

A comparison of SRK/T formula with Hill RBF 2 and Barrett Universal II in the calculation of intraocular lens power

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Abstract

Objective: To compare the accuracy of SRK/T, Barrett Universal II and Hill radial basis activation function-2 formulas in intraocular lens power calculation using different axial lengths.

Methods: The retrospective study was conducted at the Lahore General Hospital, Lahore, Pakistan, and comprised data from June to December 2020 of patients who underwent phacoemulsification with non-toric, monofocal intraocular lens implantation. Data was sorted in 3 groups on the basis of axial length; group 1 22-25mm, group 2 >25mm, and group 3 <22mm. Intraocular lens power was calculated using SRK/T with IOL Master, while online calculators were used for Barrett Universal II and Hill radial basis activation function-2 formulas. Data was analysed using SPSS 21.

Results: Of the 100 patients, 47(347%) were males and 53(53%) were females. There were 49(49%) diabetics, and 57(57%) were right eyes. There were 77(77%) patients with mean age 62.38±9.5 in group 1, 17(17%) patients with mean age 52.59±12.78 in group 2, and 6(6%) patients with mean age 61.33±7.61 years in group 3. Mean axial length in group 1 was 23.55±0.81mm with anterior chamber depth of 3.1±0.37mm. In group 2, mean axial length was 27.54±2.8mm, with anterior chamber depth of 3.4±0.15mm. In group 3, mean axial length was 21.74mm, with anterior chamber depth of 3.14±0.44mm. Mean prediction error of SRK/T versus Barrett Universal II was 0.092±0.041D ($p=0.078$), SRK/T versus Hill radial basis activation function-2 was 0.066±0.037D ($p=0.221$) and Barrett Universal versus Hill radial basis activation function-2 was -0.025±0.019D ($p=0.553$). Mean prediction error of group 1 versus group 2 was -0.105±0.14D, group 2 versus group 3 was 0.046±0.216D and group 2 versus group 3 was 0.151±0.243D ($p=1.0$). In 74% eyes, absolute prediction error was within ±0.5D in group 1, 64% in group 2 and 50% in group 3 for all formulas.

Conclusion: SRK/T formula was found to be as reliable as Barrett Universal II and Hill radial basis activation function-2 in terms of calculating intra ocular lens power for all axial lengths.

Keywords: Cataract, Intraocular lens, Phacoemulsification, Biometry, SRK/T, Barrett Universal II, Hill RBF2.

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Introduction

Cataract surgery with intraocular lens (IOL) implantation is no longer a rehabilitation procedure. It is now considered a refractive surgery. It started with Harold Ridley's story of first IOL implant in 1949. During World War II, the pilots of war aircrafts suffered from eyeball injuries with glass intraocular foreign bodies. Glass was inert and did not cause any inflammation in their eyes. This intrigued Ridley who performed cataract surgery and implanted first ever IOL in a 45-year-old woman.¹ As there was no concept of IOL power calculation, it resulted in a post-operative refractive surprise of -14 Diopters (D). Since then, researchers are endeavouring to make the refractive outcome close to the natural lens. First-generation IOL by Ridley was followed by anterior chamber lens, or second-generation IOL, from 1952 to 1962. From 1953 to 1973, there was a period of iris supported lenses and then came

the anterior chamber lenses of the modern era. Posterior chamber lenses were introduced in 1975 and now we are living in the times of foldable lenses.^{2,3}

With the evolving techniques in modern cataract surgery, there is also the development of newer generation of formulas with the aim of bringing postoperative refractive results closest to the ideal. In calculation of IOL power, the concept of effective lens position (ELP) is extremely important. First-generation formula, which was published by Fyodorov in 1967, assumed that ELP had a constant value.⁴ In Binkhorst, SRK I and SRK II, statistical regression approach was employed based on the axial length (AXL) of the eye.⁵ Anterior corneal curvature and AXL were used to find out ELP in Holladay, SRK/T and Hoffer Q, which is the third-generation formula. Olsen, Barrett Universal II (BUII), Holladay II, Hill radial basis activation function-2 (RBF2) and Hoffer H5, the fourth- and fifth-generation formulas, included more than 5 variables in the calculation of IOL power. Race and gender are also considered in H5 formula. In Hill RBF-2, artificial intelligence (AI) is used and data is based on more than 12,000 eyes.⁶ It is self-validated and it excludes out-of-bound eyes when the measured eye does

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not correspond to the available data. This helps to find out unreliability of the results while calculation.

Despite all efforts, there is no ideal formula to date. Data from different parts of the world indicate that refractive results after cataract surgery are different in different races.⁶ In Pakistan, the most commonly used formula is the third-generation SRK/T. The current study was planned to compare the accuracy of SRK/T with fourth-generation BU11 and fifth-generation Hill RBF-2 formulas in IOL power calculation using different AXLs.

Materials and Methods

The retrospective observational study was conducted at the Lahore General Hospital, Lahore, Pakistan, and comprised data from June to December 2020 of patients who underwent suture-less uneventful phacoemulsification with in-the-bag, non-toric and monofocal IOL implantation. Data was retrieved after approval from the institutional ethics review board. Informed consent, as a matter of routine, had been taken from all the patients before surgery. Record of patients who had complicated cataract, previous ocular or refractive surgery, corneal pathologies, incomplete preoperative and postoperative data, patients with acoustic biometry, astigmatism greater than ±2D, eyes with sulcus-fixated IOL or scleral fixation, mature and hard cataracts in which optical biometry was not possible, and patients who suffered from peroperative or postoperative complications was excluded. Also excluded was data of patients with out-of-bound results obtained by Hill RBF-2 formula.

Data retrieved included name, age, gender, history of any systemic disease, uncorrected and corrected visual acuity (VA) using Snellen acuity chart, refractive error in astigmatic eyes using spherical equivalent, IOP, slit lamp examination findings and B-scan, where needed. Other than IOL power, parameters included keratometry readings, AXL, depth of anterior chamber and postoperative refractive prediction.

The patients were divided into three groups based on AXL; group 1 22-25mm medium eyes, group 2 >25mm large eyes, and group 3 <22mm small eyes. For SRK/T formula, IOL Master 500 was used, while online calculators were used for Hill RBF-2 (Version 2.0, January 2019) and BU11 formulas.⁷

To avoid surgeon bias, data related to surgeries conducted by a single senior surgeon. Proparacaine eye drops were used before surgery. This was followed by sub-tenon injection

of Xylocaine. Intraocular lens (Acrysof IQ; SN60WF) was implanted with the help of injector into the bag. At the end of the surgery, sub-conjunctival injection of gentacin and dexamethasone was given. Topical therapy with dexamethasone, moxifloxacin and nepafenac was started on the first post-operative day.

Complete eye examination, including VA, was done on the first post-operative day. Auto-refraction-based subjective refraction was performed at week four post-surgery and it was used to calculate the prediction error (PE) by subtracting preoperative refractive prediction from postoperative refractive error. Accuracy of each formula was determined by calculating median absolute errors (MedAEs) and mean absolute error (MAE). Finally, the percentage was calculated of eyes with PE within ±0.5D and >±0.5D. Negative mean PE (MPE) indicated a myopic error and hyperopic error was indicated by a positive value.

Data was analysed using SPSS 21. Each group was analysed for descriptive statistics. For age, keratometry, AXL and anterior chamber depth, mean and median values were calculated along with their respective standard deviation and interquartile ranges (IQRs). Normality of data was assessed. Means among the formulas and among different groups were compared using analysis of variance (ANOVA). P<0.05 was considered statistically significant. Bonferroni correction was used to adjust multiple comparisons.

Results

Of the 100 patients, 47(347%) were males and 53(53%) were females. There were 49(49%) diabetics, and 57(57%) were right eyes. There were 77(77%) patients with mean age 62.38±9.5 in group 1, 17(17%) patients with mean age 52.59±12.78 in group 2, and 6(6%) patients with mean age 61.33±7.61 years in group 3. Mean AXL in group 1 was 23.55±0.81mm with anterior chamber depth of 3.1mm. In group 2, mean AXL was 27.54±2.8mm, with anterior chamber depth of 3.4±0.15mm. In group 3, mean AXL was 21.74mm, with anterior chamber depth of 3.14mm.

SRK/T had the lowest MPE, followed by BU II and Hill RBF-2 had -0.1373D, but the difference was non-significant

Table-1: Pairwise comparison of prediction errors (Pes) among groups and among formulas.

(I) group	(J) group	Mean	Std. Error	Sig.a	95% Confidence Interval for Difference	
Prediction Error	Prediction Error	Difference (I-J)			Lower Bound	Upper Bound
Group 1	Group 2	-0.105	0.14	1*	-0.445	0.235
Group 1	Group 3	0.046	0.216	1*	-0.479	0.572
Group 2	Group 3	0.151	0.243	1*	-0.442	0.745
SRKT	Barrett	0.092	0.041	0.078*	-0.007	0.191
SRKT	Hill RBF	0.066	0.037	0.221*	-0.023	0.156
Barrett	Hill RBF	-0.025	0.019	0.553*	-0.072	0.021

Based on estimated marginal means; a. Adjustment for multiple comparisons: Bonferroni; * statistically non-significant.

Table-2: Mean and median prediction errors (PEs) among different formulas and groups.

Group	Mean Prediction Error			Median Prediction Error		
	SRKT	Barrett	Hill RBF	SRKT	Barrett	Hill RBF
Group 1	-0.1097	-0.1309	-0.1534	-0.05	-0.13	-0.16
Group 2	0.1159	-0.1503	-0.0447	0.085	-0.01	0.035
Group 3	-0.1833	-0.1717	-0.1783	0.045	0.185	0.185
Total	-0.0777	-0.1365	-0.1373	-0.03	-0.07	-0.07

SRKT: Sanders, Retzlaff, Kruff Formula, RBF: Radial Basis activation Function

Table-3: Comparison of formulas with respect to mean absolute errors and median absolute errors.

Group	Mean Absolute errors			Median Absolute errors		
	SRKT vs Barrett	SRKT vs Hill RBF	Barrett vs Hill RBF	SRKT vs Barrett	SRKT vs Hill RBF	Barrett vs Hill RBF
Group 1	0.0212	0.0437	0.0225	0.08	0.11	0.03
Group 2	0.2662	0.1606	-0.1056	0.095	0.05	-0.045
Group 3	-0.0116	-0.005	0.0066	-0.14	-0.14	0.00

Formulas in Bold indicate the basic formula to compare the other one for interpretation

SRKT: Sanders, Retzlaff, Kruff Formula, RBF: Radial Basis activation Function

($p > 0.05$). All the formulas showed similar results with different AXLs (Table 1). SRK/T had the lowest median PE (MedPE) for group 1 and 3. Absolute PE (APE) was within $\pm 0.5D$ in 74% in group 1, 64% in group 2 and 50% in group 3 with all the 3 formulas. Similarly, APE in refraction was $> \pm 0.5D$ in 26% in group 1, 36% in group 2 and 50% in group 3 with all the 3 formulas (Table 2).

The lowest MedAE was with BUll versus Hill RBF-2 for group 3, while for group 1, MedAE was the lowest for SRK/T versus BUll, and in group 3, MedAE 3 was the lowest with SRK/T versus Hill RBF-2 (Table 3).

Discussion

The IOL Power Club has made certain recommendations to increase the reliability and validity of the studies done for accuracy of IOL power calculation.⁸ It was made mandatory to include the demographic data, like age, gender and race, in the study. It is also recommended that MAE and MedAE should be calculated and compared in such studies.⁸ The current study included both these values for comparison. Other recommendations included APE calculation within $\pm 0.5D$ and $> \pm 0.5D$ in percentage, selection of only one eye from every patient, avoiding the use of SRK II or SRK I formulas, optical biometry, measuring anterior chamber depth from the corneal epithelium to the lens and not the distance from the corneal endothelium to the lens, taking PE as postoperative refraction minus preoperative predicted refraction.⁸ All these recommendations were followed by the current study. Measuring postoperative refraction at 3 months was also recommended⁸ but the current study could get record of only one month postoperatively.

In Pakistan, SRK/T is the most widely used formula. It uses AXL and corneal curvature readings in diopters in the calculation of IOL power. In BUll formula, Dr Barrett had used the location of principle planes, thickness of the lens and the refractive index.,⁹ Hill RBF-2 is constantly evolving as new data is being added.¹⁰

The current results in terms of PE are similar to literature,¹¹ according to which, 72.7% eyes had PE within $\pm 0.50D$ compared to 74% cases in the current study. This percentage was similar for AXL ranging 22-25mm.

The Swedish National Cataract Register study¹² in 2015 defined the success of cataract surgery regarding postoperative refraction. According to the definition,¹² 71% operated eyes should be within $\pm 0.5 D$ of PE. The current study reached this benchmark with 74%.

Melles et al.¹³ included BUll and SRK/T formulas along with five other formulas for AXL ranging 23-25mm, and concluded that all the tested formulas had resulted in refractive error of $< 0.50D$ in 72-80% eyes. However, their results did not fall under the set benchmark when eyes outside the above range of AXL was used. Other researchers have shown that SRK/T had fewer eyes with PE within $\pm 0.50D$.¹⁴

There are different reports regarding percentage of eyes with PE within $\pm 0.50D$. It was 80.6% to 82.9% by Cooke and Cooke¹⁵ and 72.3% by Kane et al.¹⁶ Plausible justification for this difference in percentages could be variable sample size with variable AXLs in different studies. Similarly, Gokce et al.¹⁷ using 7 formulas in small eyes (AXL $< 22mm$) reported PE of not more than 71% with all formulas. In our series of small eyes, PE was 50%. In an Indian research, 71% eyes were within ± 0.5 and 98% within $\pm 1D$ with BUll compared to SRK II and SRK/T.¹⁸

Although there was a certain level of unreliability reported with Hill RBF-1, with the use of Hill RBF-2, there was no effect of AXL on the accuracy of refractive prediction.¹⁹ Other authors have shown reliable results with both Hill RBF-2 and BUll formula irrespective of AXLs.^{13,14,20} The current results showed 50% eyes within $\pm 0.50D$ of PE in small AXL and 64% eyes with long AXL. However, no significant difference was seen among the three formulas.

Eyes with pre-operative axial myopia are more prone to have postoperative hyperopic PE. A Chinese researcher suggested that post-operative hyperopic PE could be reduced by Wang-Koch AL adjustment formulas.²¹ In contradiction, the current series showed myopic PE in all formulas when used for long eyes, except for SRK/T.

Longer eyes show lowest MedAE.²² Zhang et al. studied

eyes with AXL >29mm and reported lower MedAE with SRK/T than Haigis.²³ Kane et al¹⁴ observed no difference among these three formulas in myopic eyes which supports the current results.

When there was such a wide range of variability in the existing data, a systematic review and meta-analysis was done by Wang Q, which showed an overall better performance of BUll in myopic eyes.²⁴

PE at 4 weeks is also affected by the anterior capsular contraction. When anterior lens capsule contracts, there is posterior shifting of IOL resulting in hyperopic shift. We did not see any difference between postoperative refraction done at weeks 1 and 4. Even if the capsular bag had shifted posteriorly in the current series, it would have got a positive effect because of the myopic results except in group 2 with SRK/T.

Results are also affected by the type of biometer.

Use of new-generation formulas in Pakistani population, using 2015 recommendations by the Swedish National Cataract Register study¹² is a strength of the current study. Surgeon bias was overcome by single-surgeon surgeries. Similarly, only AcrySof IQ lens was used in all cases to further reduce the chance of bias caused by different lens types.

Despite all these strengths, the limitations of the study include its retrospective design and a limited sample size, especially for the long and short eyes. Being a single-centre study, the results cannot be generalised to the whole population. LENSTAR LS 900 biometer is better for Hill RBF-2, but, owing to non-availability, IOL Master 500 was used. Some eyes were excluded because of out-of-bound results of Hill RBF-2. It could have changed the results if included in the study.

Conclusion

SRK/T formula was found to be as reliable as BUll and Hill RBF-2 in the calculation of IOL power for all AXLs.

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Conflict of interest: None.

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Abbreviations: SRK = Sanders, Retzlaff, Krapp Formula, Hoffer Q = Hoffer Q, Hill RBF2 = Radial Basis activation Function, H5 = Hoffer H5 formula

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