Original Article

Evaluation of Barrett universal II formula for intraocular lens power calculation in Asian Indian population

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Purpose: Barrett Universal II (BU-II) is considered as one of the most accurate intraocular lens (IOL) power calculation formulas; however, there is no literature studying the same in Indian population. The aim of this study was to evaluate the accuracy of BU-II formula in prediction of IOL power for cataract surgery in Asian Indian population. This was an institutional, prospective, observational study. **Methods:** Patients with senile cataract who underwent phacoemulsification with posterior chamber IOL implantation were enrolled in the study. Biometry data from Lenstar-LS900 was used and IOL power was calculated using four IOL formulas: modified SRK-II, SRK/T, Olsen, and BU-II. Primary outcome was measured as the prediction error in postoperative refraction for each formula and secondary outcome was measured as the difference in mean absolute errors between the four formulas. SPSS Version-21 with $P < 0.05$ considered significant. **Results:** A total of 244 eyes were included in the study and were divided into three groups in accordance to axial length (AL): Group 1 (AL: 22–24.5 mm; $N = 135$), Group 2 (AL <22 mm; $N = 53$), and Group 3 (AL >24.5 mm; $N = 56$). BU-II formula gave the lowest mean absolute error (0.37 ± 0.27D) and median absolute error (0.34) in predicted postoperative refraction in the entire study population. When compared with the other formulas, mean absolute error was significantly lower in all three groups ($P < 0.0005$) as well, except for Olsen formula in the normal AL group, where the results were comparable ($P = 0.742$). **Conclusion:** BU-II performed as the most accurate formula in the prediction of postoperative refraction over a wide range of ALs.

Key words: Barrett, IOL formula, prediction error, refraction

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Increasing patient demand for refractive accuracy and spectacle independence has transformed cataract surgery into a refractive procedure rather than a rehabilitative one. Refinement in preoperative biometry, operative techniques, and availability of various premium intraocular lenses (IOLs) are the major factors responsible for helping in achieve the abovementioned goals. There has been a lot of work in the area of IOL power calculation; however, a perfect formula that proves to be accurate over a wide range of ALs still remains an enigma.

One of the commonly used IOL power calculation formulas is the modified SRK II (Sanders, Retzlaff, and Kraff) formula, which is a regression formula with corrections in A constant based on the ALs.[1] This formula has been the preference of most cataract surgeons due to the ease of calculation it offers, without the need for sophisticated biometry devices with incorporated IOL formula software. Another commonly used formula, the SRK/T formula that was introduced in 1990 is formulated as a combination of both regression and theoretical approach and has been found to be accurate, particularly in eyes with AL more than 27 mm.[2] Olsen formula, on the other hand, uses exact ray tracing technique and thick-lens considerations for IOL power calculation and a C constant that indicates the final position of IOL.[3] The Barrett Universal II (BU-II) formula, an updated version of BU formula, was introduced in 2010 by Graham D Barrett and has shown promising results so far.[4,5] The formula can be accessed in the online form in Asia Pacific Association of Cataract and Refractive Surgeons website.[6]

In this study, we aimed to evaluate the accuracy of BU-II formula in predicting the IOL power for cataract surgery in Asian Indian population.

Methods

This was a prospective observational study enrolling cataract patients operated by various cataract surgeons at a tertiary care eye hospital during the period of January 2016 to January 2017. All patients of visually significant cataract in the age group of 40 to 80 years, who underwent an uneventful phacoemulsification surgery (microincision cataract surgery) with posterior chamber IOL implantation, operated by various cataract surgeons under the supervision of the study

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coordinators, were included in the study. Patients with previous intraocular pathologies and previous intraocular surgeries were excluded from the study. Also, those with any intraoperative complications, such as posterior capsular rent or any unforeseen postoperative complications were excluded. Ethical clearance was obtained from the Institute Ethics Committee on 25-07-2015, and the study adhered to the tenets of declaration of Helsinki. A written informed consent was obtained from each patient and only those who were consenting and willing for follow-up were enrolled into the study.

All patients underwent a basic clinical work-up for cataract surgery with biometry using Lenstar LS 900 (Haag-Streit AG, Koeniz, Switzerland). Preoperative visual acuity, AL, keratometry (Km), anterior chamber depth, lens thickness (LT), and white to white were documented and IOL power was calculated using the four formulas: modified SRK II, SRK/T, Olsen, and BU-II. Only those patients who were suitable for phacoemulsification (micro-incision cataract surgery) with posterior chamber IOL implantation were enrolled. All surgeries were done by experienced cataract surgeons and Acrysof SN60WF IOL (Alcon Laboratories, Inc.) and Tecnis ZCB00 (Abbott Medical Optics Inc.) were implanted in the bag. IOL power was calculated using Mod SRK II and BU II; in the cases where the difference in calculated IOL power was more than 0.5 D between the two formulas, IOL was implanted according to the SRK/T value. The patients' uncorrected and best-corrected distance visual acuity was documented at one-month follow-up and the postoperative refractive error was documented using auto-refractometer and confirmed using retinoscopy; the former was used for calculation purpose.

The ***prediction error in postoperative refraction*** for each IOL power formula was calculated as the difference between the actual postoperative refraction (spherical equivalent) and the predicted error by formulas. The predicted errors in postoperative refraction of modified SRK II, SRK/T, and Olsen formula were given by Lenstar LS900 and that of BU-II formula was calculated from the online calculator.

The prediction error in postoperative refraction is calculated as difference between actual postoperative refractive error and predicted error by each formula. This can be analyzed in various ways, described as follows:

- ***Mean Arithmetic Error***: This is the average of prediction error considering the sign of the prediction error
- ***Mean Absolute Error***: This is the average of absolute value (without considering sign of the prediction error)
- ***Median Absolute Error***: This is the midpoint value of absolute prediction errors distribution.

All the above were calculated individually for each formula in the various study groups. The ***primary outcome of the study*** was the prediction error in postoperative refraction for each formula: modified SRK II, SRK/T, Olsen and BU-II. ***The secondary outcome*** was taken as the difference in mean absolute error in prediction of postoperative refraction between the four formulas.

Data was analyzed for the study sample divided into three groups in accordance to the AL as follows:

- Group 1 (normal AL): AL 22–24.5 mm
- Group 2 (short AL): AL <22 mm
- Group 3 (long AL): AL >24.5 mm.

Sample-size calculation to detect a spherical equivalent prediction error >0.125D and a standard deviation (SD) of 0.40 dioptres (D) mandated a minimum number of 47 eyes in each group for a significance level (α) of 0.05 and a test power of 0.80. Statistical analysis was performed using SPSS software (version 21.0, SPSS, Inc.). The differences in mean absolute prediction error in postoperative refraction between the formulas were assessed by Freidman test (a non-parametric test). In the event of significant result, post-hoc analysis was done by Wilcoxon Signed-Rank test. P value less than 0.05 was considered as significant.

Results

Of the 648 eyes of 648 patients operated during the study period, only 244 eyes were eligible to be included in the study. The rest were excluded either due to inadequate biometry data (N = 224) or due to associated ocular co-morbidities and previous intraocular surgeries (N = 164) or due to postoperative complications (N = 16). The number of patients in the 3 study groups according to ALs was 135 eyes in Group 1 [normal AL: AL 22–24.5 mm], 53 eyes in Group 2 [short AL: AL <22 mm], and 56 eyes in Group 3 [long AL: AL >24.5 mm].

The mean age of the study group population was 60.2 ± 9.8 years (range: 42–80 years), with 100 male patients (mean age 60.93 + 8.78 years; range 42–80 years) and 144 female patients (mean age 59.76 + 10.05 years; range 42–75 years). The mean age of the study subjects in group 1 (normal AL) was 60.68 ± 8.83 years, group 2 (short AL) was 58.79 ± 10.12 years, and those in group 3 (long AL) was 59.48 ± 10.21 years. The mean preoperative visual acuity was 0.56 ± 0.25 LogMAR units in the whole study population, with 0.57 ± 0.27, 0.57 ± 0.21, and 0.52 ± 0.18 in group 1 (normal AL), 2 (short AL), and 3 (long AL), respectively ($P > 0.05$). The preoperative biometric parameters with their mean values, median, and range are summarized in Table 1.

The mean uncorrected visual acuity (UCVA) and mean best corrected visual acuity (BCVA) of the study subjects at 1-month postoperative period were 0.23 ± 0.15 LogMAR units and 0.05 ± 0.09 LogMAR units, respectively. The mean postoperative refractive error (spherical equivalent) at 1 month was 0.13 ± 0.50 D (range: - 1.25D to + 1.50D). The results of the sub-group analysis are summarized in Table 2.

The mean arithmetic error, mean absolute error, and median absolute error of predicted postoperative refraction of the various IOL power calculation formulas in the entire study population as well as in different sub-groups are summarized in Table 3. In the entire study sample population, the BU-II formula gave the lowest mean absolute error 0.37 ± 0.27 D and median absolute error 0.34 in predicted postoperative refraction. This was noted in the individual groups as well, with mean absolute error of 0.37 ± 0.27 D in normal AL group (group 1), 0.35 ± 0.28D in eyes with AL <22 mm (group 2), and 0.38 ± 0.25 D in eyes with AL >24.5 mm (group 3).

Statistically significant differences were observed between the mean absolute errors in postoperative refraction given by the four formulas (by Freidman test) in all three groups (normal, short, and long AL). BU-II gave the lowest mean absolute prediction error in postoperative refraction and median absolute error in all three groups, namely, normal

Table 1: Preoperative biometry data of the study subjects

Statistical Parameters	Axial Length (mm)	Mean Keratometry (D)	IOL Power (D)
Entire Study Population			
Mean±SD	23.26±1.63	44.29±1.89	21.30±4.02
Median	23.08	44.18	21.5
Range	19.55-30.78	39.24-51.47	4-30.5
Eyes with Normal Axial Length (Group 1)			
Mean±SD	23.13±0.58	44.15±1.48	21.67±1.54
Median	23.13	41.17	21.5
Range	22.01-24.48	39.93-48.66	18-28.5
Eyes with Short Axial Lengths (Group 2)			
Mean±SD	21.32±0.61	46.21±1.50	25.63±2.37
Median	21.41	46.18	25.5
Range	19.55-21.96	43.63-49.54	21.5-30.5
Eyes with Long Axial Lengths (Group 3)			
Mean±SD	26.28±1.70	42.62±1.40	14.29±4.90
Median	25.98	42.38	14.75
Range	24.50-30.78	40.66-45.88	4-20.5

Table 2: Visual acuity and postoperative refractive error of the study subjects

Parameters	Mean±SD	Median	Range
Entire Study Population			
UCVA at 1 month LogMAR)	0.25±0.15	0.18	0.00-0.60
BCVA at 1 month (LogMAR)	0.05±0.09	0.00	-0.08-0.03
Refractive Error (D)	0.13±0.50	0.13	-1.25-+1.50
Eyes with Normal Axial Length (Group 1)			
UCVA at 1 month (LogMAR)	0.23±0.15	0.18	0.00-0.60
BCVA at 1 month (LogMAR)	0.05±0.90	0.00	-0.08-0.30
Refractive Error (D)	0.07±0.47	0.00	0.00-+1.5
Eyes with Short Axial Lengths (Group 2)			
UCVA at 1 month (LogMAR)	0.26±0.16	0.30	0.00-0.48
BCVA at 1 month (LogMAR)	0.52±0.09	0.00	0.00-0.18
Refractive Error (D)	0.35±0.59	0.33	-0.83-+1.5
Eyes with Long Axial Lengths (Group 3)			
UCVA at 1 month (LogMAR)	0.20±0.10	0.18	0.00-0.48
BCVA at 1 month (LogMAR)	0.04±0.07	0.00	0.00-0.18
Refractive Error (D)	0.14±0.46	0.19	-1-0.825

AL group (group 1), short AL group (group 2), and long AL group (group 3).

The comparison (by *post hoc* analysis using Wilcoxon signed ranks test) of the mean absolute prediction errors between the IOL formulas in the 3 study groups is summarized in Table 4. In all the three AL groups, there was statistically significant difference between mean prediction error in postoperative refraction of modified SRK II and BU II (*P* value <0.0005), SRK/T and BU II (*P* value <0.0005); however, the difference in mean absolute prediction errors between Olsen and BU-II formulas was statistically significant in the short AL and the long AL groups (*P* value <0.0005), but not in the normal AL group (*P* value = 0.742).

Analysis of the percentage of study eyes in which the prediction error in postoperative refraction was within ±1D and ±0.5D of the given target postoperative refraction by the four formulas was the highest with BU-II formula with approximately 98% and 71% of the eyes achieving within ±1D and ±0.5D of the given target postoperative refraction, respectively [Fig. 1].

Discussion

Cataract surgery is the most commonly performed surgery by ophthalmologists across the world, and with improving technology, it is now both a visual rehabilitative and a refractive procedure. The postoperative refractive outcomes after a cataract surgery not only depend upon a well-refined surgical procedure but also on accurate IOL power calculation.

Modified SRK II (regression formula) and SRK/T (both regression and theoretical) are among the commonly used IOL

Table 3: Prediction error of postoperative refraction of the study subjects

Formula	Mean Arithmetic Error±SD (D)	Mean Absolute Error±SD (D)	Median Absolute Error (D)	Range (D)
Entire Study Population				
Mod SRK II	0.27±0.70	0.59±0.47	0.49	-1.54-2.2
SRK/T	0.13±0.51	0.44±0.34	0.37	-1.22-1.54
Olsen	0.18±0.52	0.42±0.31	0.37	-1.33-1.62
BU II	0.14±0.44	0.37±0.27	0.34	-1.31-1.43
Eyes with Normal Axial Length (Group 1)				
Mod SRK II	0.19±0.67	0.54±0.44	0.43	-1.54-1.86
SRK/T	0.08±0.48	0.41±0.32	0.34	-1.22-1.51
Olsen	0.13±0.51	0.39±0.29	0.36	-1.3-1.6
BU II	0.08±0.45	0.37±0.27	0.33	-1.31-1.43
Eyes with Short Axial Lengths (Group 2)				
Mod. SRK II	0.59±0.70	0.74±0.53	0.75	-0.84-2.13
SRK/T	0.35±0.59	0.59±0.39	0.54	-0.89-1.56
Olsen	0.39±0.60	0.56±0.39	0.60	-0.80-1.6
BU II	0.28±0.36	0.35±0.28	0.30	-0.47-1.3
Eyes with Long Axial Lengths (Group 3)				
Mod SRK II	0.28±0.78	0.64±0.52	0.55	-1.33-2.22
SRK/T	0.13±0.49	0.42±0.27	0.41	-1.22-0.89
Olsen	0.19±0.46	0.40±0.29	0.33	-0.80-1.00
BU II	0.26±0.38	0.38±0.25	0.36	-0.54-0.86

Table 4: Subgroup analysis showing the comparison of mean absolute prediction errors obtained by the four IOL power calculation formulas

Formulas Compared	*P*		
	Group 1	Group 2	Group 3
Mod SRK II and BU II	<0.0005	<0.0005	<0.0005
SRK/T and BU II	<0.0005	<0.0005	<0.0005
Olsen and BU II	0.742	<0.0005	<0.0005

power formulas. While the former works well in the normal AL range (22–24.5 mm), the latter is better suited for extremely long ALs (greater than 27 mm).[1,7] The Olsen formula, on the other hand, is a thick lens formula that uses exact ray tracing technique for the calculation of IOL power.[3] There are other available formulas such as Hoffer Q and Holladay I and II, but none of them can be used over a wide range of ALs and different IOL designs.

The BU formula was published in 1993 by Dr Graham D. Barrett as a possible solution for the same, and this was later modified in 2010 and called the BU-II formula (a modification of Barrett's earlier formula) introduced in 2010. This formula had shown to give better postoperative outcome in comparison to all other existing IOL power calculation formulas in its original publication and in a study in only high myopic eyes (AL >26 mm).[8] At the time of commencement of our study in late 2015, this formula was not extensively evaluated over the entire range ALs and was not evaluated in eyes of Asian Indian population. In India, the modified SRK II is still widely used by most cataract surgeons due to the ease of calculation it offers, without necessitating the use of the advanced sophisticated biometry devices with incorporated IOL formula software.

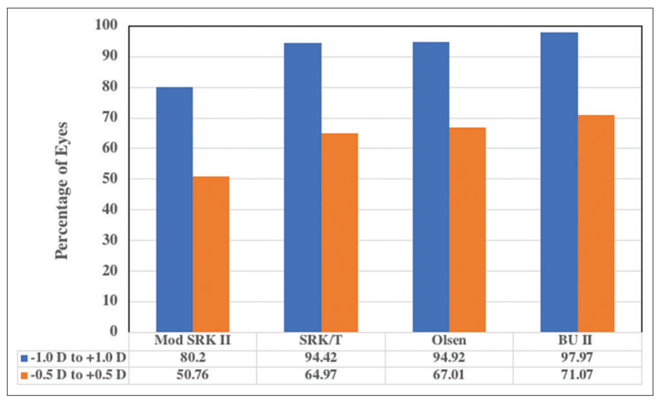

Figure 1: Histogram showing the percentage of study eyes with prediction error of postoperative refraction within ±1D and ±0.5D of the given target postoperative refraction using the four IOL power calculation formulas

Therefore, we evaluated the refractive outcomes to compare the results obtained with the modified SRK II formula with the other recent formulas—SRK/T, Olsen, and the BU-II formula.

Recently, Melles RB *et al*. compared the accuracy of IOL calculation formulas (BU-II, Haigis, Hoffer Q, Holladay 1, Holladay 2, Olsen, and SRK/T) in the prediction of postoperative refraction using Lenstar 900 optical biometry and published the results in February 2018.[9] They found that BU II and Olsen formulas had the best outcomes in terms of accuracy of postoperative spherical equivalent and performed well across a range of ALs and biometric dimensions. In another study published in 2017, Roberts T V *et al*. compared Hill-radial basis function, BU, and current third-generation formulas, namely, Holladay II, SRK/T, and Hoffer for the calculation of

IOL power during cataract surgery.[10] They concluded from their results that Hill-radial basis function and Barrett formulas provided the lowest mean arithmetic error compared with existing formulas in short and long eyes, respectively. The BU-II formula had the lowest percentage of refractive surprises (>1 D from predicted error) across all ALs.

This study to the best of our knowledge is the first study in Asian Indian population, reporting the comparison of the postoperative refractive outcome of BU-II formula with other three formulas: modified SRK II, SRK/T, and Olsen, using the Lenstar LS 900 biometry platform across an entire range of ALs. The distribution of the study population was 55.32% in the normal AL group (n = 135), 21.72% with AL less than 22 mm (n = 53), and 22.95% with AL greater than 24.5 mm (n = 56 eyes).

In this study, the mean absolute error was used instead of mean arithmetic error as a marker of accuracy for statistical analysis as the latter can lead to erroneous results due to cancellation during summation. The analysis of mean absolute prediction error as a marker of accuracy was suggested by Aristodemou P *et al*. in response to the article by Hoffer *et al*.[11,12] We compared the difference in mean absolute errors in predicted postoperative refraction between the four formulas by a non-parametric test (Friedman test) because the distribution of mean absolute error does not follow normal distribution. In the event of significant result, *post hoc* analysis was done to compare other three formulas to BU-II formula by Wilcoxon signed ranks test. Considering the entire study population of our study, the lowest mean absolute error in prediction was with BU-II formula (0.37 ± 0.27), which was significantly lower than all three formulas in all three AL groups except for the normal axial group, wherein the results were comparable with Olsen formula.

On calculating the percentage of prediction error within the acceptable range of error, BU-II formula gave the best results with 97.97% and 71.07% within ±1D and ±0.5D, respectively. This is well within the benchmark standard determined for National Health Services, United Kingdom (85% of prediction error within ±1D and 55% of prediction error within ±0.5D).[13] Our study results concur with results of other studies done with BU-II formula.[8,14,15]

At the time of commencement of our study, there was not enough literature evaluating a single IOL power formula for possible and accurate usage over an entire range of ALs. The BU-II formula showed promising result in its original publication but was not extensively tested in entire AL range except for the study by Adi Abulafia *et al*. in myopic eyes (AL >26 mm) and that by Olga Reitblat *et al*. conducted in eyes with high (>46 D) and low (<42 D) average keratometry readings.[8,13] Although after the commencement of our study, two more published studies reported comparison of the BU-II formula with other formulas: one by Cooke *et al*. in 1454 eyes (2016) and Kane *et al*. in 3241 eyes (2016),[14,15] and there was no study in the Asian Indian population till now evaluating the comparison of the postoperative prediction error of BU-II formula.

In the former study, Cooke *et al*. evaluated the accuracy of 9 IOL calculation formulas using 2 optical biometers, optical low-coherence reflectometry (OLCR) device (Lenstar L5 900) and the partial coherence interferometry (PCI) device (IOL Master), and the performance of each formula was ranked for accuracy by machine and by AL.[14] The Olsen formula was found to be the most accurate with OLCR measurements and performed better regardless of AL and BU-II performed the best if only PCI measurements (without LT) were available. However, no statistical analysis of mean absolute prediction error was done. In the other study, Kane *et al*. compared seven intraocular formulas using IOL Master biometry measurements without using LT measurements and BU-II formula ranked first after statistical tests comparing the mean absolute prediction error.[15] The Olsen formula was not compared in this study. The LT measurements may have added to the accuracy of BU-II formula.

Conclusion

Our study, which is the first such study in Asian Indian population, in conclusion, points to the fact that BU-II is the most accurate in predicting postoperative refractive error and is suitable to be used for a wide range of ALs.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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