PREDICTABILITY OF CONTEMPORARY REGRESSION AND THEORETICAL FORMULAE IN INTRA-OCULAR LENS POWER CALCULATION IN SMALL INCISION CATARACT SURGERY

Mohtasham Tauheed[1], Yusuf Rizvi[2], Vaibhav Yadav[3], Ritu Jain[4]

[1]Junior Resident, Department of Ophthalmology, Rohilkhand Medical College and Hospital, Bareilly.
[2]Associate Professor, Department of Ophthalmology, Rohilkhand Medical College and Hospital, Bareilly.
[3]Junior Resident, Department of Ophthalmology, Rohilkhand Medical College and Hospital, Bareilly.
[4]Associate Professor, Department of Ophthalmology, Rohilkhand Medical College and Hospital, Bareilly.

ABSTRACT

BACKGROUND
Present era of refractive cataract surgery mandates the requirement of accurate intra-ocular lens (IOL) power calculation. Attainment of this objective underscores the need for accurate biometric data and suitable formulae for precise IOL power calculation. Applicability of contemporary theoretical and regression formulae for different sets of eyes remains an area of interest.

MATERIALS AND METHODS
A retrospective analysis was done on 304 eyes (301 patients) that underwent uneventful cataract surgery at our hospital, after due approval of Institutional Ethical Committee. Accurate biometric data; axial length (AL), corneal curvature (K value) & anterior chamber depth (ACD) were ensured. IOL power for implantation was predicted by six contemporary formulae (Sanders-Retzlaff-Kraff (SRK-I), SRK-II, SRK/T, Binkhorst, Holladay 1 & Hoffer Q), employing incorporated software of the Nidek US4000 device. This was compared with the ideal expected power determined by the post-operative spherical equivalent of refractive status at 6 weeks. Refractive status variations from the predicted value for each set of formulae were statistically compiled & analysed employing one way ANOVA on SPSS software.

RESULTS
Mean age of patients was 59.68 ± 10.3 years (range 40-90 years), mean axial length was 22.72 ± 0.92 (range 19.34-25.19) mm, mean keratometric value was 44.87 ± 1.78 (range 39.13 - 50.13) diopters and mean ACD was 2.93 ± 0.41 (range 1.81 - 5.36) mm. Myopic shift in predicted values was noted for each set of formulae except SRK-1. Mean refractive variations were 0.366, -0.142, -0.148, -0.150, -0.163 & -0.0778 for SRK-1, SRK II, SRK/T, Binkhorst, Holladay-1 & Hoffer-Q respectively.

CONCLUSION
Predictability of Hoffer-Q formula for IOL calculation was most accurate for normal & long eyes above 23 mm, followed by SRK-2, SRK/T, Binkhorst & Holladay-1 in order.

KEYWORDS
Biometric formulae, Intra ocular lens, lens power.

HOW TO CITE THIS ARTICLE: Tauheed M, Rizvi Y, Yadav V, et al. Predictability of contemporary regression and theoretical formulae in intra-ocular lens power calculation in small incision cataract surgery. J. Evid. Based Med. Healthc. 2018; 5(20), 1554-1558. DOI: 10.18410/jebmh/2018/327

BACKGROUND
Cataract surgery being a single stage procedure is fraught with the risk of refractive surprises on account of faulty IOL power calculations. The precision of both the ocular biometric measurements and power calculation formula is required for a favourable outcome, to meet high patient expectation. A multitude of factors affect accuracy in IOL power calculation. Intrinsic errors in keratometric evaluation, axial length measurements with correction factor variability, site of loop implantation, orientation of plano-convex implants, postoperative changes in corneal curvature, density of cataract, IOL tilt & decentration, each play a small but significant role in deviating the accurate IOL power.[1,2] In addition the formulae assumed to mediate an ideal postoperative outcome too suffer from inaccuracies. Theoretical formulae are based on a presumed geometrical model of eye that suffers from limitations. Right from Fyodorov's initial theoretical model in 1967 to the present fourth generation Haigis formula, correction factors have been inculcated to minimize error; (Table 1). First generation formulae assumed the 'Effective lens position' and 'Anterior chamber' depth to be the same in all classes. Lens thickness was taken into account by later formulae. The

Financial or Other, Competing Interest: None.
Submission 18-04-2018, Peer Review 21-04-2018,
Acceptance 04-05-2018, Published 08-05-2018.
Corresponding Author:
Dr. Yusuf Rizvi,
Associate Professor,
Department of Ophthalmology,
Rohilkhand Medical College and Hospital,
Bareilly, Uttar Pradesh 243006.
E-mail: yrizavi06@yahoo.co.in
DOI: 10.18410/jebmh/2018/327

recent fourth generation formula by 'Haigis' uses 3 constant optimisations for all ranges of eye length and IOL types.[3,4] The regression formulae like the SRK I & SRK- II are derived from empirical data and based on retrospective analysis of postoperative refraction after IOL implantation.[5,6] Even though no assumptions are made about the optics of eye, the statistical technique of regression analysis of the data depends entirely on the accuracy of data.[7]

The recent technological advances in the form of partial coherence interferometry & optical low coherence reflectometry have reduced errors in biometric measurements.[8,9] Even then no single method has been agreed upon to determine net central refractive power of the surgical eyes. In addition, majority of centres delivering cataract services continue to use ultrasound transducers for axial length measurements, manual optical Keratometers and employ SRK II formula as preferred mode for IOL calculations.[10] A large scale study to investigate the reliability & applicability of biometric formulae becomes relevant.

Generation	Name	Type	Expansion
First	SRK -I	Regression	$P_e = A – 2.5 L – 0.9 K$
First	Fyodrov's	Theoretical	P_e = 1336-LK/(L-C) (1-CK/1336)
First	Gullstrand's	Theoretical	P_e = 1348K + 4L
First	Colenbrander's	Theoretical	P_e = [1366/L-C-0.05]- [1366/(1366/K) – C -0.05]
First	Binkhorst	Theoretical	P_e = [N/(L-C)] - [NK/N -KC)]
Second	Modified Binkhorst	Theoretical	P_e = 1366(4r – L) / (L-C) (4r-C)
Second	SRK - II	Regression	P_e = A1 – 0.9K – 2.5L
Third	SRK / T	Theoretical	P= 1.0135n –kL_{opt} / (L_{opt} – $ACD_{post\ op}$) (1.0135- ACD_{postop}/k/ n)
Third	Holladay I	Theoretical	P=1.0125n-k(L+0.2)/ (L+0.2-ACD)(1.0125-ACD_{postop} k/n)
Third	Hoffer - Q	Theoretical	P= [1336 /L-ACD-0.05] –[k+r/1 - 0.749.10^{-6} (ACD+0.05)(k+r)]
Fourth	Holladay II	Mix of theoretical & regression	7 variables employed to derive ACD with surgeon factor inculcation
Fourth	Haigis	Theoretical & Regression mix	$ACD_{postop} = a_0+a_1ACD_{preop} + a_2L$

Table 1. Generation Wise Various Theoretical and Regression Biometric Formulae

Abbreviations-

P_e = post-operative emmetropic IOL power (dioptres); L = Axial length of eye (mm); K = Corneal dioptric power (dioptres); C = pseudophakic depth of anterior chamber; N=Aqueous & Vitreous refractive index; A= constant derived for lens type; A1=modified A constant value as per axial length, r= radius of curvature of anterior surface of cornea; R_x = Refraction; L_{opt} = 0.657+0.98L; a_0 = lens constant; a_1= constant tied to anterior chamber depth; a_2 = measured axial length

Aims and Objectives-

i) To assess predictability outcome of six contemporary biometric formulae in IOL power calculation.
ii) To configure optimum formula according to biometric criteria in small incision cataract surgery.

MATERIALS AND METHODS

This was an observational study conducted on 304 eyes (301 patients) that underwent uneventful cataract surgery employing manual small incision cataract extraction technique, performed by a single surgeon to reduce surgeon related discrepancies in results. A rigid PMMA lens was implanted in all eyes with biometric evaluation employing ultrasonic axial length measurement with a Nidek US 800 B scan & optical Keratometer for K values. The measurement A constant was as per the manufacturers specifications. Only senile cataract cases were considered with inclusion age above 40 years.

Exclusion Criteria-

- Previous history of any intraocular or keratorefractive surgery
- History of ocular injury or uveitis
- Cataract eyes with co-existing glaucoma or lens induced glaucoma
- Intraoperative complications that were likely to affect refractive outcomes like vitreous loss, posterior capsular tear, zonular dehiscence, floppy iris & excessive bleed.
- Postoperative complications like severe iritis, corneal haze, wound leak, eccentric IOL placement, high wound induced astigmatism or poor best corrected visual outcome below 6/12.

The postoperative spherical equivalent of refractive error (E) was calculated employing the given formula; E = Spherical power (D_S) + ½ Cylindrical power (D_{cy}).

The implanted IOL power (P_i) was used to calculate the required emmetropic power (P_e) for the given eye, using the formula;

$P_e = P_i + (1.25 \times E)$ where P_i is the power of the implanted lens.

The variations (ΔP), of this required emmetropic power from the predicted power employing the different theoretical

& regression biometric formulae were tabulated and statistically analysed employing one-way ANOVA on SPSS software. A p value < 0.05 was considered statistically significant.

RESULTS

Out of the 304 evaluated eyes, 145 (47.69%) were from male and 159 (52.3%) from the female populace. Male: Female ratio being 0.913. Mean age of the operated patients was 59.68 ± 10.31 years. Maximum patients (77) were in the age group of 55 to 60 years. The biometric data revealed a mean axial length of 22.72 ± 0.92. 218 eyes (71.71%) had an axial length between 22 to 24 mm. Axial hypermetropia (< 22 mm) was 2.5 times commoner than axial myopia (> 24 mm); 62 hyperopic eyes compared to 24 myopic.

The average keratometric values, ranged between 39.13 & 50.13 dioptres (D). 169(55.59%) patients had the measured K value in the range of 40 to 45 D, while 131(43.09%) had a K value above 45 D. The mean average K value was 44.87 ± 1.78 D.

The implanted lens power (P_i) ranged between +13 & +31.5 D. Majority of the implanted lenses (44) had the power of 22 D. The average implanted power was 21.76 ± 1.93 D. The postoperative refractive status at 6 weeks revealed a distinct myopic bias, with 263(86%) cases reporting some degree of spherical equivalent residual myopia. Only 5 (2%) of the 304 operated eyes attained complete emmetropia. The mean spherical equivalent refractive power was – 0.67 ± 0.97 D.

The deviations of the calculated lens power (ΔP) from the required emmetropic power (P_e), displayed a variegated presentation depending on the formula employed for calculation. The average ΔP values were influenced by the axial lengths (Axl) and average keratometric values (K_{avg}) of the measured eyes as depicted in table-2 & table-3 respectively.

Axl range (mm)	ΔP (SRK-I)	ΔP (SRK-II)	ΔP (SRK/T)	ΔP (Binkhorst)	ΔP Holladay-1	ΔP (Hoffer-Q)
< 20	1.31 D	-1.685 D	-3.32 D	-3.81 D	-3.61 D	-4.64 D
20 -21	0.91 D	-0.99 D	-1.55 D	-2.01 D	-1.72 D	-2.09 D
>21-22	0.10 D	-0.886 D	-1.21 D	-1.19 D	-1.19 D	-1.25 D
>22-23	-0.47 D	-0.466 D	-0.97 D	-0.95 D	-0.98 D	-0.88 D
>23-24	-0.83 D	-0.829 D	-0.89 D	-0.89 D	-0.90 D	-0.75 D
>24-25	-1.02 D	-0.86 D	-0.68 D	-0.64 D	-0.70 D	-0.48 D
>25	-1.45 D	-0.945 D	0.70 D	-0.61 D	-0.90 D	-0.49 D

Table 2

The average mean deviations of calculated lens power $\Delta P_{avg,}$ for all groups of eyes were +0.366, -0.142, -0.148, -0.150, -0.163 & -0.0778 dioptre for the SRK-I, SRK-II, SRK/T, Binkhorst, Holladay-I and Hoffer-Q formulae respectively.

Deviations from emmetropic power ΔP, for various keratometric ranges have been highlighted in table- 3.

Kavg (Dioptres)	ΔP (SRK-I)	ΔP (SRK-II)	ΔP (SRK/T)	ΔP (Binkhorst)	ΔP Holladay-1	ΔP (Hoffer-Q)
39 – 41	-0.42 D	-0.32 D	-0.69 D	-1.86 D	-1.11 D	-1.41 D
>41-43	-0.91 D	-0.91 D	-1.17 D	-1.76 D	-1.43 D	-1.46 D
>43-45	-0.59 D	-0.72 D	-1.08 D	-1.32 D	-1.21 D	-1.15 D
>45-47	-0.31 D	-0.59 D	-0.81 D	-0.50 D	-0.72 D	-0.53 D
>47-49	-0.12 D	-0.92 D	-1.17 D	-0.37 D	-0.82 D	-0.71 D
>49-51	-0.59 D	-0.41 D	-0.52 D	+1.10 D	+0.68 D	+0.44 D

Table 3

By application of one-way ANOVA test, the inter-group statistical analysis of various formulae showed no significant superiority in predictability for either group, for various axial length distributions; (P>0.05). The comparative account for the level of significance for each set of formula is depicted in table 4.

Biometric Formula	Sum of Squares	Degree of Freedom (df)	Mean Square Value	Fischer (F) Value	P Value
SRK-I	409.886	193	2.124	1.025	0.449
SRK-II	363.581	193	1.884	0.914	0.709
SRK/T	354.624	193	1.837	0.889	0.762
Binkhorst	509.816	193	2.642	1.095	0.303
Holladay-1	404.414	193	2.095	0.974	0.568
Hoffer-Q	460.484	193	2.386	1.057	0.378

Table 4

A similar statistical analysis based on average keratometric values (K_{avg}) showed significant variations in predicted refractive outcomes for Binkhorst, SRK-I and Holladay-1 formulae. The levels of significance for each formula on inter-group analysis by ANOVA test is highlighted in table 5.

Biometric Formula	Sum of Squares	Degree of Freedom (df)	Mean Square Value	Fischer (F) Value	P Value
SRK – I	173.826	61	2.850	1.486	0.019
SRK –II	150.315	61	2.464	1.355	0.057
SRK/T	135.659	61	2.224	1.206	0.164
Binkhorst	235.975	61	3.868	1.736	0.002
Holladay-1	165.874	61	2.719	1.385	0.045
Hoffer-Q	179.692	61	2.946	1.347	0.060

Table 5

DISCUSSION

The refractive power of eye, is a function of the dioptric power of the cornea & lens, the axial length of eye and the position of lens within the eye.[5] These biometric inputs are crucial in attaining optimal postoperative refractive outcomes to ensure spectacle independence. Studies report that each mm deviation in corneal curvature, axial length and anterior chamber depth measurement results in 5.7D, 2.7D & 1.5 D of refractive error respectively.[11,12] Such discrepancies in IOL calculation can be further compounded by inappropriate IOL calculation formulae. Also, the applicability of each formula to different sets of eyes with varied biometric composition remains a debatable issue.

The last 30 years of IOL surgery has witnessed refinement of IOL calculation formulae, with each successive generation of formula adding additional parametric data to attain optimum IOL power. The SRK II, a 2nd generation formula has been favoured by most clinicians in third world countries.[12] The Hoffer Q, SRK/T and Holladay 1 are 3rd generation formulae that determine the effective lens position to seek an emmetropic outcome. Notwithstanding the added inputs, the workability of each formula finds its limitations with respect to the biometric nature of the evaluated eye. Hence a comprehensive study finds utility for an average cataract surgeon who is often faced with refractive surprises despite ideal surgical results.

The present study was designed as a retrospective chart review of 304 operated eyes that underwent uneventful cataract surgery by manual small incision technique. Predictability of six currently used theoretical & regression formulae were evaluated by comparing deviations (ΔP), from the ideal Post- operative refractive power (P_e).

The highest predictability outcome was noted for the Hoffer Q formula, with an overall mean deviation of -0.0778 ± 1.0283 D and the least for SRK I formula, (+0.366 ± 0.926 D). The SRK II (+0.142 ± 0.852 D), SRK/T (-0.147 ± 0.828 D), Binkhorst (-0.150 ± 1.116 D) & Holladay 1 (-0.163 ± 0.922 D) figured next in succession in their predictive accuracy. There were however noted differences in the predictability for various biometric & keratometric subsets of eyes, highlighting the fact that no single formula has universal applicability for all eyes. Also, the ethnicity & racial variation of eyes among population groups, questions the wisdom of applying the same set of formulae for Indian eyes as those being employed in Western scenario. Miraftab et al, while examining the role of anterior chamber depth in IOL calculation formulae in 309 Iranian eyes, reported a mean axial length of 23.11 ± 0.63 mm & mean anterior chamber depth as 3.19 ± 0.41 mm.[12] In European populations the mean ACD is reported at least 1.0 mm higher. However, the mean axial length of 22.72 ± 0.92 mm & mean ACD of 2.93 ± 0.41 mm as observed by our study compared well with an Indian study on 480 eyes that reported a mean axial length & mean ACD of 22.33 ± 0.49 mm & 2.77 ± 0.3 mm in male and 22.99 ±0.71 mm & 2.73 ± 0.2 mm in female population respectively.[13]

Most studies evaluating efficacy of IOL power calculation formulae have been performed on phacoemulsification with foldable IOL implantation of acrylic lenses.[9,10,12,14,15] Since manual small incision cataract surgery (SICS) requires wider incision size (5.5-7.5 mm) with relatively larger capsulotomies, a higher astigmatism with anterior shift of IOL placements is expected. This affects the refractive outcome of SICS eyes when compared to phacoemulsification technique. The predictive accuracies for various IOL power calculation formulae may hence differ in SICS setting. To the best of our knowledge this is the largest retrospective analysis of predictive efficacy of IOL formulae for SICS eyes.

The classical version of comparison of theoretic & regression formulae as suggested by Hoffer KJ subscribed the view that all formulae function well within normal range of axial length (22.0-24.5 mm).[4] Maximum accuracy is noted for Holladay I for medium long eyes (24.5 – 26 mm) and SRK/T for very long eyes (> 26 mm). Hoffer Q formula was assigned maximum accuracy for short eyes (<22 mm) while SRK I formula was suspect of poor result outside normal range.

Investigating the predictive accuracy of IOL formulae in short eyes (<22 mm), multitude of studies have assigned supremacy to Haigis & Hoffer Q formula.[14,15] In our study the Hoffer Q formula showed poor predictability with an increasing myopic shift with decreasing axial length. Incidentally SRK I & SRK II formula were more reliable with a mean deviation of +0.77D & - 1.18 D respectively.

Performing a retrospective analysis of 43 Indian myopic eyes (AL > 24.5 mm) that underwent IOL implantation, Mitra et al, reported a tendency of hyperopic postoperative refractive error with all examined formulae.[10] The smallest error of +0.24 D was caused by Holladay I, while Hoffer Q

& SRK/T formulae caused relatively larger shifts of +0.58D & +0.92D respectively. Even though our study noted a marginally better predictive accuracy for the Hoffer Q formula in the subset of myopic eyes, no statistically significant superiority could be ascribed in relation to Holladay I or SRK/T formulae. The significant myopic shift of our study that contrasted with hyperopic shift could be assigned to the tendency for anterior placement of lens in SICS surgeries or the choice of PMMA as the IOL material with A constant variation.

Our study also scrutinized the efficacy of each formula for different sets of corneal curvature (K) values. Even though no statistically significant superiority ($p<0.05$) of either formula was established employing one-way ANOVA, the least set of variances was noted for K values between 47-49 D (0.12) & 45-47 D (0.31). This suggested an analogy that K values between 45 to 49 D are better suitable for postoperative prediction of refractive powers. Individually on subjecting each formula to intergroup analysis for different K values, Binkhorst formula revealed significant variation in predicted IOL power values ($p=0.002$). In the same setting SRK/T formula highlighted least significant variation ($p=0.164$), making it a more consistent predictor for varied groups of K values.

CONCLUSION

In high volume cataract surgeries employing SICS technique with rigid PMMA lenses, in Indian scenario, Hoffer Q IOL calculation formula augurs high predictability for normal & long eyes with Axial length ≥23 mm. The frequently employed SRK II is a suitable calculation formula for all sets of eyes with varied axial lengths & keratometric values and may be trusted in routine & camp conditions.

REFERENCES

[1] Garg A, Lin JT, Latkany R, et al. Mastering the techniques of IOL power calculations. 2nd edn. Jaypee Brothers Medical Publishers Pte Ltd 2009:8-9.

[2] Norrby S. Sources of error in intraocular lens power calculation. J Cataract Refract Surg 2008;34(3):368-376.

[3] Haigis W. Intraocular lens calculation in extreme myopia. J Cataract Refract Surg 2009;35(5):906-911.

[4] Hoffer KJ. The Hoffer Q formula: a comparison of theoretic and regression formulae. J Cataract Refract Surg 1993;19(6):700-712.

[5] Olsen T. Calculation of intraocular lens power: a review. Acta Ophthalmol Scand 2007;85(5):503-506.

[6] Lee AC, Qazi MA, Pepose JS. Biometry and intraocular lens power calculation. Curr Opin Ophthalmol 2008;19(1):13-17.

[7] Narvaez J, Zimmerman G, Stulting RD, et al. Accuracy of lens power prediction using the Hoffer Q, Holladay 1, Holladay 2 and SRK/T formulae. J Cataract Refract Surg 2006;32(12):2050-2053.

[8] Kiss B, Findl O, Menapace R, et al. Biometry of cataractous eyes using partial coherence interferometry: clinical feasibility of a commercial prototype I. J Cataract Refract Surg 2002;28(2):224-229.

[9] Hui S, Yi L. Comparison of two optical biometers in intraocular lens power calculation. Indian J Ophthalmol 2014;62(9):931-934.

[10] Mitra A, Jain E, Sen A, et al. A study regarding efficacy of various intraocular lens power calculation formulae in a subset of Indian myopic population. Indian J Ophthalmol 2014;62(7):826-828.

[11] Preussner PR, Olsen T, Hoffmann P, et al. Intraocular lens accuracy limits in normal eyes. J Cataract Refract Surg 2008;34(5):802-808.

[12] Miraftab M, Hashemi H, Fotouhi A, et al. Effect of anterior chamber depth on the choice of intraocular lens calculation formula in patients with normal axial length. Middle East Afr J Ophthalmol 2014;21(4):307-311.

[13] Bhardwaj V, Rajeshbhai GP. Axial length, anterior chamber depth-a study in different age groups and refractive errors. J Clin Diagn Res 2013;7(10):2211-2212.

[14] Moschos MM, Chatziralli IP, Koutsandrea C. Intraocular lens power calculation in eyes with short axial length. Indian J Ophthalmol 2014;62(6):692-694.

[15] Olsen T, Thim K, Corydon L. Accuracy of the newer generation intraocular lens power calculation formulae in long and short eyes. J Cataract Refract Surg 1991;17(2):187-193.