Evaluation of Axial Length and Refractive Results in Patients Undergoing Phacovitrectomy Due to Dense Vitreous Hemorrhage: A Prospective Case Control Study

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Research Article

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Abstract

**Purpose:** To evaluate the axial length (AL) measurement and refractive results in patients who underwent phacovitrectomy due to dense vitreous hemorrhage and to investigate the effectiveness of ultrasound (US) biometry in this patient group.

**Methods:** In this single-center study, patients with cataract and dense vitreous hemorrhage (VH) who underwent combined phacovitrectomy procedure (Group 1) and patients with cataract who underwent phacoemulsification procedure as control group (Group 2) were included. AL and biometry were performed with US in group 1 and IOL Master 500 in group 2. Postoperatively, AL and biometry of the patients in group 1 were performed with both US and IOL Master 500. Main outcome measures were preoperative and postoperative AL measured by US and IOL Master and refractive outcomes including refractive prediction error (PE), and absolute prediction error (APE).

**Results:** Median preoperative AL measured by US was 23.33 mm (I), median postoperative AL measured by IOL Master 500 was 23.18 mm (II), and median postoperative AL measured by US (III) was 23.44 mm in group 1 (p=0.04, I- II; p=0.01, I- III; p<0.01, II- III). Preoperative US and postoperative IOL Master 500, and preoperative US and postoperative US AL measurement showed a statistically significant strong positive correlation with a high-reliability coefficient. Median PE and APE were similar between the two groups (p=0.25, p=0.99, respectively).

**Conclusions:** US biometry can be used easily, safely, and effectively in patients with dense vitreous hemorrhage with near the optimal refractive results.

Introduction

Vitreous hemorrhage (VH), associated with blood leaking from ruptured vessels and into the vitreous, is one of the most common causes of sudden vision loss in adults. Although VH can occur for many pathologies, it is often linked with proliferative diabetic retinopathy, retinal tear, retinal vein occlusion, and trauma.[1–3] Pars plana vitrectomy (PPV) remains a standard procedure for persistent VH. PPV can be challenging in eyes with dense cataracts, creating a cloudy environment. Phacovitrectomy, combining phacoemulsification and PPV in a single intervention, provides the advantage of better visualization of the posterior segment during surgery, as cataract is cleaned with phacoemulsification before PPV. Phacovitrectomy has other advantages over sequential surgery, such as the faster recovery of visual acuity and removal of anterior vitreous structures without the risk of touching the lens.[4–7] Biometry must be performed before the surgery as part of a plan to remove the cataract simultaneously or because the lens can be touched iatrogenically.[8, 9]

Axial length (AL) measurement is one of the most critical steps in intraocular lens (IOL) power calculation.[10] Accuracy within 0.1 mm of the measurement is required, as an error of 0.1 mm in AL in normal eyes is equivalent to an error of approximately 0.27 D in the plane of the glasses.[11] Various biometric measuring devices are available today to determine the axial length, such as ultrasound
sensors (contact and immersion), IOL Master (Carl Zeiss Meditec AG [CZM], Jena, Germany), OA-2000 (Tomey, Nagoya, Japan), and Lenstar LS900 (Haag Streit, Switzerland). Studies show that IOL Master with swept-source optical coherence tomography (SS-OCT) and partial coherence interferometry (PCI)-based biometrics is more accurate and has become the “gold standard” in biometrics. [12] On the other hand, in cases of media opacity such as heavy VH and dense cataracts, AL measurement is a bit problematic, especially with PCI-based biometrics. Thus, ultrasonography (US) is still a standard and effective method in patients with VH. Although IOL power calculation in phacoemulsification surgery is more accurate, it is pretty compelling for phacovitrectomy. Cleaning of the vitreous body influences AL and postoperative IOL location, and measurement safety may be lower than standard phaco surgery. In these cases, the results of studies on measuring the accuracy of IOL power have so far been reported to be inconsistent. Besides, the reliability and effectiveness of US, which is the most optimal method for these patients, is still unknown. In our study, we planned to investigate the accuracy of preoperative US on both refractive outcome and AL measurements in patients who underwent phacovitrectomy for dense VH and cataracts.

Methods

This study is a single-center, prospective, non-randomized case-control study between November 2021 and March 2022, patients who underwent phacovitrectomy for dense VH and cataracts (group 1) and who underwent phacoemulsification only for cataracts (group 2) were included in the study.

All surgeries and all measurements were performed by the same surgeon (X.X) in the eye department of a tertiary hospital. This study was approved by the ethics committee and adhered to the principles of the Declaration of Helsinki.

Inclusion criteria were determined as Forrester grade 1 VH, which means all quadrants prevented the fundus from being traced in group 1 and the presence of cataract in both groups. The Forrester system divides the vitreous opacity into 5 degrees, with the severity gradually increasing from grade 5 to grade 1. All eyes with cataracts were classified according to Lens Opacities Classification System III (LOCS III). Patients with N3-5 nuclear cataract, C4-5 cortical cataract, and P5 posterior subcapsular cataract underwent phacoemulsification.[13, 14]

Exclusion criteria were determined as a previous history of ocular surgery, any corneal pathology that may affect the refraction, a history of myopic or hyperopic refraction above 6 D, other ocular pathologies such as degenerative myopia, glaucoma or uveitis, retinal detachment during surgery, gas or silicone oil is used as an intraocular tamponade after vitrectomy in group 1, and the presence of any ocular disease other than cataract in group 2. In addition, cases in both groups who developed any intraoperative complication or if the IOL was placed in a location other than the capsular bag were excluded from the study.

Surgical Technique
Surgery was performed with subtenon anesthesia (4 cc bupivacaine 0.5%, 4 cc lidocaine 2.0%) in both groups. In group 1, surgical procedures were performed to the same standard in all patients. Phacoemulsification was performed using a 2-stage temporal 2.8 mm incision in the transparent cornea. Intraocular lens placement was performed prior to vitrectomy using a cartridge insertion system without incision magnification. A 10 – 0 nylon suture was used to close the corneal wound to ensure wound sealing and anterior chamber volume during vitrectomy; the suture was removed at the end of the PPV procedure. PPV was performed with a 23-gauge system (Constellation, Alcon, Fort Worth, TX, USA). PPV includes core vitrectomy, posterior vitrectomy, and vitreous base shaving steps. Endolaser photocoagulation was completed as needed. The sclerotomies were closed with 7 – 0 transconjunctival polyglactin (Vicryl, Ethicon, Bridgewater, NJ, USA) sutures. Intraocular tamponade was not used at the end of the operations.

In group 2, only phacoemulsification surgery was performed with the same standard in all patients. Surgery was performed using a 2-stage temporal 2.8 mm incision in the transparent cornea, as in group 1. Intraocular lens placement was performed using a cartridge insertion system without incision magnification. A monofocal hydrophilic IOL (Acriva, VSY, Istanbul, Turkey) was implanted in the capsular bag in all patients in both groups.

**Measurements**

All patients in the study underwent a complete ophthalmic evaluation, including best corrected visual acuity (BCVA) evaluation, slit lamp biomicroscopic examination, indirect fundus ophthalmoscopy, and IOP measurement using Goldmann applanation tonometry. Applanation ultrasound (Optikon 2000, Rome, Italy) was performed after installing one drop of topical anesthetic drop (Alcaine 0.5%) on the inferior conjunctiva. The A-scan unit was accoutered with a 10 MHz transducer probe, electronic calipers (gates) were used, and velocities were adjusted by device per medium, e.g., 1640 m/s for cornea and lens 1530 for aqueous and vitreous for AL measurements. All measurements for both devices were performed based on the manufacturer's suggestions. IOLMaster, the AL measurement was based on a patented interference optical procedure, PCI. In this method, an external interferometer (semipermeable mirror) divides a 160 m beam of coherent 780 nm infrared light into two pieces that are reflected and superimposed by two mirrors (S1, S2). The superimposition of these two compounds is projected onto the eye. The eye symbolizes a composition of two mirrors: the cornea and the retinal pigment epithelium (RPE). The cornea and the RPE reflect both partially coherent components. The interval between the two reflective biological surfaces (cornea and RPE) is the AL. In a photodetector, all four reflected components are brought into interference. If the distance difference of the two Michelson interferometers equals the optical distance difference between cornea and RPE, a constructive interference signal is detected.[15–17]

In the preoperative measurements in group 1, axial length was measured by A-scan contact US biometry with signal-to-noise ratio (SNR) values ≥ 2.1. (It was always performed using the contact technique and
by the same examiner (Y.O) and was calculated by taking at least five reliable measurements.) IOL Master could not measure AL effectively due to the density of the vitreous opacity. Keratometric measurements were calculated with IOL Master 500 (Carl Zeiss Meditec AG [CZM], Jena, Germany). IOL power was calculated using the Sanders-Retzlaff-Kraff/Theoretical (SRK-T) formula. In group 2, AL, keratometric, and IOL power measurements were calculated using the same formula with the same device.

Postoperative AL was made only in group 1. AL was measured with A-scan contact US biometry and IOL Master 500 at one month postoperatively. In both groups, refractive error was measured with an auto refractometer (KR-1, Topcon, Tokyo, Japan) in the first month after surgery. The prediction error (PE) was reflected as the difference between the postoperative refractive outcome expressed as spheric equivalent and refraction predicted by each biometer. The absolute error is calculated as the absolute value of the prediction error (APE).

**Statistical Analysis**

The data were analyzed with the SPSS 22.0 (SPSS Inc., Chicago, IL, USA) program. Data distribution was analyzed with the Shapiro-Wilk test. Because the variables were not normally distributed, Wilcoxon t-test was used to compare preoperative and postoperative measurements. Spearman r correlation coefficient was used to evaluate the correlation between the measurements of both biometric devices. The median values of the postoperative refractive measurements of the groups were compared using the Mann–Whitney U test. A p-value less than 0.05 was considered statistically significant.

**Results**

The fifty-five eyes of 45 patients were included in the study. Thirty eyes of 25 patients were in group 1, and 25 eyes of 20 patients were in group 2. The mean age was 60 ± 2 in group 1 and 61 ± 1 in group 2. The female-male ratio was 10:15 in group 1 and 11:9 in group 2. The median values of lenses placed in the bag were 22 D in group 1 and 22.5 D in group 2. In group 1, the median preoperative BCVA was 2.48 log of the minimum resolution angle (logMAR), while the median postoperative BCVA was 0.39 logMAR at one month. Postoperative vision improved significantly in group 1 (p < 0.001). In group 2, the median preoperative BCVA was 2.10 logMAR, while the median postoperative BCVA was 0.1 logMAR at one month (p < 0.001). Baseline demographic and clinical characteristics of patients in groups 1 and 2 were enlightened in Table 1. Median preoperative AL measured by US was 23.33 mm (I), median postoperative AL measured by IOL Master 500 was 23.18 mm (II), and median postoperative AL measured by US (III) was 23.44 mm in group 1 (p = 0.04, I- II; p = 0.01, I- III; p < 0.01, II- III). (Table 2) The preoperative US and the postoperative IOL Master 500, and the preoperative US and the postoperative US AL measurement showed a statistically significant strong positive correlation (r = 0.92, p < 0.001; r = 0.85, p < 0.001) with a high-reliability coefficient (Cronbach's alpha 0.94 and 0.89) (Table 3) On the other hand, preoperatively planned refraction, postoperative spherical value, postoperative spherical equivalent, postoperative cylindrical value were similar between the two groups. Also, median PE and APE were 0.05 and 0.57 in
group 1 and −0.35 and 0.64 in group 2 (p = 0.25, p = 0.99, respectively), as seen in Table 4. The correlation plots of AL are shown in Fig. 1.

Table 1
Baseline demographic and clinical characteristics of patients in Groups 1 and 2.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of eyes</td>
<td>30 (25 patients)</td>
<td>25 (20 patients)</td>
</tr>
<tr>
<td>Age (mean ± SD)</td>
<td>60 ± 2</td>
<td>61 ± 1</td>
</tr>
<tr>
<td>Sex</td>
<td>10 Female 15 Male</td>
<td>11 Female 9 Male</td>
</tr>
<tr>
<td>Median BCVA (min-max) logMAR</td>
<td>2.48 preoperative (0.70–3.00)</td>
<td>2.10 preoperative (1.90–2.40)</td>
</tr>
<tr>
<td></td>
<td>0.39 postoperative (0–2.00)</td>
<td>0.10 postoperative (0.10–0.10)</td>
</tr>
</tbody>
</table>

BCVA: Best corrected visual acuity

Table 2
The comparison of axial lengths in Group 1.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative Ultrasound (I)</th>
<th>Postoperative IOL Master 500 (II)</th>
<th>Postoperative Ultrasound (III)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>23.33 (21.22–24.94)</td>
<td>23.18 (21.09–24.58)</td>
<td>23.44 (21.19–24.80)</td>
<td>I-II p = 0.04*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I-III p = 0.01*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II-III p &lt; 0.01*</td>
</tr>
</tbody>
</table>

The Wilcoxon signed-rank test, *p < 0.05, IOL = Intraocular lens
Table 3
The correlation and reliability analysis in comparison to axial lengths in Group 1.

<table>
<thead>
<tr>
<th></th>
<th>Postoperative IOL Master 500</th>
<th>Postoperative Ultrasound</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>Alpha**</td>
<td>r</td>
</tr>
<tr>
<td>Preoperative Ultrasound</td>
<td>0.92</td>
<td>0.94</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Spearman correlation test, *p < 0.05, ** reliability analyzes, IOL = Intraocular lens

Table 4
The preoperative planned refraction and postoperative refractive changes in Groups 1 and 2.

<table>
<thead>
<tr>
<th></th>
<th>Phacovitrectomy group (Group 1)</th>
<th>Phacoemulsification Group (Group 2)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median (Min-Max)</td>
<td>Median (Min-Max)</td>
<td></td>
</tr>
<tr>
<td>Preoperative planned refraction (D)</td>
<td>-0.41 (-1.00- 0.00)</td>
<td>-0.40 (-0.7- -0.1)</td>
<td>0.98</td>
</tr>
<tr>
<td>Postoperative spherical value (D)</td>
<td>-0.15 (-3.25- 1.50)</td>
<td>-0.25 (-1.00- 1.25)</td>
<td>0.7</td>
</tr>
<tr>
<td>Postoperative spherical equivalent (D)</td>
<td>-0.72 (-3.50- 0.50)</td>
<td>-0.75 (-2.00- 0.75)</td>
<td>0.45</td>
</tr>
<tr>
<td>Postoperative cylindrical value (D)</td>
<td>-1.0 (-3.25-0.50)</td>
<td>-0.75 (-2.00 - -0.25)</td>
<td>0.57</td>
</tr>
<tr>
<td>Refractive prediction error (D)</td>
<td>0.05 (-3.50- 1.00)</td>
<td>-0.35 (-1.6- 0.85)</td>
<td>0.25</td>
</tr>
<tr>
<td>Absolute prediction error (D)</td>
<td>0.57 (0- 3.50)</td>
<td>0.64 (0.1–1.6)</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Mann-Whitney U test, *p < 0.05

Discussion

Today, with the development of technology and medical science, old and more traditional methods are being replaced by new and more technological methods. However, in some areas of medicine,
conventional methods still maintain their validity in practice. Meanwhile, according to the American Society of Cataract and Refractive Surgery (ASCRS) survey, anterior segment surgeons use optical biometry 80% and contact or immersion US 20% as the primary method.\[18\] Although PCI biometry, a type of optical biometry, has excellent reproducibility, accuracy, and comparability with US.\[19\] Also, these optical instruments are used without touching the eyes, preventing iatrogenic injuries. On the other hand, failure in AL measurement with PCI-based biometry can be seen in 8–37.4% due to dense media opacities (cataract or VH) or poor fixation.\[20, 21\] However, the literature about the postoperative refractive error and AL measurement in eyes with VH is scarce. Only one study in the literature conducted by Wang et al.\[9\] investigated the measurement and detection rate of AL length with four different biometrics (OA-2000, IOL Master, LENSTAR, US) in eyes with VH preoperatively. The overall AL measurement detection rate was 62.5% (25 eyes) with OA-2000, 15% (6 eyes) with IOL Master and LENSTAR, and 100% with US.\[9\] Looking at the subgroups, the detection rate was 100%, 41.7% and 41.7% for Forrester grade 3 and 46.4%, 3.57%, and 3.57% for Forrester grade 1–2. (OA-2000, IOL Master, and LENSTAR, respectively).\[9\] They also emphasized that the measurement rate of OA-2000, which uses SS-OCT technology, is higher in patients with intense VH compared to IOL Master and LENSTAR, PCI-based biometry.\[9\] Besides, all three optical biometers failed to measure the AL in Forrester Grade 1. However, US could easily measure 100% of eyes in all stages.\[9\] In this study, the eyes included were at different Forrester stages and evaluated only preoperatively, but in our study, all eyes were Forrester 1, which reflects extensive VH and evaluated both preoperatively and postoperatively.\[9\]

Meanwhile, Gonzalez-Godinez et al.\[22\] assessed the AL measurement failure rate using PCI and SS-OCT-based optical biometry. They showed that AL measurement failure rate with PCI-based optical biometry was 68.57%, and SS-OCT-based optical biometry was 21.43% in eyes with dense cataracts.\[22\] Even SS-OCT, which reflects the current and state-of-the-art technology, cannot achieve 100% success in dense cataracts and VH.\[9\] US can easily detect grade I and II VH at a rate of 100%. US operates with a longer wavelength (0.19 mm) and lower frequency (8 MHz); it has better penetration than optical biometers. In our study, the preoperative US and the postoperative IOL Master 500, and the preoperative US and the postoperative US AL measurement showed a statistically significant strong positive correlation \((r = 0.92, p < 0.001; r = 0.85, p < 0.001)\) with a high-reliability coefficient (Cronbach's alpha 0.94 and 0.89).

Another critical point is that we aimed for the SNR to be greater than/equal to 2.1 in all measurements made with US. We tried to catch these scans by retaking measurements when necessary, thus increasing the quality of the measurement. Olsen and Thorwest\[23\] compared AL measurements made by US and IOL Master. They showed that if the SNR is greater than/equal to 2.1, the difference in preoperative and postoperative AL measurements is minimized. Suto et al.\[24\] supported this situation and reported that if the SNR is less than 2, an insignificant mean hyperopic shift in postoperative refraction is observed. In line with our results, it is thought that US can be used easily, safely, and effectively in patients with intense VH with a high SNR value.

As shown in Table 1, AL was statistically significantly shorter preoperatively than postoperatively by US (23.33 mm vs. 23.44 mm). Presumably, AL measurement with contact US is related to where the probe
contacts the cornea, leading to applanation and flattening of the anterior corneal surface so that the
measurement may vary depending on the individual. Distance is calculated as this formula (speed x time
/2.) Thus, VH alters the vitreous humor density to varying extent, initiating propagation velocity to be
changed. The AL measurements measured by US were statistically significantly longer than those
measured by IOL Master postoperatively (23.44 mm vs. 23.18 mm). Hao Bai et al.[25] compared contact
A scan US and IOL master in 137 eyes of 121 patients with cataracts; they found a high degree of
agreement between the two methods (r = 0.99 p = < 0.01), also, contrary to our study, IOL Master
measured longer AL than those of A scan US (24.37 vs. 23.81 p < 0.001). Tehrani et al.[26] investigated
the effect of visual acuity and lens opacity on AL measurement in IOL Master and US biometry. Visual
acuity is a positive, and lens opacity is an adverse prognostic parameter on the probability of successful
measurement. They found that IOL Master measures longer AL than US. [26]

On the other hand, Nakhli et al.[27] and Rajan et al.[20] measured shorter AL in the PCI group compared to
US group preoperatively and postoperatively, in line with our study. As noted, the results are inconsistent
in the literature. This situation may be related to many different reasons. The operating mechanisms of
US and PCI are entirely different, and their sensitivity and measurement evaluation systems differ
according to the characteristics of image processing systems. Resolution enhances as wavelength
diminishes. Thus, as light has a very short wavelength according to sound, laser light has a better
resolution. The precision of AL for ultrasound is approximately 0.10–0.12 mm compared to 0.012 mm for
PCI AL.

IOL Master assesses the AL along the visual axis, whereas US biometry assesses along the optical axis.
Also, A-scan US measures the distance between the anterior surface of the cornea and the internal
limiting membrane (ILM). PCI systems, however, measure the distance from the second principal plane of
the cornea (0.05 mm deeper than the corneal apex) to RPE. This result can be interpreted either by the
fact that US biometry depends on personal factors or that the optic axis is longer than the visual axis,
rather than the distance of RPE, which is farther from the cornea than ILM would account for a difference
of 130 µ approximately.

In our study, many factors affect the refractive prediction error, such as the device measuring the axial
length, loose zonular fibers, the effective lens position, the IOL calculation formula, and the IOL type
selection. Also, especially in dense cataracts, high myopia, intense VH, and poor patient cooperation,
bio metric measurements can be affected, and unexpected results may exist. However, we found PE 0.05
and APE 0.57 in US measurements using the SRK-T formula in our series. In the phacoemulsification
group used as the control group measuring IOL Master, there was a slight myopic shift in PE (-0.35), and
APE was calculated as 0.64. However, there was no difference between the two groups in terms of PE and
APE (p = 0.25, p = 0.99). As mentioned, US measures AL from the ILM, and myopic shift may be seen in
phacovitrectomy patients in relation to that US measures AL shorter than the actual value.[28] On the
other hand, it has also been reported that no myopic shift was observed in large series of
phacovitrectomy.[8, 29, 30] Briefly, this topic is controversial in the literature. The results in our series were
close to optimal refractive outcomes in this respect conclusively.
No prospective study reveals the efficacy and credibility of US biometry on the IOL calculation and AL measurement in eyes with dense VH in the literature. Our study is the first in this respect. The limitation of our study included that measurements were not made with SS-OCT-based biometry since it was not available in our center. US biometry can be used easily, safely, and effectively in patients with dense VH with near optimal refractive results.

Declarations

Compliance with ethical standards

Funding

This study was funded by the authors and did not receive any grant from finance agencies in the public or commercial sectors.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

This study protocol was approved by Haydarpaşa Numune Training and Research Hospital Clinical Research Ethics Committee (2021/159-3404) and conducted in accordance with the ethical standards of Declaration of Helsinki (1964) and its later amendments.

Informed consent

Informed consent was waived due to the retrospective nature of this study.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References


Figures

![Figure 1](image1)

![Figure 1](image2)

![Figure 1](image3)

Figure 1
The correlation plots of axial measurements