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Research Article

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Accuracy of Intraocular Lens Power Calculation Formulae

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Abstract

Aim: To investigate the accuracy of seven currently-used intraocular lens (IOL) power calculation formulae.

Patients and methods: A total of 429 eyes of 429 patients were retrospectively analyzed. A low-optical coherence reflectometry device (Lenstar, Haag-Streit) was used for the calculations. SRK/T, Hoffer Q, Haigis, Holladay-2, Olsen, Hill-RBF and Barrett Universal II formulae were studied. The study included patients who underwent phacoemulsification surgery with a 2.8 mm corneal cut by a single surgeon. Refraction measurement was done at the first postoperative visit, and then spherical equivalent values were recorded for each patient. Mean absolute error (MAE) was calculated as the absolute value of postoperative spherical equivalent value minus predicted error for each formula.

Results: The mean age of the patients was 67.51 ± 5.75 years. Mean axial length was 23.42 ± 2.02 mm (min: 20.03, max: 32.68, median: 23.09). Mean IOL power was 21.1 ± 5 diopters (min: -1.5, max: 3.5). Postoperative spherical values were between -1.50 and +1.00 diopters. Mean absolute errors were 0.317 for SRK/T, 0.280 for Holladay-2, 0.273 for Hoffer Q, 0.264 for Haigis, 0.347 for Barrett Universal II, 0.339 for Hill-RBF, and 0.351 for Olsen.

Conclusion: Hoffer Q, Holladay-2, and Haigis formulae had significantly lower MAE values than SRK/T, Barrett Universal II, Hill-RBF, and Olsen formulae. Although the Haigis formula gave the lowest MAE value, there was no significant difference with the Hoffer Q and Holladay-2 formulae.

Keywords

Phacoemulsification; Intraocular lens; Hoffer q; Haigis; SRK-T; Holladay-2; Olsen; Hill-RBF; Barrett universal II

Introduction

Cataract surgery is currently performed with high rates of success. Due to developing devices and technology, surgery is not limited to only removing the opacified lens, but can perform lens exchange with refractive aims. Surgeries remove the patient's natural lens and replace it with an artificial intraocular lens (IOL). This artificial lens inserted into the eye has led to more satisfying surgical success due to accurate calculation of where the lens should be positioned and the dioptric power [1].

Intraocular lens power measurement was first performed using ultrasonic methods, but the use of optical methods in recent years has begun to obtain more accurate results [2]. Though optical methods are superior, the inability of the light bundle to pass through the lens in mature cataracts appears to be a disadvantage compared to ultrasonic methods [3]. Considering that preoperative intraocular lens calculations may be deficient, Zhang et al. made measurements using an intraoperative optic wave refractive analysis (ORA) device and reported there was no difference between the preoperative and intraoperative measurements [4].

While development of devices using new methods continues, there are results reported for new formulae estimating the intraocular lens power with new methods. After the first lens formulae of SRK and Binkhorts five decades ago, the second generation SRK-2 formula, third generation SRK/T, Holladay and Hoffer Q formulae, the fourth generation Holladay-2, Olsen and Haigis formulae and finally the fifth generation Hill-RBF and Barrett Universal II formulae have entered use [5,6].

Along with the low number of studies about the new generation of intraocular lens power calculations, the number of studies about all formulae is very low [7-13].

Patients and Method

This study was retrospectively completed by screening the files of cataract patients operated by two surgeons from 2015-2018. Informed consent was obtained from all patients along with ethical committee permission. One eye of each patient was studied. Patients operated on both eyes had one randomly-chosen eye included in the study.

Inclusion criteria for the study are as follows:

- Those who underwent suture-free cataract surgery with the phacoemulsification method
- Those with measurements taken with an optical biometry device
- Those with postoperative vision acuity 20/40 and above
- Those with the same type of monofocal intraocular lens inserted (Acriva BB UDM 611, VSY Biotechnology, Turkey)
- Those who attended the one-month follow-up
- Exclusion criteria for the study are as follows:
- Cases with complications,
- Those with previous surgery
- Those with refractive surgery
- Corneal pathologies (keratoconus, scar, dystrophy)
- Those with retinal detachment surgery
- Those with macular edema

Phacoemulsification surgery was performed under topical anesthesia, with 2.8 corneal incision and 5.0-5.5 mm diameter capsulorhexis and insertion of a lens into the capsule. Intraocular lens power measurements and postoperative measurements were completed by a single researcher.

The single-type IOL used in the surgery of Acriva IOL (VSY Biotechnology, Turkey) has a haptic monofocal plate, with a constant recommended as 118.0 by the manufacturer. This constant is

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recommended as 118.3 for the SRK-T formula. Optical diameter is 6 mm and haptic diameter is 11 mm. Haptic optical angle is 0 degrees with refractive index of 1.46.

The optical biometry device used for measurements was an optical low-coherence interferometer (Lenstar LS-900, Haag-Streit AG, Koeniz, Switzerland). The IOL power calculation formulae used for measurements were the Haigis, Hoffer Q, SRK/T, Olsen, Barrett Universal II, Hill-RBF and Holladay-2 formulae. Keratometry measurements and other anterior chamber depth and lens thickness values were measured with the same device.

The main parameter used for assessment in the study was the mean absolute error (MAE). At the first month check-up, spherical equivalent value was subtracted from the prediction error value with the absolute value of this value taken and mean obtained to calculate the MAE value for each formula with optimization.

Statistical analysis was performed with the SPSS program using the Bonferroni-corrected one-way ANOVA test.

Results

A total of 429 eyes in 429 patients were studied. Of patients, 198 were female (46.2%) and 231 were male (53.8%). The mean age of patients was 67.51 ± 5.75 (min: 55, max: 81) years.

Mean axial length was 23.42 ± 2.02 mm (min: 20.03, max: 32.68, median: 23.09). Mean IOL power was 21.1 ± 5 diopters (min: -1.5, max: 32.5). Apart from 1 patient, no other patient had negative IOL inserted. Preoperative spherical diopter values were between -0.50 and -22 diopters for 47% of patients, with the remaining 53% varying from 0.00 to +11.0 diopters. Postoperative spherical values were between -1.50 and +1.00 diopters. Of patients, 98% had acceptable values [14] from -1.00 to +1.00. All information related to refractive values is given in Table 1.

Mean absolute error values for the seven formulae were as follows; 0.317 for SRK/T, 0.280 for Holladay-2, 0.273 for Hoffer Q, 0.264 for Haigis, 0.347 for Barrett Universal II, 0.339 for Hill-RBF and 0.351 for Olsen. The three formulae with lowest values of Hoffer Q, Holladay-2 and Haigis were not identified to be statistically significantly different, while there was a statistically significant difference between these three formulae and the SRK/T, Barrett Universal-II, Hill-RBF and Olsen formulae. Detailed information related to all mean absolute error and numerical error values are shown in Table 2.

Discussion

The most commonly used parameters in formulae measuring intraocular lens power are axial length and anterior chamber depth. For axial length measurements, every 0.1-millimeter error causes a diopter error of 0.27. If ultrasonic biometry is not performed with the immersion method, the cornea is excessively compressed and erroneous measurements may be obtained [15]. For anterior chamber depth measurements, every 1-millimeter error may cause postoperative deviation of 1.5 diopters [16]. Problem related to erroneous measurements have largely been solved by optical biometry devices. The use of automatic devices instead of manual keratometry has begun to obtain more reliable results. In this study, optical biometry and automatic keratometry were used, to prevent possible errors in axial length and keratometry measurements.

Reliability of studies may be reduced by operations performed by many surgeons and the use of different IOLs. Due to the use of a single IOL and one person performing measurements, the parameters which can affect outcomes are standardized and only the formula is assessed. In this study, a single-type IOL was inserted and all measurements were performed by the same researcher, in order to be able to assess the formula alone as much as possible.

One of the main targets of the formulae is to identify the effective lens position (ELP). The lens inserted in the eye during cataract surgery does not have the same volume as our congenital lens, so the position within the capsule may change toward the anterior or posterior. Pseudophakia patients have a tendency toward increased anterior chamber depth. If the intraocular lens has anterior position, there may be a trend toward myopia, while if it is located posterior, there may be a trend toward hypermetropia [17-19]. In our study, nearly one third of patients were myopic, one third were emmetropic and the remaining one third remained hypermetropic. The IOLs in this study were inserted according to the Barrett formula and the emmetropic rate was observed as one third. If the IOLs were inserted according to the Haigis formula, the rate of emmetropic patients may have been higher.

Some reported studies observed no difference between formulae, while other studies reported different formulae were effective. The

Table 1: Refractive Values.

Refractive Values		
	Preoperative	**Postoperative**
Spherical		
Mean	-0.08	0.00
Minimum	-22.00	-1.50
Maximum	+11.00	+1.00
Standard Deviation	4.95	0.39
Cylindrical		
Mean	-0.57	-0.61
Minimum	-3.75	-1.75
Maximum	+3.00	+2.00
Standard Deviation	0.84	0.74

Table 2: Absolute Error Values.

Absolute Errors for All Formulae							
	Hoffer Q	**SRK/T**	**Holladay-2**	**Haigis**	**Olsen**	**Barrett**	**Hill-RBF**
	0.273	0.317	0.28	0.264	0.351	0.347	0.339
MAE	0.00/1.87	0.00/2.14	0.00/2.09	0.00/1.18	0.00/1.34	0.00/1.16	0.00/2.21
Min-Max	0.229	0.268	0.244	0.217	0.255	0.224	0.272
MAE: Mean Absolute Error							

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study by Jeong et al. investigated the Haigis, Holladay-1, Hoffer Q and SRK/T formulae and did not identify a significant difference between the formulae [6]. The study by Olsen and Hoffman examined the Haigis, Hoffer Q, Holladay 1 and SRK/T formulae and did not identify a significant difference [20]. Narvaez et al. found no significant difference between the Hoffer Q, Holladay-1, Holladay-2 and SRK/T formulae in their study [7]. Melles et al. studies two different types of IOL and found that for both types the Barrett formula provided best results, followed by the Olsen and Haigis formulae [21]. Kane et al. found the best results were obtained with the Barrett formula, while contrary to our study the Haigis, Hoffer Q and Holladay-2 formulae provided the worst results [8]. A study by Cooke and Cooke comparing current formulae observed the Barrett formula had lowest MAE value of 0.306, with the second-lowest MAE values obtained as 0.319 from the Haigis formula [10].

Robert et al. studied the Holladay-2, SRK/T, Hoffer Q, Hill-RBF and Barrett universal II formulae and found the MAE values for all formulae varied from 0.300 to 0.340, with no significant difference observed [22]. The study by Wang and Chang investigated the Haigis, Hoffer Q, Holladay-1 and SRK/T formulae and reported the Haigis formula provides significantly lower measurements compared to the other formulae [9]. The Haigis formula uses three constants of a0, a1 and a2, and in this way targets a postoperative refraction value close to zero. In our study, the Hoffer Q, Holladay-2 and Haigis formulae provides significantly lower errors compared to the other formulae and though there was no statistical difference between these three formulae, the lowest value was obtained with the Haigis formula.

Just as in the latest formulae, the use of more parameters is expected to provide better results. However, when the results of the study are examined this is not the case. When the MAE values for the latest generation of formulae are examined, they appear good; however, it appears they provided higher error values compared to the error values for formulae from previous generations. Most IOLs used in the reported studies have an optic-haptic angle, while the IOL used in this study has an angle of zero degrees. The reason for different results compared to other studies may be associated with the optic-haptic angle being zero. Secondly, the formulae were generally prepared for use with a certain type of IOL. As a result, a certain formula will be superior in studies with that IOL. To fully understand whether the formulae provide good results or not, it may be better to study different IOLs [22].

Strong aspects of our study include studying currently-used formulae, using a single-type IOL, postoperative measurements performed by a single person, a high rate of patients remaining from -0.75 to +0.75 postoperatively and the use of a single device for all measurements. Among the disadvantages are that though the number of patients is substantial, it did not reach patient numbers in the thousands which are required to fully decide about the intraocular lens power calculation formulae.

Conclusion

In conclusion, in this study assessing seven different current formulae, the Holladay-2, Hoffer Q and Haigis formulae provided significantly lower error compared to the SRK/T, Barret Universal II, Olsen and Hill-RBF formulae for intraocular lens power calculations. Among formulae with low errors used for measurements, the lowest error was obtained with the Haigis formula.

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