AS-OCT-based measurement strategy, the average vault was 0.64 mm, with a standard deviation (SD) of 0.25 mm (10). At a significance (α) level of 0.05 and a power (β) of 80%, a sample size calculation indicated that a minimum of 16 subjects would be required to give 80% power at a 5% two-sided significance level to detect a 5% mean difference. The repeatability of the IOL Master 700 measurements was quantified based upon intraclass correlation coefficient (ICC) values. The differences between instruments were analyzed by paired t-test, while correlations between the two instruments were assessed using Pearson correlation coefficient (r) values. Bland and Altman plots were employed to assess the agreement of vault, C-ICL, and ACD measurements between different devices. Measurement variability was evaluated using 95% limit of agreement values (95% LOA = mean agreement). P < 0.05 was the significant threshold.

**RESULTS**

In total, this study enrolled 82 eyes of 43 patients (mean age: 26.03 ± 4.05 years, range: 19 to 36); 19 (44.19%) male, 24 (55.81%) female). The mean follow-up time was 5.04 ± 5.20 months (range: 1–12 months). The baseline characteristics of the study population were shown in Table 1. A non-toric ICL was implanted in 29 eyes (35.4%), while 53 eyes (64.6%) underwent toric ICL implantation.

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**TABLE 1 | Baseline patient characteristics.**

| Parameters       | Value  |
|------------------|--------|
| Age              | 26.03 ± 4.05 (19 to 36) |
| Sex (female, male) | 24/19 |
| Manifest refractive sphere (D) | −10.41 ± 3.17 (−4.75 to −19.5) |
| Manifest refractive cylinder (D) | −1.98 ± 1.34 (0 to −5.5) |
| Axial length (mm) | 28.01 ± 1.71 (24.89 to 31.98) |
| TICL / ICL (n)   | 53/29 |
| Follow-up (months) | 5.04 ± 5.20 (range 1–13 months) |

D, diopter; n, number; mm, millimeter.

**TABLE 2 | Repeatability of IOL Master 700 measurements of vault, C-ICL, and ACD.**

| Parameters | ICC  | 95%lower | 95%upper | p-value |
|------------|------|----------|----------|---------|
| Vault      | 0.996| 0.993    | 0.998    | <0.001  |
| C-ICL      | 0.995| 0.991    | 0.998    | <0.001  |
| ACD        | 0.997| 0.995    | 0.999    | <0.001  |

**TABLE 3 | Comparison of parameters measured using the IOL Master700 and AS-OCT.**

| Parameters  | IOLMaster700 | AS-OCT | T       | p-value |
|-------------|--------------|--------|---------|---------|
| Vault (mm)  | 0.58 ± 0.17  | 0.59 ± 0.18 | −0.453 | 0.652   |
| C-ICL (mm)  | 2.38 ± 0.18  | 2.40 ± 0.19 | −2.574 | 0.121   |
| ACD (mm)    | 3.22 ± 0.22  | 3.24 ± 0.22 | −2.675 | 0.091   |

**TABLE 4 | Agreement and correlations among parameters measured using the IOL Master700 and AS-OCT.**

| Parameters  | AS-OCT | Mean of difference (95% LoA) | Coefficient (r) | P-value |
|-------------|--------|-----------------------------|----------------|---------|
| Vault       | 0.58 ± 0.17 | 0.59 ± 0.18 | 0.00 (−0.08 to 0.08) | 0.971 | <0.001 |
| C-ICL       | 2.38 ± 0.18 | 2.40 ± 0.19 | −0.02 (−0.14 to 0.11) | 0.944 | <0.001 |
| ACD         | 3.22 ± 0.22 | 3.24 ± 0.22 | −0.02 (−0.13 to 0.10) | 0.963 | <0.001 |

Pearson r, Pearson correlation coefficient; LoA, limit of agreement.
FIGURE 2 | Bland-Altman plots comparing the level of agreement between IOL Master 700 and AS-OCT measurements of vault (A), C-ICL (B), and ACD (C). The vertical axis represents the difference between these measurements and the horizontal axis shows the corresponding mean value. The 95% LoA is indicated using dashed lines, and the middle bold line represents the mean difference between these measurements.
Assessment of the Repeatability of Vault Measurements by Using the IOLMaster700

ICC results in Table 2 demonstrated the repeatability of vault measurements, C-ICL measurements, and ACD measurements obtained using the IOLMaster700 instrument, consistent with the high reliability of this technology as a tool for measuring these three parameters (p < 0.001).

Comparison of IOL Master700 and AS-OCT Measurements

Table 3 demonstrates the comparison of parameters measured using IOLMaster700 and AS-OCT approaches. Vault, C-ICL and ACD values as measured using the IOLMaster700 were slightly smaller than measurement with AS-OCT, but there were no significant differences (p = 0.652, p = 0.121 and p = 0.091, respectively).

Correlations and Agreement Between IOL Master700 and AS-OCT Measurements

As shown in Table 4, there were significant correlations between the vault, C-ICL, and ACD values measured via the IOLMaster700 and AS-OCT (r = 0.971, r = 0.944, and r = 0.963, respectively; p < 0.001). Good agreement was observed between the measurement values obtained from the IOLMaster700 and AS-OCT. Bland-Altman analysis plots indicated that the 95% limits of agreement for vault, C-ICL, and ACD measurements were −0.08 to 0.08 mm, −0.14 to 0.11 mm, and −0.13 to 0.10 mm between these two devices, respectively (Figure 2).

DISCUSSION

One of the most important parameters to be assessed after ICL implanted was the measurement of vault (14). Studies had been reported on complications after ICL implantation associated with vault (5–7). Low vault was a risk factor of formation of cataract. High vaults can produce an narrow of the anterior chamber angle at risk of developing increased intraocular pressure. AS-OCT (CASIA) was widely used for vault measurement after ICL implantation. The CASIA system is a swept source OCT that uses a wavelength of 1,310 nm, providing low vaults were a risk factor of the humor can also impact these measurements. Even so, we observed very strong correlations between AS-OCT and IOLMaster700, consistent with clinically acceptable differences between these two devices.

In our study, vault, C-ICL and ACD values as measured using the IOLMaster700, was slightly smaller than measurement with AS-OCT, but these differences were not significant. This may be due to differences in device resolution or scan location. Differences in the refractive indices of ICL materials and the humor can also impact these measurements. Even so, we observed very strong correlations between AS-OCT and IOLMaster700, consistent with clinically acceptable differences between these two devices.
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