

The comparison of the intraocular lens power calculation formulas in long eyes

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Abstract

Objective: To investigate the accurate intraocular lens power formula in eyes with axial length over 26mm by using optical biometry.

Methods: The retrospective case series was conducted at Medicana International Avcilar Hospital, Istanbul, Turkey from 2016 to 2018, and comprised data related to years between 2014 and 2018. Optical low-coherence reflectometry had been used in measurements. The calculation methods were included Hill-radial basis function, Sanders-Retzlaff-Kraff-Theoretical, Hoffer Q, Barrett Universal II, Olsen, Haigis and Holladay-2. The spherical equivalent values that were obtained with automated refractometer at the first postoperative month were recorded. Mean absolute error for each formula was estimated. SPSS 16 was used for data analysis.

Results: There were 56 eyes of as many patients with a mean axial length of 26.70 ± 0.88 mm. The postoperative numerical error was within ± 0.50 diopters in 46(82%) patients, and between the -0.50 and -1.00 diopters in 10(18%). The mean absolute error values were significantly lower in Haigis, Sanders-Retzlaff-Kraff-Theoretical, HofferQ and Holladay-2 formulas compared to the Barrett, Hill, and Olsen formulas ($p < 0.05$). There was no statistically significant intra-group difference for Haigis, Sanders-Retzlaff-Kraff-Theoretical, Hoffer Q, and Holladay-2 formulas ($p > 0.05$).

Conclusion: In long eyes with an axial length over 26mm, Haigis, Sanders-Retzlaff-Kraff-Theoretical, Hoffer Q and Holladay-2 formulas yielded better postoperative refractive outcomes compared to Hill-radial basis function, Barrett Universal II and Olsen formulas. The Haigis formula had the lowest refractive numerical error.

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Introduction

The cataract surgery is performed primarily by intracapsular, then extracapsular, and, finally, by phaco-emulsification methods in terms of historical evolution. Although the main factor affecting surgical success is the complete removal of the cataractous lens without any tear to the posterior capsule, the precise calculation of the intraocular lens (IOL) power placed during the surgery has great importance due to the fact that lens interventions are now being done for refractive purposes.

For the IOL power calculation, the first generation Sanders-Retzlaff-Kraff-1 (SRK-1) and Binkhorst formulas, followed by the second-generation SRK-2 formula, then the third generation SRK-Theoretical (SRK-T), Holladay-1 and Hoffer Q, and, lastly, the fourth generation Holladay-2, Haigis, Hill-Radial Basis Function (Hill-RBF), Barrett and Olsen formulas have begun to be used.¹⁻³

The first method to measure IOL power was the ultrasonographic method. Today, the optical method is becoming more popular because it does not touch the patient's eye and gives more accurate results.⁴ The major disadvantage of the optical method is seen in brown-

mature cataractous lenses which interfere with the light passing through the lens and reaching the retina. For this reason, there are ultrasonic probes at the same time in the devices to measure the axial length in mature cataractous lenses.

By the use of the optical method, the postoperative refractive error is minimised, but not removed altogether. The new generation formulas give a postoperative refractive outcome within a range of ± 1.00 diopters. Indeed, the margin should be within a range of ± 0.50 diopters which can be achieved in only half of the patients. Since the presumed postoperative refractive error can be seen more comparable in normal axial length (22-26mm), it is not reasonable in patients with longer axial lengths. After cataract surgery, the patients with axial length > 26 mm get mostly hyperopic refractive outcomes more than 1.00 diopters.⁵

In literature, there is a limited number of studies using both optical biometry device and new generation formulas in long eyes. The current study was planned to investigate the accurate IOL power formula in eyes with axial length > 26 mm by using optical biometry and new generation formulas.

Materials and Methods

The retrospective case series was conducted in the Eye

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Clinic of Medicana International Avcilar Hospital, Istanbul, Turkey, between 2016 and 2018, and comprised data related to years between 2014 and 2018. Charts of all the patients who had undergone cataract surgery were reviewed. The sampling technique and sample calculation could not be done due to the selection of all of the long eyes.

Those included were patients who underwent cataract surgeries with an axial length >26mm, measurements with optical biometry, those with a postoperative visual acuity of 20/40 or greater, and those with an intraocular lens as Acriva plate haptic (VSY Biotechnology, Turkey). The lens constant of 118.3 was used.

All patients underwent 2.8 clear corneal incisions phacoemulsification surgery, bag-implanted IOL with a diameter of 5.0-5.5mm capsulorrhexis. All cataract surgeries, IOL measurements and preoperative-postoperative refraction measurements were performed by the same surgeon.

Complicated cases were excluded and so were patients with corneal pathology, such as keratoconus, corneal scarring, dystrophy, retinal detachment, macular oedema, cases with vitreous loss, previous surgery, refractive surgery patients and those who had not been seen in the first-month visit.

Optical low-coherence reflectometry (OLCR) was used in the measurements (Lenstar, Haag-Streit). The calculation methods included were Hill-RBF, SRK-T, Hoffer Q, Barrett Universal II, Olsen, Haigis and Holladay-2.¹⁻³ All patients were evaluated with all the seven formulas. Prediction

error for same power of the IOL was recorded for each formula. The power of the IOL was selected according to the results of the Barrett formula. The anterior chamber depth and keratometry values were measured with the same device. Before the OLCR, some formulas were only available on the internet site for each formula. No internet site calculation was used in this study due to the calculation methods of all the formulas available in the software with the recommendations of the manufacturer. The spherical equivalent values obtained with automated refractometer at the first postoperative month were recorded.

Mean absolute error (MAE) values were calculated for each formula as absolute value of the difference between the spherical error at first-month visit and prediction error for each method estimated by the OLCR. Mean numerical error (MNE), MAE and median absolute error values were calculated for each formula separately.

Data was analysed using SPSS 16. One-way analysis of variance (ANOVA) was also used. Statistical significance was set at $p < 0.05$.

Results

There were 56 eyes of as many patients with a mean age of 66.1 ± 5.8 years (range: 58-79 years). Of the total, 32(57%) patients were females and 24(43%) were male.

The mean axial length was 26.70 ± 0.88 mm (range: 26.02-30.19). Mean IOL power was 14.2 ± 2.7 (range: 3.50-19.50). Negative diopter IOL was not inserted in any patient. The mean preoperative spherical equivalent value was -6.76 ± 3.22 diopters, while the

Table-1: Pre- and post-operative refractive changes.

	Preoperative Spherical Diopter	Refractive Changes (n:56)		Postoperative Spherical Equivalent
		Preoperative Spherical Equivalent	Postoperative Spherical Diopter	
Mean	-6.45	-6.76	-0.27	-0.51
Minimum	-1.75	-1.38	-0.25	0.12
Maximum	-17.00	-17.00	-1.25	-1.00
Standard Deviation	2.70	2.75	0.31	0.21

Table-2: Minimum, maximum and standard deviations in all formulas.

	Hill	SRK-T	Results of All Formulas (n:56)				
			Hoffer Q	Barrett	Olsen	Haigis	Holladay 2
Mean	0.372	0.311	0.274	0.536	0.420	0.238	0.315
Minimum	0.04	0.01	0.02	0.04	0.01	0.03	0.00
Maximum	1.95	0.79	0.72	0.98	0.97	0.98	1.19
Standard Deviation	0.300	0.212	0.179	0.195	0.204	0.217	0.258

Hill: Hill-radial basis function; SRK-T: Sanders-Retzlaff-Kraff-Theoretical, Barrett: Barrett Universal II.

postoperative spherical equivalent value was -0.51 ± 0.21 diopters.

The postoperative numerical error was within ± 0.50 diopters in 46 (82%) patients, and between -0.50 and -1.00 diopters in 19 (18%). For all formulas except Barrett, the numerical error tended to be negative (Table-1).

MAE values were significantly lower in Haigis, SRK-T, HofferQ, and Holladay-2 formulas compared to the Barrett, Hill-BRF and Olsen formulas. There was no significant intra-group difference for the Haigis, SRK-T, HofferQ and Holladay-2 formulas which calculated the IOL power more precisely, while the lowest MAE value was seen in Haigis formula (Table-2).

Discussion

A precise biometry measurement is the most important point to reach the predicted postoperative value in eyes >26 mm in axial length. One of the mainstay is to use an effective biometry device for accurate measurement of the axial length. In literature, postoperative undesired refractive outcomes were seen in lower rates with the use of the optical method than the ultrasonographic method by avoiding indentation error.⁶⁻⁸ The current study was carried out with a biometry device using optical method which calculated the IOL power more accurately.

Besides the accurate measurement of the axial length, the second step to have the predicted postoperative refractive outcome is the use of IOL power estimation formulas. The anterior chamber depth is used as a parameter in the Binkhorst formula for the first-generation form, whereas SRK-II is a regression formula for the second-generation formulas. In the third generation, Holladay-1, SRK-T and Hoffer Q used the corneal curvature in addition to the anterior chamber depth.

In a study by Hoffer in long eyes, SRK-T, Hoffer Q and Holladay-1 formulas were compared and the study reported that the MAE values were in similar rates in the range of 0.41 and 0.45.⁹ Tsang et al. studied long eyes in Chinese population and reported that Hoffer Q showed the lowest postoperative refractive error.¹⁰

Fourth generation formulas Haigis, Barrett, Olsen and Holladay-2 aim at achieving more accurate results using lens thickness, white-to-white distance, preoperative refraction, and patient age.^{11,12} Abulafia et al. reported that the last generation formulas also have a hyperopic tendency when compared with the older ones.¹³ In literature, while the postoperative

hyperopic refractive result was seen in majority of patients,¹⁰⁻¹⁴ in the current study negative refractive outcomes were obtained in all formulas, except Barrett.

While the Barrett formula yielded good results in previous studies, it gave the worst results in the current study of long eyes. One possible explanation might be that previous studies were done with partial coherence interferometry (PCI) device which cannot measure lens thickness. Cooke et al. studied long eyes with OLCR device and reported that while Barrett and Holladay-2 formulas yielded positive numerical errors, Olsen and Haigis formulas had negative numerical error values. The study commented that the calculations of the Barrett formula might be different within two different devices and the results might be undesirable in long eyes with OLCR.¹⁵

In the current study, Haigis formula had the lowest MAE. Wang et al. and Fam et al. reported that the lowest postoperative refractive outcome was seen in Haigis formula that might be related to the precise measurement of the anterior chamber depth by the optical biometry.^{14,16} Cooke et al. reported that the Haigis formula was the lowest with an MAE value of 0.280 in the long eyes. The study stated that the formula estimated the effective lens position by adjusting the a_2 constant to the axial length, resulting in comparable postoperative refractive outcomes in all axial lengths.¹⁵

Conclusion

In long eyes with axial length >26 mm, Haigis, SRK-T, Hoffer Q, and Holladay-2 formulas yielded better postoperative refractive outcomes compared to Hill, Barrett and Olsen formulas, with the Haigis having the lowest refractive numerical error.

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