Accuracy of ultrasound vs. Fourier-domain optic biometry for measuring preoperative axial length in cases of rhegmatogenous retinal detachment

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Abstract

Purpose: To identify a method for accurately measuring preoperative axial length (AL) in cases of rhegmatogenous retinal detachment (RRD).

Study Design: Retrospective study.

Methods: This retrospective study included 83 eyes of 83 patients who underwent vitrectomy for RRD and had both preoperative and postoperative data for AL. Preoperative AL measurements for the affected eye were obtained using ultrasound (aUS-AL) and compared with those for affected and fellow eyes measured using optical biometry (aOB-AL and fOB-AL, respectively). Absolute differences between preoperative aUS-AL, aOB-AL, or fOB-AL measurements and postoperative AL (aPost-AL) were examined.

Results: In the 41 eyes without macular detachment, the absolute difference between aOB-AL and aPost-AL (0.06±0.07 mm) was significantly smaller than that between aUS-AL and aPost-AL (0.21±0.18 mm) and that between fOB-AL and aPost-AL (0.29±0.35 mm) (P=0.017 and P<0.001, respectively). In the 42 eyes with macular detachment, the absolute difference between aOB-AL and aPost-AL (1.22±2.40 mm) was significantly larger than that between aUS-AL and aPost-AL (0.24±0.24 mm) and that between fOB-AL and aPost-AL (0.35±0.49 mm) (P=0.006, P=0.016, respectively).

Conclusion: The current findings suggest that aOB-AL is more accurate than aUS-AL or fOB-AL in cases of RRD without macular detachment, while aUS-AL or fOB-AL is more accurate than aOB-AL in cases with macular detachment.

Keywords

axial length, rhegmatogenous retinal detachment, macular detachment, Fourier-domain optic biometry, ultrasound

Introduction

Phacovitrectomy, which refers to simultaneous cataract surgery and pars plana vitrectomy (PPV), has become a common procedure for rhegmatogenous retinal detachment (RRD) [1–5], given that it improves retinal attachment rate due to adequate intraoperative vitrectomy [1], eliminates the need for additional cataract surgery [2, 3], and reduces the postoperative visual recovery period [4, 5]. While phacovitrectomy has increased retinal attachment rates in cases of RRD, postoperative refractive errors can substantially impact visual outcomes [6–8]. The factors that influence refractive error in RRD include the measurement error of the axial length (AL) [6–12], shallow anterior chamber depth related to the use of air or gas intraoperatively [8, 13–15], and the formula used to calculate intraocular lens (IOL) power [16]. Among these, the measurement error of preoperative AL exerts a particularly large influence, and the presence of preoperative macular detachment has been identified as an important factor affecting AL measurement error [8].

In recent years, advances have been made in AL measurement devices [17–19]. For many years, IOL power calculations for cataract surgery have been based on AL measurements obtained using ultrasound. In the 1990s, time-domain optic biometry was introduced, allowing for improved accuracy when measuring AL compared with ultrasound-obtained measurements [20, 21]. However, time-domain optic biometry is limited because AL cannot be measured in many patients with severe cataracts and/or vitreous opacities [22]. To address this issue, researchers developed optic biometry techniques that incorporate Fourier-domain methods [17, 18]. Currently, Fourier-domain optic biometry is the preferred method for measuring AL in patients undergoing cataract surgery [18].

Studies of RRD report that preoperative measurements of AL obtained via ultrasound of the affected eye (US-AL) or via optic biometry of the fellow eye (OB-AL) are suitable for calculating IOL power [6, 8–10, 12, 23]. However, in these studies, OB-AL was only examined using time-domain methods, and no studies have performed similar analyses using Fourier-domain methods. Therefore, in this study, we retrospectively compared preoperative US-AL with Fourier-domain OB-AL measurements to identify the more accurate method for use in cases of RRD.

Methods

This retrospective study included patients who had undergone vitrectomy for RRD between August 2017 and September 2021. All patients underwent measurements of US-AL in the affected eye and OB-AL in the affected and fellow eyes (aUS-AL, aOB-AL, and fOB-AL, respectively) preoperatively, as well as measurements of OB-AL in the affected eye postoperatively. Exclusion criteria were: history of vitrectomy, pre- and postoperative macular pathological changes, including staphyloma, proliferative changes, low intraocular pressure (<5 mmHg), choroidal detachment, concomitant scleral buckling, requirement for reoperation, and abnormalities other than cataracts.

This study was approved by the Ethics Committee of Okayama University Hospital, Okayama, Japan, and adhered to the tenets of the Declaration of Helsinki. Each patient was informed about the risks and benefits of surgery before providing written informed consent.

Ophthalmological examinations

All patients underwent comprehensive ophthalmologic examinations pre- and postoperatively. The examinations included assessments of best-corrected visual acuity with refraction (RC-5000, Tomey Corporation) using a 5-m Landolt C acuity chart, non-contact tonometry (FT-1000, Tomey Corporation), indirect and contact lens slit-lamp biomicroscopy, optical coherence tomography (OCT) (DRI OCT-1 Atlantis, Topcon Corporation), US-AL (AL-3000, Tomey Corporation), and OB-AL using a Fourier-domain method (OA-2000, Tomey Corporation). The length to measure the AL is different between ultrasound (corneal surface to the internal limiting membrane) and OCT (corneal surface to the retinal pigment epithelium [RPE]), so the OB-AL values were converted to US-AL values using the software supplied with the OA-2000 [24]. The US-AL and OB-AL measurements were performed by skilled operators. Postoperative ophthalmologic examinations were performed at least one month after surgery when the retina was attached. Postoperative AL was defined as the postoperative AL of the patient’s eye obtained by OB (aPost-AL) [23].

Main outcome measures

The main outcome measures were absolute differences between aUS-AL, aOB-AL, fOB-AL, and aPost-AL.

Surgical procedure

All patients underwent surgery under 4% xylocaine ophthalmic anesthesia and 2% xylocaine subcapsular tenon anesthesia. PPV involved a 25-gauge transconjunctival microincision and was performed using the Constellation Vision System (Alcon Laboratories Inc). Vitreous traction around the retinal breaks was released, and the subretinal fluid was drained via a posterior drainage retinotomy. Then, fluid-20% sulfur hexafluoride gas exchange and endolaser photocoagulation of the retinal breaks and intentional retinal holes were performed. Patients aged >50 years underwent cataract surgery simultaneously. In all cases, a 2.5-mm scleral corneal wound was created, and a 3-piece acrylic lens (NX-70, Santen) was inserted into the bag. The SRK-T formula was used in all cases.

Statistical analysis

Pearson's correlation coefficients were used to examine correlations between pre- and postoperative AL. Absolute values for differences in pre- and postoperative AL were compared using one-way analysis of variance with the Tukey–Kramer test. Statistical significance was set at $P<0.05$. Data are presented as the mean ± standard deviation.

Results

The study included 83 eyes of 83 patients with a mean age of 61.2±10.5 years, including 28 women (34%) and 55 men (66%). Preoperative measurements were possible in all 83 eyes (100%) for aUS-AL and fOB-AL, and in 80 eyes (96%) for aOB-AL. Three eyes (4%) in which aOB-AL could not be measured had macular detachments. OCT measurements of macular detachment height were possible in 24 eyes (57%); however, measurements were not possible in the remaining 18 eyes (43%) because the RPE was too far from the detached retina. The retinal detachment height at the macula was 575±385 μm in the 24 eyes, for which macular detachment height could be measured using OCT. Sixty-six eyes (80%) underwent simultaneous cataract surgery; in all 66 cases, the IOL was inserted in the bag, with no IOL capture or dislocation. The intraocular pressure (IOP) was 14.8±3.3 mmHg preoperatively and 15.4±3.0 mmHg postoperatively. There was no significant correlation between the difference in IOP before and after surgery and the absolute difference in pre- and postoperative AL ($R= 0.15$ and 0.11 for aUS-AL and aOB-AL, respectively). Postoperative examinations were performed with a mean of 2.6±4.3 months after surgery.

Measurements of aUS-AL, fOB-AL, and aOB-AL were possible in all 41 eyes without macular detachment (100%). The aUS-AL, aOB-AL, and fOB-AL values were 25.70±1.67 mm, 25.74±1.68 mm, and 25.66±1.61 mm, respectively, all of which exhibited a strong correlation with aPost-AL (25.71±1.67 mm) ($R=0.986$, 0.999, 0.962, respectively, all $P<0.001$, Fig. 1). The absolute difference between aOB-AL and aPost-AL (0.06±0.07 mm) was significantly smaller than between aUS-AL and aPost-AL (0.21±0.18 mm) and between fOB-AL and aPost-AL (0.29±0.35 mm) ($P=0.017$, $P<0.001$, respectively, Fig. 2). The absolute differences between aUS-AL and aPost-AL and between fOB-AL and aPost-AL were not significantly different ($P = 0.209$). The preoperative equivalent spherical power was -4.63±4.44 D (+1.75 to -17.50 D). IOL power was calculated based on aOB-AL in all 33 eyes that underwent cataract surgery (100%). The postoperative refraction was -3.43±2.80 D, and the absolute difference from the target postoperative refraction (-2.85±2.44 D) was 0.66±0.54 D.

Among the 42 eyes with macular detachment, aUS-AL and fOB-AL measurements were possible in all eyes (100%), while aOB-AL measurements were possible in 39 eyes (93%). Both aUS-AL and fOB-AL were highly correlated with aPost-AL (25.39±1.63 mm, R=0.978 and 0.929, respectively, both P<0.001); however, aOB-AL was not significantly correlated with aPost-AL (R=0.188, P=0.251, Fig. 3). The absolute values of the differences between measurements of aUS-AL, aOB-AL, and fOB-AL and measurements of aPost-AL were 0.24±0.24 mm, 1.22±2.40 mm, and 0.35±0.49 mm, respectively. The absolute difference between aOB-AL and aPost-AL was significantly larger than that between aUS-AL and aPost-AL and that between fOB-AL and aPost-AL (P=0.006, P=0.016, Fig. 4). No significant differences in the absolute difference between aUS-AL and aPost-AL and that between fOB-AL and aPost-AL were observed (P=0.933). The preoperative equivalent spherical power was -1.00±3.46 D (-7.00 to 8.75 D). For the 33 eyes that underwent cataract surgery, IOL power was calculated based on aOB-AL in 17 eyes (52%), aUS-AL in 15 eyes (45%), and fOB-AL in one eye (3%). The difference between the expected postoperative refractive value and the postoperative refractive values were -1.08 ± 1.08D, -1.00 ± 1.74D, and -2.95D, respectively. Of the 16 patients with a macular detachment height of more than 1,000 µm, six (38%) had aOB-AL measurements, nine (56%) had aUS-AL measurements, and one (6%) had fOB-AL measurements. The postoperative refraction was -3.07±2.43 D, with an absolute difference of 1.33±1.20 D from the target postoperative refraction value (-2.10±1.90 D).

Figure 5 shows the differences between aUS-AL, aOB-AL, and fOB-AL and aPost-AL measurements in patients with RRD involving macular detachment. For cases in which macular detachment height could not be measured, the difference between aOB-AL and aPost-AL was shorter than the differences between aUS-AL or fOB-AL and aPost-AL. The absolute values of the differences between aUS-AL, aOB-AL, or fOB-AL measurements and aPost-AL measurements in 21 patients with a macular detachment height of less than 1,000 μm were 0.24±0.23 mm, 0.16±0.25 mm, and 0.37±0.61 mm, respectively. There were no significant differences in the absolute values of these three differences (all P>0.05, Fig. 6). Of these 21 eyes, we were able to examine the difference between the expected postoperative refractive value and the postoperative refractive values in 13 eyes that had an IOL inserted. The details of ALs for IOL determination were 8 eyes by US-AL, 5 eyes by aOB-AL, and 0 eyes by fOB-AL. The absolute difference in AL before and after surgery was 0.17 ± 0.12 mm and 0.04 ± 0.03 mm for US-AL and aOB-AL, respectively, and the difference between the expected postoperative refraction value and the postoperative refraction values was -0.69 ± 1.00 D and -0.82 ± 0.69 D, respectively.

Discussion

In the present study, we retrospectively compared aUS-AL, aOB-AL, and fOB-AL measurements with aPost-AL measurements to clarify the most accurate method for measuring preoperative AL in patients with RRD. Our findings indicate that aOB-AL was significantly closer to aPost-AL than aUS-AL or fOB-AL in cases of RRD without macular detachment. In contrast, aUS-AL and fOB-AL were closer to aPost-AL than aOB-AL in cases with macular detachment.

To the best of our knowledge, although several studies have examined the accuracy of the time-domain OB-AL for preoperative AL measurement in patients with RRD, none have examined the accuracy of the Fourier-domain OB-AL [8–10]. Pongsachareonnont et al. report that there was no significant difference between pre- and postoperative AL in patients with RRD without macular detachment when measurements were obtained using either aUS-AL or time-domain OB-AL; however, the preoperative time-domain OB-AL in cases of RRD with macular detachment was 0.98±1.02 mm shorter than the postoperative time-domain OB-AL [9]. This measurement error corresponds to a refractive conversion value of 2.74±2.86 D myopia, which is clinically unacceptable [25, 26]. The present results are consistent with those reported by Pongsachareonnont et al. However, there are two notable differences. First, in RRDs without macular detachment, fOB-AL was significantly closer to aPost-AL than to aUS-AL or fOB-AL in our study (Fig. 2). Second, even in RRDs with macular detachment, when limited to RRDs with small (<1,000 µm) macular detachment heights, the absolute difference between aOB-AL and aPost-AL was not significantly different from that between aUS-AL or fOB-AL and aPost-AL (Fig. 6). Kang et al. used time domain OCT to examine pre- and postoperative ALs and reflex values in macula-on RRD and report that the postoperative myopic shift was 0.41D [27]. Since there was no significant difference in AL before and after surgery (25.4 ± 1.67 mm and 25.3 ± 1.78 mm, respectively), they hypothesized that the myopic shift was caused by changes in the position and thickness of the lens rather than by the AL change. We think that our results (pre- and postoperative ALs of 25.70 ± 1.67 mm and 25.71 ± 1.67 mm, respectively; 0.58 D myopic shift) are similar to those reported by Kang et al., although the pre- and postoperative AL differences were smaller and the degree of myopic shift was greater in our study. El-Khayat et al. report that, in patients with RRD involving macular detachment, IOL power calculations based on the time-domain OB-AL or US-AL of the affected eye resulted in greater myopia than those based on the time-domain OB-AL of the fellow eye [10]. Rahman et al. further report that IOL power could be determined for RRD with macular detachment based on time-domain OB-AL; however, the OB-AL of the fellow eye was chosen based on the ALs and refractive values for both eyes. They report an acceptable postoperative refractive error (-0.34±0.89 D) [8].

The following two reasons may explain why preoperative OB-AL was shorter for cases of RRD with macular detachment. First, light reflected from the detached retinal surface may have influenced measurements. Second, measurements may have been obtained outside the macula due to poor fixation [25, 28]. Our results indicate that aUS-AL and fOB-AL are preferable in clinical settings, given that aOB-AL can result in myopic shift postoperatively. The use of fOB-AL is based on the idea that the ALs and refractive values of the left and right eyes are the same, and if the ALs of the left and right eyes are different a large postoperative refractive error will occur. Furthermore, in this study, the IOL power was determined based on the fOB-AL in only one of the 33 eyes with combined cataract surgery for the patients with macula-off RRD. Thus, we think that fOB-AL should be used very carefully, and that US-AL is the appropriate preoperative AL measurement for calculating IOL power in eyes with RRD involving macular detachment.

In addition to AL, factors that may cause postoperative refractive error include the corneal refraction value, anterior chamber depth, and formula used to calculate IOL power [8, 13–15, 29, 30]. Jeoung et al. report that corneal refraction values changed only slightly before and after cataract surgery combined with vitrectomy [29]. Further, although some reports indicate that there are no changes in anterior chamber depth following vitrectomy with gas [31], others report anterior deviation of the IOL, resulting in postoperative refractive error (myopic shift) [8, 13–15]. Studies suggest that postoperative refractive values can vary based on the formula used to calculate IOL power [30]. In this present study, the SRK-T formula was applied to all cases, and other prediction formulas were not examined. Our results indicate that for cases of RRD without macular detachment, the aOB-AL was associated with an average refractive error of 0.66 D despite only a small difference in pre- and postoperative AL (mean 0.06 mm, refractive equivalent 0.17 D) [25, 26]. These differences in refractive power highlight the need for additional studies to examine factors other than the AL measurement error that contribute to postoperative refractive error.

Our study had several limitations, including its retrospective nature, the small number of included patients, examination of the AL including highly myopic eyes, OB-AL converted to US-AL values using the software supplied with the OA-2000, the lack of uniformity in performing simultaneous cataract surgery [19, 24, 32], and the insufficient examination of the postoperative refractive error.

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Figure legends

Fig. 1 Comparison of preoperative and postoperative axial length in patients with rhegmatogenous retinal detachment without macular detachment

aUS-AL, preoperative axial length of the affected eye by ultrasound; aOB-AL, preoperative axial length of the affected eye by optic biometry; fOB-AL, preoperative axial length of the fellow eye by optic biometry; aPost-AL, postoperative axial length

Fig. 2 Comparison of absolute differences between preoperative and postoperative axial length in patients with rhegmatogenous retinal detachment without macular detachment

＊; P < 0.05, ＊＊; P < 0.01, N.S.: Not significant. aUS-AL, preoperative axial length of the affected eye by ultrasound; aOB-AL, preoperative axial length of the affected eye by optic biometry; fOB-AL, preoperative axial length of the fellow eye by optic biometry; aPost-AL, postoperative axial length

Fig. 3 Comparison of preoperative and postoperative axial length in patients with rhegmatogenous retinal detachment involving macular detachment

aUS-AL, preoperative axial length of the affected eye by ultrasound; aOB-AL, preoperative axial length of the affected eye by optic biometry; fOB-AL, preoperative axial length of the fellow eye by optic biometry; aPost-AL, postoperative axial length

Fig. 4 Comparison of absolute differences between preoperative and postoperative axial length in patients with rhegmatogenous retinal detachment involving macular detachment

＊; $P < 0.05$, ＊＊; $P < 0.01$, N.S.: Not significant. aUS-AL, preoperative axial length of the affected eye by ultrasound; aOB-AL, preoperative axial length of the affected eye by optic biometry; fOB-AL, preoperative axial length of the fellow eye by optic biometry; aPost-AL, postoperative axial length

Fig. 5 Comparison of preoperative macular detachment height and differences between preoperative and postoperative axial length in patients with rhegmatogenous retinal detachment involving macular detachment

aUS-AL, preoperative axial length of the affected eye by ultrasound; aOB-AL, preoperative axial length of the affected eye by optic biometry; fOB-AL, preoperative axial length of the fellow eye by optic biometry; aPost-AL, postoperative axial length

Fig. 6 Comparison of absolute differences between preoperative and postoperative axial length in patients with rhegmatogenous retinal detachment with a macular detachment

height less than 1,000 μm

N.S.: Not significant. aUS-AL: preoperative axial length of affected eye by ultrasound, aOB-AL: preoperative axial length of affected eye by optic biometry, fOB-AL: preoperative axial length of fellow eye by optic biometry, aPost-AL: postoperative axial length