Double Peak Axial Length Measurement Signal in Cataract Patients with Epiretinal Membrane

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Abstract

Purpose: To evaluate the accuracy of axial length (AL) measurement for intraocular lens (IOL) calculation in patients with cataract and epiretinal membrane (ERM).

Methods: This prospective, cross-sectional study was performed in cataract patients with ERM. All subjects were sent for standard optical biometry, prepared for cataract surgery. Signals of AL measurement were detected as double peaks and recorded as AL1 (first peak), and AL2 (second peak). The IOL power was calculated from AL1 and AL2, and reported as IOL1 and IOL2. The IOL2 was chosen for cataract surgery in all cases. Postoperative predictive errors were compared between IOL1 and IOL2.

Results: Thirty-seven eyes from 37 patients were included. Mean AL1 was significantly shorter than AL2 (23.13 ± 1.28 vs. 23.60 ± 1.34 mm, $p < 0.001$), resulting in higher power of IOL1 than IOL2 (mean difference was 1.53 ± 0.96 diopters, $p < 0.001$). At 3-months post-operation, twenty-nine eyes (78.4%) (95% CI: 62.8%–88.6%) showed refractive error within ± 0.5 diopter and all eyes were within ± 1.0 diopter. Postoperative predictive errors including mean arithmetic error (ME) and mean absolute error (MAE) of IOL2 were significantly lower than those of IOL1 (ME: IOL1 vs. IOL2, -0.94 ± 0.91 vs. 0.08 ± 0.51 ; MAE: 0.97 ± 0.88 vs. 0.39 ± 0.33 diopter, all $p < 0.001$).

Conclusions: AL measurement in ERM can be detected as a double peak signal during biometric measurement. The IOL power calculated from the first and second peak signals are significantly different. However, the IOL power derived from the second peak signal provides better refractive outcomes. The results suggest that the second peak signal represent an accurate AL measurement.

Introductions

Cataract is the leading global cause of visual impairment and blindness [1, 2]. For decades, cataract surgery with intraocular lens (IOL) implantation has been accepted as the optimum way to restore vision. As a combination of factors, the precision of IOL calculation has played an important role in determining visual outcomes. To calculate the IOL power requires ocular biometry or data from several ocular parameters such as corneal curvature, corneal diameter, and anterior chamber depth (ACD) including the axial length [3, 4]. Therefore, obtaining accurate biometric measurement, especially the axial length (AL), is crucial for IOL calculation and postoperative visual outcome. Typically, the principle of AL measurement using an optical biometer is to detect the highest reflecting signal of the light source at the macula [3, 5] (Fig. 1A). The optical device projects the coherent beam of light into the eye and receives the reflecting signal originating at the retinal pigment epithelium, then converts the signal into the AL [3, 6, 7]. However, AL measurement in patients with macular diseases such as epiretinal membrane (ERM) frequently shows a double peak signal (Fig. 1B) or undefined signals causing measurement errors. Olsen T, et al. proposed that an AL error of 0.1 mm could induce a refractive error of 0.27 diopter [8]. Hence, acquiring an accurate AL is a prerequisite for the IOL calculation, not only in normal eyes but also in eyes with pathological conditions such as ERM. This study aimed to analyze the accuracy of AL signals

detected from a standard time-domain optical coherence tomography-based biometer (TD-OCT) in patients with ERM that always demonstrates a double peak signal. The IOL power would be calculated from both the first and second peak signals of the AL measurement. Postoperative refractive outcomes including mean arithmetic error (ME) and mean absolute error (MAE) would be compared between the results derived from both AL peak signals. The IOL power that induced fewer postoperative refractive errors would indicate the accurate peak of AL signal.

Materials And Methods

This prospective, cross-sectional study was performed in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Ethics Committee for the Protection of Human Participants in Research at the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand (Siriraj Institutional Review Board), and given a certificate of approval number Si231/2016, protocol 209/2559 [EC2]). All patients provided written informed consent before study enrollment.

Patients diagnosed with cataract and ERM based on clinical examination and/or the optical coherence tomography (OCT) of the macula and scheduled for cataract surgery were sent for ocular biometry testing. The ocular parameters including keratometry, white-to-white diameter, ACD, and the AL were obtained by an experienced technician using a standard TD-OCT. Since the AL measurement often revealed double peak signals, the first peak was recorded as AL 1, and the second peak was recorded as AL 2. Afterwards, the IOL power was calculated using the SRK-T formula for each AL. The first IOL power (IOL 1) was derived from the AL 1 and the second IOL power (IOL 2) was obtained from the AL 2. However, the IOL power adopted from IOL 2 was chosen for implanting in every patient's eye. A single-piece, foldable acrylic IOL, SA60AT was used with the optimized A-constant of 119.0 for all cases. Eyes with previous kerato-refractive surgery, severe dryness, irregular corneal surface including scar, and ocular pathology other than cataract and ERM were excluded.

All patients underwent uneventful cataract surgery by a single surgeon. Routine follow-up appointments were performed 1-day, 1-week, 1-month, and 3-months post-operatively. Postoperative manifest refraction was measured at the 3-month visit. The mean arithmetic error and mean absolute error of both IOL 1 and IOL 2 were analyzed and compared in order to determine the accuracy of AL derived from each signal. The mean arithmetic value of the predictive refractive error (ME) was determined by an average of the difference of spherical equivalence between the postoperative manifest refraction and predicted postoperative refraction. The mean absolute value of the predictive refractive error (MAE) was determined by an average of the absolute value of the difference of spherical equivalence between the postoperative manifest refraction and predicted postoperative refraction. The precision of the IOL power calculation is greatest when the MAE approaches zero [9–11].

Statistical Analysis

Statistical analysis was performed with SPSS version 18.0 (SPSS Inc. Chicago, IL, USA). The quantitative data were recorded in means, standard deviations, ranges, and percentage. Comparisons between AL 1 and AL 2, IOL 1 and IOL 2, and ME and MAE derived from IOL 1 and IOL 2 were analyzed using Paired t-test. P-values less than 0.05 was considered statistically significant.

Results

Thirty-seven eyes from 37 patients were included. All patients presented with cataract and ERM, but no other ocular diseases or previous ocular surgery. Of the 37 participants, 24 were female (64.9%). The mean age of patients was 65.1 years (range 43 and 78 years). Preoperative best corrected visual acuity was 1.02 ± 0.94 of the Logarithm of the Minimum Angle of Resolution (LogMAR). All demographic data were presented in Table 1.

Table 1
Demographic Data of Patients Diagnosed with Cataract and Epiretinal Membrane.

	n
Number of patients (n)	37
Number of eyes (n)	37
Age (year)	65.1 $\pm$ 7.7 (range, 43 – 78)
Sex (female)	24 (64.9%)
Laterality (Left eye)	21 (56.8%)
Preoperative LogMAR BCVA	1.02 $\pm$ 0.94 (range, 0.2 – 4)
Postoperative LogMAR BCVA	0.41 $\pm$ 0.27 (range, 0 – 1)
Data are presented as mean $\pm$ standard deviation.	
LogMAR is an acronym for the Logarithm of the Minimum Angle of Resolution.	
Best corrected visual acuity is abbreviated to BCVA.	

The mean AL 1 derived from the first peak signal was significantly shorter than the mean AL 2 obtained from the second peak signal ($p < 0.001$) and the difference between AL 1 and AL 2 was clinically significant (0.47 ± 0.30 mm) [12]. As a result, the mean power of IOL 1 was significantly higher than the IOL 2 ($p < 0.001$) and the difference between IOL 1 and IOL 2 was more than 3 incremental steps of IOL power (1.53 ± 0.96 diopters) (Table 2). After surgery implanting the IOL 2, the best corrected visual acuity was improved in all eyes. At three months post-operation, 78.4% of patients (95% CI, 62.8–88.6%) had postoperative refractive error within 0.5 diopter. All patients achieved postoperative refractive error within 1.0 diopter (Table 3).

Table 2

Comparison of the Axial Length, IOL Power and Refractive Outcomes derived from Two Peaks of the Axial Length Signals measured using the Standard Optical Biometer.

	First Signal		Second Signal		Difference	P value
	(1st Peak)		(2nd Peak)			
AL (mm)	AL1	23.13 ± 1.28 (range, 21.43 to 28.01)	AL2	23.60 ± 1.34 (range, 21.66 to 28.41)	0.47 ± 0.30 (range, 0.22 to 2.05)	<0.001*
IOL power (D)	IOL1	21.45 ± 3.19 (range, 11.21 to 26.56)	IOL2	19.93 ± 3.39 (range, 10.24 to 24.90)	1.53 ± 0.96 (range, 0.78 to 6.47)	<0.001*
Postoperative predictive error						
- Mean	IOL1	-0.940 ± 0.911	IOL2	0.081 ± 0.511	1.02 ± 0.59	<0.001*
Arithmetic Error (ME)		(range, -5.19 to 0.2)		(range, -1.15 to 1.14)	(range 0.53 to 4.04)	
- Mean		0.971 ± 0.877		0.393 ± 0.332	-0.58 ± 0.89	<.001*
Absolute Error (MAE)		(range, 0.015 to 5.19)		(range, 0.01 to 1.15)	(range -4.04 to 0.96)	
Data are presented as mean ± standard deviation.						
AL = axial length						
AL 1 = axial length obtained from the first peak signal of a standard optical biometer.						
AL 2 = axial length obtained from the second peak signal of a standard optical biometer.						
IOL = intraocular lens						
IOL 1 = intraocular lens power derived from the AL 1						
IOL 2 = intraocular lens power derived from the AL 2						
*P < 0.05 is considered as statistically significant difference.						

Table 3

Percentage of eyes with postoperative refractive error when the intraocular lens power derived from the second peak signal of axial length was chosen for cataract surgery.

Spherical Equivalent (diopter)	0.00	± 0.25	± 0.50	± 0.75	± 1.00
Number of eyes (n)	6	19	29	34	37
Percentage of eyes (total 37 eyes)	16.2	51.3	78.4	91.9	100

In terms of postoperative refractive outcomes, the IOL 2 resulted in significantly ME than those of the IOL 1 (0.08 ± 0.51 vs. -0.94 ± 0.91 diopter, $p < 0.001$). Moreover, the IOL 2 provided significantly lower MAE than the IOL 1 ($p < 0.001$). The predictive refractive error of cataract surgery in patients with ERM was less when using AL 2 to calculate the IOL power than when using AL 1 (Table 2 and Figure 2).

Discussion

An accurate AL measurement obtained from the optical biometer is the mainstay of the IOL calculation for cataract surgery. Typically, a single high-spike signal appearing at the level of the retina indicates the AL measured by the optical biometer. However, in eyes with ERM, we observed an unusual “double peak” signal of AL during the measurement. We hypothesize that the fibrous membrane of ERM (thickening of the internal limiting membrane) may interfere with the light projected from the optical device onto the macula, causing the AL signal to be split into double peaks (Figure 1B). Practically, one of the two AL-peak signals must be chosen for the IOL calculation. Therefore, we compared the AL derived from both the AL 1 and AL 2 including their respective IOL powers (IOL 1 and IOL 2). Although only the IOL 2 was selected for implanting in patients’ eyes, postoperative predictive errors were analyzed for both the IOL 1 and IOL 2. Predictive errors of the IOL 2 were significantly less than those of the IOL 1. This suggests that the second peak of AL signal yielded more accurate AL measurement and better refractive outcome than the first peak of AL signal.

A standard TD-OCT biometer employs partial coherence laser interferometry to measure the AL by analyzing the transmission time of light from the anterior corneal surface reaching the retinal pigment epithelium, and converting it into the length of the eye [3]. In normal eyes, the light will pass through the anterior segment of the eye, crystalline lens, vitreous, the inner retina that includes the internal limiting membrane through outer plexiform layer, outer nuclear layer, external limiting membrane, and photoreceptor layer before reaching the retinal pigment epithelium at the macula. Kuriyan E, et al. reported a series of patients with different severities of ERM where the average thickness of the inner retina layer was increased to about 225 microns, much thicker than eyes without ERM (3.64 microns) [13]. According to this, the ERM could induce additional inner retinal thickness up to 0.225 mm to the normal retina (0.2 mm) [10] before reaching the retinal pigment epithelium. We also observed a 0.47 mm difference between the AL 1 and AL 2, which was assumed to be the total thickness of the retina prior to retinal pigment epithelium (distance between the internal limiting membrane and retinal pigment epithelium). In our patients, the mean difference between the IOL 1 and IOL 2 was 1.53 diopters; representing more than three incremental steps of the regular IOL power (0.5 diopter). A large discrepancy between the two IOL powers derived from the two different ALs is a critical issue because an error of IOL power is considered to be the major cause of unsatisfactory refractive outcome after cataract surgery [14, 15]. Generally, the best corrected visual acuity is applied to evaluate the visual outcome of any ocular surgery. However, in these patients we are mainly concerned about postoperative refractive error rather than the best corrected visual acuity as the ERM itself may have a detrimental effect on visual function.

According to the pathophysiology of ERM, the AL 2 is most likely to be an anatomically genuine AL. Therefore, we decided to choose the IOL 2 for implanting in all cases. As we presumed, almost 80% of patients that received the IOL 2 had refractive error within 0.5 diopter, and all were within 1.0 diopter. The ME and MAE were significantly lower in the IOL 2 than IOL 1. Furthermore, the maximum MAE of the IOL 2 was 1.15 diopters, whereas the predictive refractive errors calculated using the IOL 1 could induce a maximum MAE of 5.19 diopters. These results confirm our assumption that the second peak of the AL signal represents the actual AL. Previous study also demonstrated that patients with ERM might have a postoperative myopic shift of 0.63 diopter after cataract surgery due to erroneous IOL calculation caused by underestimating the AL [16]. Choosing the correct AL could prevent patients from clinically significant refractive error. Therefore, when planning cataract surgery, surgeons and technicians should be aware of the characteristic double peak signal of the AL in patients with ERM or other vitreoretinal diseases.

Our study has some limitations. First, we did not classify the severity of ERM, which varies in severity. It is possible that patients with early stage ERM may produce a low reflectance of the first AL signal or barely detectable double signals that could be misinterpreted and lead to errors in AL measurement. When there is uncertainty, the OCT imaging may help determine the retinal structures. Second, we only recruited eyes with a double peak signal of the AL caused by ERM, and other types of macular diseases were not included.

To summarize, the AL measurement signal obtained from the optical biometer for cataract patients with ERM can deviate from a single, high-spike peak. Instead, it may demonstrate a double peak signal. Our results suggest that the second peak appears to be the true signal representing an accurate AL. The actual AL derived from the second peak signal allows accurate IOL power, resulting in good refractive outcomes.

Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Pratuangsri Chonpimai], [Chareenun Chirapapaisan], [Sabong Srivannaboorn], [Siriwan Loket], [Waree Nujoi], and [Somthin Dongngam]. The first draft of the manuscript was written by [Pratuangsri Chonpimai] and [Chareenun Chirapapaisan] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

The signal of axial length measurement derived from a standard time-domain optical coherence tomography-based biometer. A) a single peak signal obtained from the normal eye; and B) a double peak signal detected in an eye with epiretinal membrane.

Figure 2

Postoperative predictive errors present as mean arithmetic error (ME) and mean absolute error (MAE) derived from IOL1, calculated from the first axial length signal (Fig. 2A) and IOL 2, calculated from the second axial length signal (Fig. 2B).