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Results: In all, 981 were analyzed. There were no significant differences in the median absolute error predicted by Barrett and the 3rd generation formulae. The Barrett Universal II formula resulted in significantly lowest mean spherical equivalent in short eyes (P=0.0047) as well as a higher percentage of eyes with prediction errors within<±0.50D, 0.50D-0.75D and >±.75D.We found that Barrett Universal II formula had the lowest predictive refraction error (PRE) and mean absolute error (MAE) across all axial lengths.

Conclusion: Barrett Universal II formula rendered the lowest predictive error compared with SRK/T, Holladay, and Hoffer Q formulas. Thus, Barrett Universal II formula may be regarded as a more reliable formula for achieving Emmetropia and reducing post-op refractive surprises across all axial lengths.

I. Introduction

The prediction of refractive outcomes after cataract surgery has steadily improved, with more recent intraocular lens (IOL) power formulas generally outperforming those of prior generations.(1,2) Yet there is still considerable debate about which formula provides the most accurate refractive prediction. Because no single formula has been shown to be highly accurate across a range of eye characteristics, some authors have suggested that cataract surgeons should use different formulas for eyes of varied ocular dimensions.(3,4) Popular third-generation formulas (Hoffer Q, SRK-T, and Holladay 1) calculate effective lens position(ELP) using anterior chamber depth (ACD), axial length(AL) and keratometry (K). The Barrett Universal 2 formula uses a theoretical model eye in which anterior chamber depth (ACD) is related to axial length (AL) and keratometry. A relationship between the A-constant and a "lens factor" is also used to determine ACD. (5) The important difference between the Barrett formula and other formulas is that the location of the principle plane of refraction of the IOL is retained as a relevant variable in the formula.

The aim of this study was to investigate and compare the accuracy of Barrett Universal II formula for all axial lengths versus the Third generation formulae : SRK-T for long eyes (AXL>24mm), Holladay 1 for medium eyes (AXL=22-23.99 mm) and Hoffer Q for short eyes (AXL ≤ 21.99 mm) in predicting refractive outcome for standard cataract surgery.

II. Patients and Methods

Study design: Retrospective, non-randomised case series

Setting: The Eye Foundation Hospital and postgraduate institute, Coimbatore, India

Duration of data collection: January 2017 and December 2018 (18 months)

The study adhered to the tenets of the Declaration of Helsinki and approved by the institutions ethics committee. Informed consent was obtained from all the participants included in the study. Patients with age related cataract undergoing uneventful cataract surgery were included in the study. Intra-operative complications, presence of any corneal pathology, glaucoma, retinal pathology, postoperative corrected distance visual acuity (CDVA) worse than 20/40, patients with preoperative corneal astigmatism of > 0.75D,eyes requiring additional surgical procedures at the time of cataract surgery (including peripheral corneal relaxing incisions), previous intraocular surgery (including previous refractive corneal surgery) were excluded from the final cohort.

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Ocular biometry was performed in all eyes using the IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany) based on swept-source optical coherence tomography (SS-OCT) technology. Patients were grouped into two groups , Group 1- Patients who had their IOL power calculated using Barrett universal Formula (Across all axial length) and Group 2- Patients who had their IOL power calculated using 3rd Generation IOL formulae(SRK-T for AXL≥24mm, what about ,Holladay 1 for AXL=22-23.99 mm and Hoffer Q for AXL≤ 21.99 mm. IOL power with the first myopic target refraction was selected for implantation All surgeries were performed by a single experienced surgeon using a 2.4 mm clear corneal incision and a standard Phacoemulsification technique. All patients had implantation of an AcryS of SN60WF intraocular lens (Alcon, Ft Worth, TX, USA). Preoperative examinations, operative details, postoperative findings, and refractive data were collected.

III. Statistical Methods

Refractive prediction error was considered as primary outcome variable. Groups (Group 1 vs. group 2) was considered as primary explanatory variable. All Quantitative variables were checked for normal distribution within each category of explanatory variable by using visual inspection of histograms and normality Q-Q plots. Shapiro- wilk test was also conducted to assess normal distribution. Shapiro wilk test p value of >0.05 was considered as normal distribution. For normally distributed Quantitative parameters the mean values were compared between study groups using Independent sample t-test (2 groups). P value < 0.05 was considered statistically significant. IBM SPSS version 22 was used for statistical analysis.(6)

a) *Statistical Analysis*

The refractive prediction error was calculated as the difference between the postoperative refractive outcome expressed as spherical equivalent and the refraction predicted by each formula. A negative value indicates a myopic prediction error that shows a more myopic result than the predicted refraction. The mean numerical refractive prediction error for each formula, the mean absolute error (MAE) and median absolute error for each formula were calculated. The percentages of eyes within <±0.50 D, 0.50D-0.75D,>±0.75 D, of the predicted refraction were calculated and analyzed.

IV. Results

The study composed of 981 eyes of 825 patients. The demographics of the patients are listed in Table 1.

Table 1: Pre-op patient demographics

PARAMETER	STUDY GROUP (Mean± SD) AXL = 22.00-23.99 mm		P VALUE
	GROUP 1(N=404)	GROUP 2(N=337)	
K 1(D)	44.23 ± 0.87	44.74 ± 0.23	0.2842
K 2(D)	44.84 ± 0.80	44.71 ± 0.46	0.2574
AXL	22.80 ± 0.52	22.54 ± 0.13	0.1619
ACD	3.02 ± 0.23	3.23 ± 0.12	0.1534
	STUDY GROUP (Mean± SD) AXL = ≥ 24 mm		
	GROUP 1(N=76)	GROUP 2(N=73)	
K 1(D)	43.2 ± 1.68	43.05 ± 1.32	0.5465
K 2(D)	43.55 ± 1.56	43.35 ± 1.33	0.4020
AXL	24.51± 0.21	24.81 ± 0.73	0.2805
ACD	3.55 ± 0.21	3.42 ± 0.10	0.3708
	STUDY GROUP (Mean± SD) AXL =≤ 21.99 mm		
	GROUP 1(N=43)	GROUP 2 (N=48)	
K 1(D)	45.99 ± 1.58	46.15 ± 1.05	0.5672
K 2(D)	46.53 ± 1.44	46.47 ± 1.12	0.8240
AXL	21.55 ± 0.09	21.35 ± 0.05	0.1334
ACD	2.93 ± 0.24	2.88 ± 0.14	0.2223

Keratometry, AXL, ACD across all the study groups were comparable. There was almost no statistical difference on comparing post op Uncorrected distance visual acuity (UCDVA),refractive prediction error(RPE),mean absolute error(MAE),CDVA across all the groups except a significant difference in mean refractive spherical equivalent(MRSE) in the group with short axial length as shown in Table 2.

Table 2: Post- operative refractive parameters

PARAMETER	STUDY GROUP (Mean± SD) AXL = 22.00-23.99 mm		P VALUE
	GROUP 1(N=404)	GROUP 2(N=337)	
UCVA	0.35 ± 0.15	0.33 ± 0.14	0.0629
MRSE	-0.19 ± 0.32	-0.14 ± 0.41	0.0628
RPE	-0.04 ± 0.20	-0.01 ± 0.43	0.2118
MAE	0.20 ± 0.04	0.24 ± 0.10	0.0660
CDVA	0.00 ± 0.00	0.00 ± 0.00	0.00
	STUDY GROUP (Mean± SD) AXL = ≥ 24 mm		
	GROUP 1(N=76)	GROUP 2(N=73)	
UCVA	0.13 ± 0.14	0.11 ± 0.1	0.3190
MRSE	-0.11 ± 0.3	-0.12 ± 0.3	0.8391
RPE	0.07 ± 0.31	0.04 ± 0.35	0.5801
MAE	0.24 ± 0.23	0.26 ± 0.24	0.6042
CDVA	0.02 ± 0.08	0.01 ± 0.04	0.3392
	STUDY GROUP (Mean± SD) AXL =≤ 21.99 mm		
	GROUP 1(N=43)	GROUP 2 (N=48)	
UCVA	0.13 ± 0.11	0.16 ± 0.13	0.2407
MRSE	-0.1 ± 0.44	-0.23 ± 0.62	0.0047
RPE	0.07 ± 0.49	0.12 ± 0.53	0.6427
MAE	0.33 ± 0.37	0.39 ± 0.38	0.4485
CDVA	0.00 ± 0.08	0.00 ± 0.02	1

However there was a good difference between the percentage prediction between the 2 groups, with the prediction error of Barret IOL formulae to be far superior and much closer to emmetropia than the other 3rd generation IOL formulae as shown in Tables 3 and 4.. There was no documented myopic or hyperopic surprise in any of the IOL formulae.

Table 3: Percentage prediction error using Barrett universal formula

	Long Eyes (%) (AXL ≥24.00mm) N=76	Normal Eyes (%) (AXL=22-23.99 mm) N=404	Short Eyes (%) (AXL≤ 21.99 mm) N=43
<± 0.50 D	96	92.3	90.6
0.50 – 0.75 D	1.3	4.7	4.6
> 0.75 D	2.6	3	4.6

Table 4: Percentage prediction error using 3rd Generation formula

	Long Eyes Srk-T (%) (Axl ⩾ 24.00 Mm) N=73	Normal Eyes Holladay (%) (Axl 22-23.99 Mm) N=337	Short Eyes Hoffer Q(%) (Axl ⩽ 21.9mm) N=48
± 0.50 D	93.1	82.5	75
0.50 – 0.75 D	6.8	7.9	8.3
> 0.75 D	0	6.2	16.6

V. Discussion

Corrected distance visual acuity has long been the principal outcome measure following cataract surgery; however, surgeons are now being judged more and more on refractive outcomes and the ability to achieve the desired refractive target and expected degree of spectacle independence. (7,8) Published results suggest that surgeons are, by and large, meeting expectations.(9,10) Refractive outcomes remain variable based upon differences in surgeon technique and experience, preoperative diagnostic technology and the population cohort.(11-14) Proposed benchmark outcomes also vary. Based on a large subset of patients undergoing surgery across the National Health Service, Gale and co-authors have previously suggested that 55% of patients should achieve postoperative spherical equivalent of ± 0.5D of the intended target and 85% of patients within ± 1.0D.(15) Subsequent papers however suggest outcomes in excess of these figures may be feasible. Simon et al achieved 67% of cases within ± 0.5D and 94% of cases within ± 1.0D in their own case series located at an academic teaching institution.(16) Considering the combination of modern optical biometry, informed formula choice and IOL constant optimization, Sheard had proposed that surgeons should be able to achieve 60% and 90% within ± 0.5D and ± 1.0D respectively.(17) To determine the effectiveness of the IOL formula in a relatively standard population, we calculated the theoretical performance of Barrett Universal II in comparison with existing optimized formulas (Holladay I, SRK/T and Hoffer Q).

In our study, the prediction error of <± 0.50D using Barrett universal formula across all axial lengths is given in Table 3. A Refraction prediction error of 96%, 92.3%, 90.6% in patients with Long, normal and short axial lengths was seen. In those whom 3rd generation formulae was used the prediction error of <± 0.50 D was seen in 93.1%, 82.5%, 75% in patients with Long, normal and short axial lengths (Table 4). However there was no statistical significance in prediction error of patients in extreme of Axial lengths Long eyes p= 0.4360, Short eyes p=0.0525. The percentage of prediction error of < ± 0.50D in normal eyes between the Barrett and 3rd Generation formulae was statistically significant (p<0.0001). This difference in statistical significance could also be due large variation in the sample size across the three groups.

The mean absolute error derived from using Barrett Universal II were lower than those of the 3rd Generation formulae, across all axial lengths (Table 2). The real challenge in giving the best post-operative refractive outcomes lie in selecting the IOL formulae that would give the lowest refractive prediction error ,especially in eyes with extreme of axial lengths (AXL >24.00mm and <22.00 mm). In our study Barrett Universal II had prediction error of 0.07 ±0.31, 0.07± 0.49 versus 0.04±0.35,-0.12±0.13 using SRK=T, Hoffer-Q in long and short eyes respectively, the differences were not statistically significant and the results are almost comparable to those published by Zhou D et al and Gökce SE et al.(18,19) In terms of overall accuracy, the Barrett Universal II formula provided the equivalent or lowest variation within the data and thereby smallest percentage of refractive surprises compared to other formulas for all cohorts. Our results, representative of a standard non-toric Indian population show that excellent results can be achieved combining optical biometry with consistent technique and latest IOL power calculation formulas. The Barrett Universal II formula is independently available and require minimal additional manipulation to achieve excellent results across all axial lengths is a further benefit. Another advantage is that it does not require calculation of surgically induced astigmatism. The limitation of our study remains the relatively small numbers in the short and long axial length groups. Study inclusion was limited to the SN60WF IOL as this was one of most commonly used IOL in this part of the world. Although it would be reasonable to expect that the formulas would produce similar outcomes for additional lenses, further investigation may be useful to confirm this.

In conclusion, we found that excellent results can be obtained with a variety of IOL power calculation formulas for eyes with different axial lengths, especially extreme of axial lengths. The Barrett Universal II formula may provide additional benefits for patients by reducing possible refractive surprises and a very effective tool to reaching the goal of emmetropia which is a desirable goal for every cataract surgeon in the present day world.

a) *What was known*

Because there is no single highly accurate formula across a range of eye characteristics, many cataract surgeons should consider and use several formulas in eyes with various ocular dimensions.

b) *What this paper adds*

The Barrett Universal II formula is the most accurate predictor of postoperative refraction compared with the third generation across all axial lengths.

Synopsis: The Barrett formula appeared to have the least bias as measured by prediction error across all axial lengths, with better accuracy in shorter axial lengths.

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