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ORIGINAL ARTICLE

Comparison of intraocular lens power calculation formulas in patients with cataract and maculopathy

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Abstract

Purpose: The purpose of the study was to compare the effect of biometric formulas used in calculating intraocular lens (IOL) power on target refraction when planning cataract surgery in patients with diabetic macular edema (DME), age-related macular degeneration (AMD), or epiretinal membrane (ERM).

Methods: The study was carried out in the Ege University Medicine Faculty Department of Ophthalmology after obtaining local ethics committee approval. Sixty-two eyes with cataracts and ERM, AMD, or DME that increased retinal thickness were included in the study group. Fifty-four eyes with cataracts and no retinal pathology were included in the control group. Lens power calculations based on measurements obtained with optical and ultrasound biometers were made using the SRK-T, Holladay 2, Hoffer Q, Haigis, and Barrett Universal 2 formulas and the results were compared.

Results: In the study group, 31 eyes (50%) had DME, 16 (26%) had AMD, and 15 (24%) had ERM. The mean of arithmetic deviations from target refraction was lowest with the Barrett Universal 2 formula ($p>0.05$). When the Haigis formula was used, there was a significant deviation in both the study and control groups, while only the control group showed a significant deviation with the Hoffer Q formula ($p<0.05$). There was no significant difference between the groups in terms of absolute deviations ($p>0.05$).

Conclusion: In cataract patients with maculopathy and increased retinal thickness, the likelihood of inaccurate IOL power calculation was lowest with the Barrett Universal 2 and highest with the Haigis formula. These results should be further examined in larger patient series.

Keywords: Age-related macular degeneration; diabetic macular edema; epiretinal membrane; intraocular lens power calculation formulas; maculopathy.

Higher patient expectations in response to technological advances in cataract surgery have led to the pursuit of perfection at every stage of surgery.[1] One of the most important steps is implanting an intraocular lens (IOL) of appropriate power, which has a direct effect on patient satisfaction after the procedure.[2] Numerous formulas using measurements obtained by A-scan ultrasound (contact or immersion) or optical biometry are used preoperatively to determine the appropriate IOL. Biometry is a key step in calculating IOL power in modern cataract surgery.[3]

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The impact of various factors on achieving post-operative target refraction is among the most debated topics in the literature. Olsen[4] reported that errors in anterior chamber depth (ACD), axial length (AL), and corneal power measurement accounted for 42%, 36%, and 22% of deviation from predicted refractive error after IOL implantation, respectively. Formulas continue to be developed to enable target post-operative results to be achieved in eyes where these sources of error reduce the sensitivity of existing formulas. For this purpose, the third-generation formulas SRK-T, Hoffer Q, and Holladay 1 as well as the fourth-generation formulas Holladay 2, Haigis, and Olsen, and even the fifth-generation Barrett Universal 2 formula are also commonly used.[5] However, besides these predictable sources of error, there is still insufficient information regarding the effect of existing pathology on post-operative refraction or formula selection, particularly in patients with retinal pathology.

Therefore, this study aimed to evaluate the effect of using different formulas (SRK-T, Hoffer Q, Holladay 2, Haigis, and Barrett Universal 2) with optical and ultrasound biometry data in IOL power calculation during cataract surgery planning for patients with conditions that cause changes in macular thickness, such as epiretinal membrane (ERM), age-related macular degeneration (AMD), and diabetic macular edema (DME).

Materials and Methods

Patients with DME, AMD, and ERM who presented to the retina unit of the Ege University Medicine Faculty Department of Ophthalmology Department between January 2014 and December 2016 and had central foveal thickness >250 µm included the study group. Furthermore, hypermetropia of more than +4 diopters (D), myopia of more than −6 D, and AL under 21 and over 26 mm were excluded from the study in both groups. Informed consent forms were obtained from all patients and ethics committee approval was obtained from the Clinical Research Ethics Committee of the Ege University Faculty of Medicine (Decision Number: 16-6.1/7). Patients with media opacity severe enough to prevent or affect the results of IOL power measurement by optical and ultrasound biometry were excluded from the study. In addition to patients who have angle closure glaucoma, or angle closure glaucoma suspect were excluded. The study group included 62 eyes of 57 patients with macular pathology who underwent cataract surgery, while 54 eyes of 49 patients who had no ocular pathology and underwent uncomplicated cataract surgery were included in the control group.

Preoperatively, all patients underwent a detailed ophthalmologic examination including best-corrected visual acuity (BCVA), intraocular pressure measurement, slit-lamp anterior segment examination, and posterior segment examination with a 90D lens. Optical biometry (Al-Scan, Nidek, Japan) and contact A-scan ultrasound biometry (Sonogage Eye mod, Cleveland, OH, USA) were also performed for IOL power calculation. Optical coherence tomography (OCT) (Topcon 3D OCT-2000, Tokyo, Japan) was performed to determine macular thickness. In addition to the appropriate IOL power calculations according to SRK-T, Hoffer Q, Haigis, and Holladay 2 formulas using ultrasound and optical biometry data, the data obtained from optical biometry were entered into the Barrett Universal 2 formula data entry window on the official site (http://calc.apacrs.org) and IOL power calculations were performed and recorded.

Post-operative examinations were performed on day 1 and again between days 5 and 7. At post-operative 1- and 3-month follow-up, BCVA determined according to autorefractometer values and spherical equivalent values were recorded. Deviations were calculated as the difference between post-operative refraction values and target refraction values.

Statistical analyses were performed using IBM SPSS version 24 (IBM Corp., Armonk, NY, USA). Demographic data were compared between the groups using either Chi-square or independent t-test. For other parameters, independent t-test was used for between-group comparisons and dependent t-test was used for within-group comparisons. $P<0.05$ was considered statistically significant.

Results

Of the 62 eyes in the study group, 31 (50%) had DME, 16 (26%) had AMD, and 15 (24%) had ERM. In total, the study included 48 females (45%) and 58 males (55%). There were 23 females (47%) and 26 males (53%) in the control group, and 25 females (44%) and 32 males (56%) in the study group. There were no significant differences in age, sex, pre-operative AL, or keratometric values between the study and control groups ($p>0.05$). However, pre-operative central retinal thickness and pre-operative visual acuity differed significantly between the groups ($p<0.001$ and $p=0.003$, respectively) (Table 1). In the present study, the mean AL measured by optical biometry was longer than the mean AL measured by ultrasound biometry in the control group, while these values were similar in the study group.

Mean post-operative refraction values in the study and control groups were −0.54 D and −0.40 D at 1 month and −0.53

Table 1. Comparison of demographic, optical, and keratometric data

Groups	N	Mean	SD	p-value
Age (years)				
Control	54	66.98	8.034	0.678
Study	62	67.65	9.164	
Gender (F/M)				
Control	49	23/26	0.502	0.658
Study	57	25/32	0.495	
Pre-operative CFT				
Control	54	233.11	13.145	<0.001
Study	62	282.52	64.446	
Optic AL				
Control	54	24.47	0.90	0.224
Study	62	25.6	1.60	
Ultrasonic AL				
Control	54	23.47	0.90	0.220
Study	62	24.83	1.75	
Pre-operative BCVA (LogMAR)				
Control	54	0.68	0.30	0.003
Study	62	0.92	0.51	
Ultrasonic K1				
Control	54	43.67	1.79	0.183
Study	62	43.50	1.82	
Ultrasonic K2				
Control	54	43.95	1.79	0.676
Study	62	43.80	1.85	
Optic K1				
Control	54	43.61	1.63	0.692
Study	62	43.75	1.80	
Optic K2				
Control	54	43.63	1.60	0.912
Study	62	43.67	1.90	

F: Female; M: Male; CFT: Central foveal thickness; AL: Axial length; BCVA: Best-corrected visual acuity; K1: Flat keratometry value; K2: Steep keratometry value; SD: Standard deviation.

D and −0.44 D at 3 months, respectively (p>0.05). There was no change in the mean of arithmetic deviations from target refraction between post-operative 1 month and 3 months in either group. Compared to the other formulas, values were closest to target refraction when using the Barrett Universal 2 formula. However, when the post-operative means of arithmetic deviations according to formulas were compared in the groups, there was no significant difference between IOL power calculation formulas (p>0.05).

When IOL power calculation formulas were evaluated between aimed refraction and obtained refraction within the groups, the Barrett Universal 2 formula yielded the least deviation, although the difference was not significant (p>0.05). When the Hoffer Q formula was used, post-operative refraction significantly different from target refraction which was 0.50 Diopter myopia for both groups in the

Table 2. Comparison of mean arithmetic deviations from post-operative refraction within the groups according to intraocular lens power calculation formula

	Control (n=54) Study (n=62)	Post-operative 1 month (D)	p-value
Barrett Universal 2 formula	Control	0.002	>0.05
	Study	−0.02	>0.05
Optical SRK-T formula	Control	−0.11	>0.05
	Study	−0.07	>0.05
Optical Hoffer Q formula	Control	−0.2	<0.05
	Study	−0.07	>0.05
Optical Haigis formula	Control	0.4	<0.05
	Study	0.6	<0.05
Optical Holladay 2 formula	Control	−0.2	>0.05
	Study	−0.07	>0.05
Ultrasonic SRK-T formula	Control	0.14	>0.05
	Study	−0.04	>0.05
Ultrasonic Hoffer Q formula	Control	−0.16	<0.05
	Study	0.02	>0.05
Ultrasonic Haigis formula	Control	0.47	<0.05
	Study	0.6	<0.05
Ultrasonic Holladay 2 formula	Control	−0.11	>0.05
	Study	0.02	>0.05

Table 3. Between-group comparison of mean absolute deviations from target refraction for the intraocular lens power calculation formulas

	Control (n=54) Study (n=62)	Mean absolute deviation (D)	p-value
Barrett Universal 2 formula	Control	0.01	>0.05
	Study	0.02	>0.05
Optical SRK-T formula	Control	0.09	>0.05
	Study	0.07	>0.05
Optical Hoffer Q formula	Control	0.07	>0.05
	Study	0.06	>0.05
Optical Haigis formula	Control	0.04	>0.05
	Study	0.05	>0.05
Optical Holladay 2 formula	Control	0.06	>0.05
	Study	0.06	>0.05
Ultrasonic SRK-T formula	Control	0.03	>0.05
	Study	0.11	>0.05
Ultrasonic Hoffer Q formula	Control	0.06	>0.05
	Study	0.06	>0.05
Ultrasonic Haigis formula	Control	0.04	>0.05
	Study	0.05	>0.05
Ultrasonic Holladay 2 formula	Control	0.06	>0.05
	Study	0.11	>.005

control group, but the difference was not significant in the study group. When the Haigis formula was used, deviation from target refraction differed significantly in both groups ($p<0.05$) (Table 2). Mean absolute deviation from target refraction was similar for all formulas ($p>0.05$) (Table 3).

Discussion

Cellular changes in retinal pathologies such as DME, AMD, and ERM may result in an increase in macular thickness. In this study examining the performance of different IOL power calculation formulas in patients with retinal pathology, we determined that the closest results to target refraction were obtained with the Barrett Universal 2 formula, while significant deviations from target refraction were observed in both groups with the Haigis formula and only in the control group with the Hoffer Q formula.

Although many different parameters are used in IOL power calculation, inaccurate AL measurement is the most common cause of unexpected post-operative outcomes.[6] Different formulas using data obtained with ultrasound and optical biometers are used for this purpose. AL is measured on the anatomic axis using A-scan ultrasound biometry and on the visual axis using optical biometry.[7] AL values measured by optical and ultrasonic biometry are reported to be strongly correlated in healthy eyes.[8] Measurements made by optical biometry are 0.2 mm greater than ultrasonic measurements because in ultrasound biometry, the probe indents the cornea and measurements are obtained at the level of the internal limiting membrane.[9] Optical biometry measures at the RPE level, which may be another cause of approximately 130 µm difference in AL measurement.[10] In the present study, the mean AL measured by optical biometry was 0.01 µm longer than the mean AL measured by ultrasound biometry in the control group, while the mean AL values obtained by these two methods were similar in the study group.

Research is ongoing to evaluate the sensitivity of formulas in complicated eyes such as those with long or short AL, previous refractive surgery, or pediatric eyes. IOL power calculation formulas give similar results in eyes with normal AL. However, it has been reported that the Hoffer Q formula is more appropriate for eyes with short AL while the SRK-T and Haigis formulas are better suited to eyes with long AL.[11] Although AL values obtained by optical and ultrasonic biometry were longer in our study group ($p>0.05$), the Hoffer Q formula resulted in significant deviation from target refraction only in the control group. We also observed unexpected results with the Haigis formula, which was previously reported to be suitable for eyes with long AL.[11] One study showed that Barrett Universal 2 formula was more sensitive than the Haigis formula in myopic eyes with AL >30 mm.[12]

Other studies have also shown that when using the Barrett formula, the estimated error is minimal compared to other formulas such as Haigis, Hoffer Q, Holladay 1, Holladay 2, Olsen, and SRK-T.[13,14] Because Barrett formula using more additional parameters such as ACD, lens thickness (LT), white-to-white measurements (WTW) than earlier generation formulas which is obtained by using only AL and keratometry data.[15] When we use all biometric parameters (such as ACD, LT, WTW, AL, and K readings) for IOL power calculation using Barrett formulas, we may get better post-operative outcome for patients.[16] Kane et al.[17] compared the Holladay 1, Hoffer Q, SRK-T, Haigis, Holladay 2, and Barrett Universal 2 formulas and reported that the Barrett Universal 2 was the most sensitive formula independent of AL. In the present study, we also found that outcomes were closest to target refraction when using the Barrett Universal 2 formula ($p>0.05$).

Patients have very high expectations from cataract surgery.[18] Therefore, post-operative refractive error can lead to patient dissatisfaction. There are no published studies regarding the ideal formula for patients with retinal pathologies, making this study a first in the literature. Limitations of the study are it was not prospective, the patient sample was relatively small, ACD measurements deficient, and lacking of disease subgroup analysis and all biometric measurements were not performed by a single physician.

Conclusion

In cataract surgery for patients with maculopathy and increased retinal thickness, IOL power calculation using the Barrett Universal 2 formula resulted in the lowest probability of undesirable results. Although the Hoffer Q formula may have low sensitivity in IOL power calculation for routine cataract surgery in patients without retinal pathology, it had better sensitivity in eyes with maculopathy. A significant deviation from target refraction was only seen in eyes with maculopathy when the Haigis formula was used. Therefore, we recommend using the Barrett Universal 2 formula as the first choice for IOL power calculation in eyes with maculopathy to avoid unwanted outcomes. Studies with larger patient series are needed to elaborate on these findings.

Ethics Committee Approval: This study was approved by Ege University Faculty of Medicine Clinical Research Ethics Committee (date: 21.07.2016; number: 16-6.1/7).

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