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Effect of anterior chamber depth on the accuracy of different intraocular lens' formulas

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ABSTRACT

Background and Objectives: Due to the difference in anterior segments among different races, intraocular lens formulas behave differently. Asian eyes have smaller anterior segment dimensions than Caucasian eyes. This study was carried out to evaluate the effect of different values of anterior chamber depth on the accuracy of Sanders, Retzlaff, Kraff/Theoretical (SRK/T), Hill Radial Basis Function (Hill RBF 2), and Barrett Universal II (Barrett U II) formulas.

Methods: This was a descriptive observational study. Ninety-six eyes of patients, who underwent phacoemulsification with intraocular lens implantation and ended uneventfully, were included. The patients were divided into two groups based on the anterior chamber depth (ACD). Group 1 had ACD > 3 mm and group 2 had ACD < 3 mm. Intraocular lens (IOL) power with SRK/T was calculated with a built-in formula in IOL Master 500. Barrett Universal II and Hill RBF 2 formulas were calculated using online calculators. Descriptive statistics were calculated for both groups. An independent *t*-test was applied for group comparison.

Results: Comparisons of the mean prediction errors of groups 1 and 2 using three different formulas were not statistically significant ($p > 0.05$). However, SRK/T had the lowest median prediction error for both groups but the highest percentage of eyes within ±0.5 D of absolute prediction error (APE) for group 1 and the lowest percentage of eyes within ±0.5 D of APE for group 2.

Conclusion: There was no statistically significant effect of different anterior chamber depths on the accuracy of SRK/T, Barrett U II, and Hill RBF 2. The three formulas behaved similarly with different depths of the anterior chamber.

Keywords: Anterior chamber depth, Barrett Universal II, Hill RBF, Phacoemulsification, Sanders, Retzlaff, Kraff/Theoretical formula.

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Introduction

There is a large variation in the anatomical measurements of human eyes, which is the reason why there is no ideal intraocular lens (IOL) calculation formula to make every eye emmetrope after cataract surgery. Efforts are continuing, since the implantation of the first IOL, to devise a formula which could be accurate for all eyes, despite variations. These formulas can be divided into two types: theoretical formulas and regression formulas. In regression formulas, postoperative results of a large number of eyes are averaged to obtain empiric formulas. Theoretical formulas consider effective lens position (ELP) and they differ in the way ELP is calculated.[1] In the earliest theoretical lens formulas, ELP was constant. In second-generation formulas [Binkhorst, Sanders, Retzlaff, Kraff (SRK) I, and SRK II], axial lengths were used to find out ELP. In third-generation formulas, which include Holladay, Hoffer Q, and Sanders, Retzlaff, Kraff/Theoretical (SRK/T), corneal curvature was also taken into account along with the axial length. Modern and new generation of formulas consider more variables to predict the IOL power. Holladay II, Hill Radial Basis Function (Hill RBF 2), Olsen, Barrett Universal II, and H5 are included in this category. Haigis' formula does not consider corneal power and takes into account ACD. Other variables used in ELP calculation are corneal diameter (Holladay, Barrett Universal II) and lens thickness (Olsen, Holladay, and Barrett Universal II). Race and gender are also taken into account in H5, which is a fifth-generation formula.

As the anatomical structures of anterior segments differ among different races, the results obtained from a particular formula also differ in different races.[2,3] With the advent of optical biometers, Asian eyes have shown smaller anterior segment measurements as compared to Caucasian eyes. It was also noticed that Asian eyes were not shorter than Caucasian eyes, only the anterior segment dimensions were smaller.[4,5]

Ample literature is available on the accuracy of different IOL formulas in different axial lengths, but very few papers were found in the literature, which considered formula accuracy with different anterior chamber depths.

This study was carried out to find out the effect of ACD on the results of SRK/T, Barrett Universal II (Barrett U II), and Hill RBF 2 formulas in Pakistani eyes.

Methods

This descriptive observational study was conducted at the Yaqin Eye Center, Lahore, Pakistan, from March 2019 to March 2020. After getting approval from the institutional ethical review board, medical records of patients, who were operated on with phacoemulsification and nontoric/monofocal intraocular (in the bag) lens implantation, were retrieved. All cases that had a complicated cataract or a history of any kind, previous ocular surgical or similar interventions, were excluded. Patients with corneal diseases, eyes with astigmatism of more than ±2 D, incomplete data, absence of postoperative records of follow-up/postoperative refraction at 4 weeks, acoustic biometry or any preoperative/postoperative complication, cases with sulcus IOL implant/scleral-fixated IOL and patients of hard cataracts where optical biometry was difficult were also excluded from the study. Patients in whom Hill RBF 2 formula showed out-of-bound results were also excluded. Ninety-six patients qualified for the inclusion criteria. Data included gender, age, right or left eye, history of hypertension, diabetes, ischemic heart disease, best corrected visual acuity (BCVA with Snellen chart), intraocular pressures, refractive error before and after surgery, complete slit lamp examination for anterior and posterior segments, and B-scan (when the retina was not visible). Spherical equivalent was considered if the eyes were astigmatic. To avoid bias, only one eye from each patient was included. An optical biometer (IOLMaster 500) was used. Other parameters were axial length, anterior chamber depth, keratometry, and postoperative refractive prediction. Distance from corneal epithelium to the lens was taken as anterior chamber depth. A single model of IOL was implanted and patients with visual acuity < 6/12 after surgery were excluded.

The selected 96 records were divided into two groups based on anterior chamber depth (ACD). Group 1 included 64 patients (ACD > 3 mm) and in group 2, 32 patients qualified the inclusion criteria (ACD < 3 mm). IOLMaster 500 was used to calculate IOL power with the SRK/T formula. Online calculators were used for Barrett Universal II formula and Hill RBF (Version 2.0, January 2019).[6,7] To avoid surgeon bias, all surgeries were carried out by a single experienced surgeon. Phacoemulsification was carried out under topical anesthesia using Millennium™ Microsurgical System from Bausch and Lomb. Foldable IOL (Acrysof IQ model; SN60WF) was implanted in the bag. Follow-up examination included BCVA, auto-refraction, subjective refraction, and slit lamp biomicroscopy. The final best corrected visual acuity was checked 4 weeks after surgery. The difference in postoperative refractive error and preoperative refractive prediction was measured to calculate the prediction error. To find out the accuracy of each formula, mean absolute error and median absolute errors (MedAE) were considered. In the end, the percentage of eyes with APEs < ±0.5 D, between ± 0.5 D and ± 1.0 D, and > ±1.0D were calculated.

Statistical analysis

SPSS version 21 (IBM Corp.) was used to analyze data statistically. Descriptive statistics were carried out for all groups. Mean and median values were calculated for age, axial length, keratometry, and anterior chamber depth. An independent *t*-test was carried out for group comparison. p-value < 0.05 was considered significant for all statistical analyses.

Results

The mean age of the patients was 60.7 ± 10.7 years. There were 49 (51.1%) male and 47 (48.9%) female participants. The mean axial length in group 1 was 24.11 ± 1.46 mm and in group 2 was 23.22 ± 0.89 mm. Mean K1 and K2 in group 1 were 43.59 ± 1.89 and 44.49 ± 1.89, respectively. For group 2, mean K1 and K2 were 43.2 ± 1.54 and 43.91 ± 1.68, respectively. Mean ACD in group 1 was 3.37 ± 0.26 mm and in group 2 was 2.71 ± 0.18 mm.

An independent *t*-test was applied to compare the mean prediction error (MPE) of groups 1 and 2 using three different formulas. For SRK/T, Barrett U II, and Hill RBF 2, there were no significant differences in the scores for groups 1 and 2 ($p > 0.05$, as shown in Table 1). Table 2 shows that the SRK/T formula had the lowest value of MPE.

When the median prediction error (MedPE) for the three formulas was analyzed, the total MedPE of SRK/T was the lowest (-0.03) when compared with the other two formulas (Table 2). In group 1, SRK/T had an MedPE of -0.02, which was lower than the other two formulas.

For MedAE, the lowest MedAE was observed with Barrett Universal II versus Hill RBF 2 for group 1. MedAE for SRK/T versus Barrett Universal II was lowest for group 2. MedAE for SRK/T versus Hill RBF 2 was lowest for group 2 (Table 3).

The percentage of eyes with < ±0.5 D, ±0.5 to ±1.00 D, and > ±1 D of APE is shown in Table 4. SRK/T formula had the

***Table 1**. Comparison of mean prediction errors between groups 1 and 2 for SRK/T, Barrett U II, and Hill RBF 2.*

Group statistics					
	Group	***N***	**Mean**	**Std. Deviation**	***p*-values**
SRK/T PE	Group 1	64	-0.09078	0.458985	0.887
	Group 2	32	-0.07547	0.569996	
Barrett PE	Group 1	64	-0.13766	0.476807	0.629
	Group 2	32	-0.08391	0.576484	
Hill RBF 2 PE	Group 1	64	-0.14172	0.504942	0.848
	Group 2	32	-0.11859	0.579025	

***Table 2**. Mean and median prediction errors among different formulas and groups.*

Mean prediction error				Median prediction error		
Group	SRK/T	Barrett	Hill RBF	SRK/T	Barrett	Hill RBF
Group 1	-0.0908	-0.1377	-0.1417	-0.02	-0.065	-0.065
Group 2	-0.0755	-0.0839	-0.1186	-0.05	-0.08	-0.11
Total	-0.0857	-0.1197	-0.134	-0.03	-0.07	-0.085

***Table 3.** Comparison of formulas concerning mean absolute errors and median absolute error.*

Mean absolute errors				Median absolute errors		
Group	**SRK/T** versus Barrett	**SRK/T** versus Hill RBF	**Barrett** versus Hill RBF	**SRK/T** versus Barrett	**SRK/T** versus Hill RBF	**Barrett** versus Hill RBF
Group 1	-0.34	-0.36	-0.03	-0.69	-0.69	0
Group 2	-0.10	-0.36	-0.1	-0.38	-0.65	-0.18

Formulas in bold indicate the basic formula for comparison and interpretation.

***Table 4**. Percentage of eyes with <0.5 D, 0.5–1.00 D, and >1 D for postoperative refractive errors.*

	Percentage of eyes with APEs					
	<0.5 D		**0.5–1.00 D**		**>1 D**	
	Group 1	**Group 2**	**Group 1**	**Group 2**	**Group 1**	**Group 2**
SRK/T	73.4	65	21.9	21.9	4.7	12.5
Barrett U II	68.8	65.6	28.1	25	3.1	9.4
Hill RBF 2	70.3	68.8	25	21.9	4.7	9.4

maximum percentage within ±0.5 D of APE in group 1. For group 2, Hill RBF 2 had a maximum percentage within ±0.5 D of APE when compared with the other two formulas.

Discussion

For this particular study, we followed the recommendations published by Hoffer et al.[8] for research work on the accuracy of IOL calculation formulas. Few studies are available in the literature describing the effect of ACD on the accuracy of the IOL formula. Even if the studies with ACD are found, they are for the old generation of formulas. We selected Barrett Universal II, SRK/T, and Hill RBF 2 for this study. We used the new version of Barrett Universal II for this particular study.

A benchmark was set by the Swedish National Cataract Register study[9] according to which, at least 71% of the operated eyes should be within ± 0.5 D of absolute error. In the present study, only SRK/T reached that percentage for group 1. In group 2, all three formulas showed less than 71% of the eyes within ± 0.5 D of APE.

Accurate measurements of anterior segment dimensions play a significant role in IOL power calculations. One millimeter of error in corneal diameter and axial length produces 5.7 D and 2.7 D of the refractive error, respectively.[10] One millimeter of error in ACD results in 1.5 D of refractive error.[8] Thus, accuracy in measuring ACD will have effects on the final refractive outcome[11]. IOLMaster had been the gold standard since its invention in 1999, but later studies showed that LENSTAR measured ACD larger than the IOLMaster 500.[12] We used IOLMaster for this particular comparative study.

Our results correspond to the findings of Eom et al.[13], who showed that ACD had a considerable effect on the accuracy of different formulas. They compared the results of Hoffer Q and Haigis. According to them, the formulas which considered ACD in IOL calculation had better predicted results when compared to the formulas which were not based on ACD.[13] Haigis is a unique formula, which uses axial length and ACD for calculation without K readings. It had better accuracy than Hoffer Q, which utilized K reading and axial length without ACD.[11] The results of Yang et al.'s[14] study were contradictory to Eom Y's study. Their research showed that Haigis' formula performed worst when ACD was less than 2.5 mm. In their series, Hoffer was more accurate in eyes with smaller ACD. Jeong et al.[15] reported that in short and normal eyes with ACD < 2.5 mm, Haigis underestimated the ELP. This resulted in a myopic prediction error.

All these previous studies considered third- and fourth-generation formulas for ACD. Studies showing the effect of ACD with Barrett U II and Hill RBF 2 are very few.[16] In a study comparing Barrett U II with other fourth-generation formulas, it was shown that Barrett U II had a smaller MedAE with ACD > 3 mm.[17] Barrett U II also had a higher percentage of eyes within ±0.5 D with ACD ≤ 3 mm. Our results showed that SRK/T had a higher percentage within ±0.5 D for ACD > 3 mm, but it was worst among the three formulas for ACD < 3 mm. Myopic prediction error was found in all formulas irrespective of the ACD in our study.

Another study with a larger sample of 309 eyes from Singapore compared Haigis, Hoffer Q, SRK/T, Holladay 1, and SRK II formulas.[18] The study concluded that the SRK II formula could predict refraction with lesser errors in patients with ACD < 3 mm and normal axial length. For ACD > 3 mm, Haigis was better. SRK/T performed equivocally to the Hoffer and Holladay1 in normal axial length. This study reported results that are quite different from the European studies as SRK II performed better than Haigis in ACD < 3 mm in the Singapore population. The reason could be that the mean ACD in Singapore is shorter than those of Americans and Europeans, which might have resulted in better accuracy of SRK II.

Our results correspond to a recent study which showed that for the short eyes with ACD < 2.4 mm, all the formulas behaved similarly without any statistically significant superiority of one over the other.[19] This study also showed that SRK/T had a lower percentage of eyes within ±0.5 D in short ACD.

The research shows that axial length and ACD do not correlate linearly in very long eyes.[20,21] The third-generation formulas that do not consider ACD would lack accuracy as compared to the formulas which used ACD in long eyes. Our study showed better results with SRK/T in eyes with ACD > 3 mm. Another important point to consider is that, although there is shallowing of ACD with a decrease in axial length in small eyes, there are also some small eyes with deep ACD.[22,23]

The effect of pupillary dilatation on ACD measurements is also reported in the literature.[24,25] We did not consider pupillary dilatation which is a limitation of this study.

The strengths of the present study are the use of an optical biometer, which shows more accurate results in different axial lengths. Biometry was carried out by a single refractionist and surgeries were performed by a single experienced surgeon. Only one model of IOL was used as studies have shown that the model of IOL also affects prediction errors.[26] We used fourth- and fifth-generation formulas, for which no study is yet available in our population.

Conclusion

There were no statistically significant differences between the accuracy of SRK/T, Barrett U II, and Hill RBF 2 in patients with ACD > 3 mm and < 3 mm ($p > 0.05$). However, all three formulas showed better clinical results in ACD > 3 mm than with ACD < 3 mm.

Limitations of the Study

The retrospective study design and small sample size are the limitations of this study. It was performed in a single center. Hill RBF 2 formula recommends LENSTAR LS 900 for biometry, but we used IOLMaster 500. The sample size was further reduced because the eyes were out of bounds in Hill RBF 2. Moreover, we did not consider whether shallow ACD was caused by inborn anatomical features or lens thickness.

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List of abbreviations

APE	Absolute prediction error
ACD	Anterior chamber depth
Barrett U II	Barrett Universal II
BCVA	Best corrected visual acuity
ELP	Effective lens position
Hill RBF 2	Hill Radial Basis Function
IOL	Intraocular lens
MPE	Mean prediction error
MedAE	Median absolute errors
MedPE	Median prediction error
SRK/T	Sanders, Retzlaff, Kraff/Theoretical

Conflict of interest

None to declare.

Grant support and financial disclosure

None to disclose.

Ethical approval

Ethical approval was granted by the Ethics Committee/Institutional Review Board/Research Committee of Ameer-ud-Din Medical College, Postgraduate Medical Institute, Lahore General Hospital, Lahore, Pakistan, via reference/letter number 00-113-20, dated 21.05.2020.

Authors' contributions

MM: Conception and design of the study, revision of the manuscript for intellectual input, and agreed to be accountable for all aspects of the work.

TGM: Conception and design of the study, acquisition, analysis of data, and drafting of the manuscript.

RA: Analysis/interpretation of the data and critical revision of the manuscript.

ALL AUTHORS: Approved the final version of the manuscript to be published.

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