Factors affecting the predictability of SRK II in patients with normal axial length undergoing phacoemulsification surgery

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ABSTRACT

Introduction: This study aims to evaluate the factors affecting the accuracy of biometry assessment using the SRK II formula in predicting the refractive outcome after uneventful cataract surgery by phacoemulsification for eyes within the normal range of axial lengths.

Methods: A retrospective review of 100 consecutive cases of uncomplicated phacoemulsification surgery performed by two surgeons from January to September 2005 in a single centre was done. Eyes with axial length greater than or equal to 22.5 mm and less than 24.5 mm were included in the study. The error of prediction was calculated by actual postoperative refractive error minus the refraction target. A comparison was made between the low predictability (prediction error more than 0.50 dioptres [D]) and high predictability (prediction error less than or equal to 0.50 D) groups of eyes. Statistical analysis was performed.

Results: A total of 267 case notes were reviewed, of which 100 met the inclusion criteria. The mean age was 68.3 years, with a mean keratometric reading of 43.94 +/− 1.27 D and mean axial length of 23.38 +/− 0.51 mm. The mean IOL power used was 21.77 +/− 1.50 D. The mean error was +0.25 +/− 0.67 (range −1.58 to +1.80)D, with the standard error of mean 0.669. 45 percent of the patients were within 0.5 D of the predicted refractive error and 83 percent were within 1.0 D. There was no difference in preoperative corneal astigmatism, mean keratometry, axial length, age or gender of the patient, laterality of the operated eye and intraocular lens power between the low and high predictability groups. There was a negative correlation between the axial length and prediction error.

Conclusion: SRK II is reliable in the prediction of the refractive outcome in normal axial length eyes. The findings in our study are comparable to those found in previous studies. We found a negative correlation between axial length and prediction error, even within the range of normal axial length eyes.

Keywords: biometry, cataract surgery, eye axial length, phacoemulsification surgery, SRK II formula, target refraction

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INTRODUCTION

Cataract surgery is one of the most commonly-performed types of surgery in ophthalmology. The two commonly-used methods for cataract removal are extracapsular cataract extraction and phacoemulsification. Phacoemulsification is a technique of lens removal that uses an ultrasonically-driven tip to fragment the nucleus of the cataract and aspirate the lens. An intraocular lens (IOL) made of inert material is inserted into the lens capsular bag at the end of the surgery to replace the natural lens that was removed. A state of emmetropia occurs when the image of a distant object is focused onto the retina without the aid of adjunctive spectacles correction. Various formulas have been developed over the last two to three decades to calculate the power of IOL required to achieve emmetropia postoperatively. These formulas can be broadly divided into theoretical formulae based on geometric optical principles (optical model of the eye)[1,2] and empirical or regression formulae based on empirical data analysis of eyes with IOL implantation.[3,4]

The SRK formula is a regression formula developed by Retzlaff, Sanders and Kraff.[5,6] This formula is based on the observed relationship between the preoperative variables (axial lengths and keratometric reading) and the actual results (implant power required to achieve emmetropia). The SRK formula is $P = A - 2.5\ AL - 0.9\ K$, where P = implant power (dioptres [D]) to achieve

Table I. Demographic data of 100 eyes undergoing phacoemulsification surgery with in-the-bag placement of IOL implant.

Demographics	No.
Age (years)	
Mean ± SD	68.3 ± 9.4
Range	38–88
Gender	
Male	45
Female	55
Race	
Chinese	84
Malay	7
Indian	3
Others	6
Laterality	
Right	44
Left	56

Table II. Mean keratometry, axial length and IOL power implanted (n = 100).

Parameter	Mean ± SD (range)
Keratometry (D)	43.94 ± 1.27 (40.5–46.5)
Axial length (mm)	23.38 ± 0.51 (22.52–24.43)
IOL power (D)	21.77 ± 1.50 (18.5–24.5)

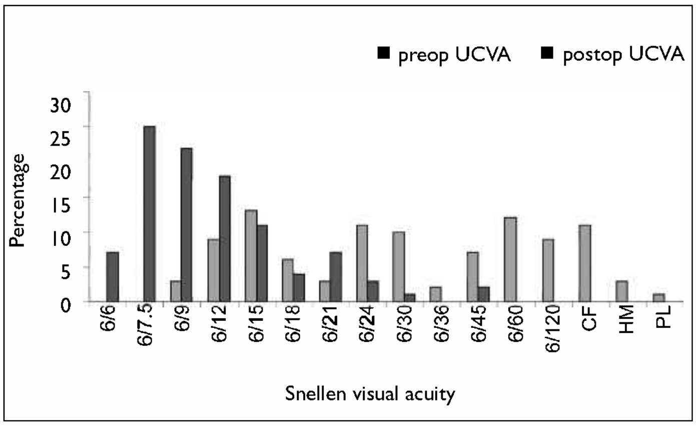

Fig. 1 Bar chart shows the comparison of pre- and postoperative uncorrected visual acuity.

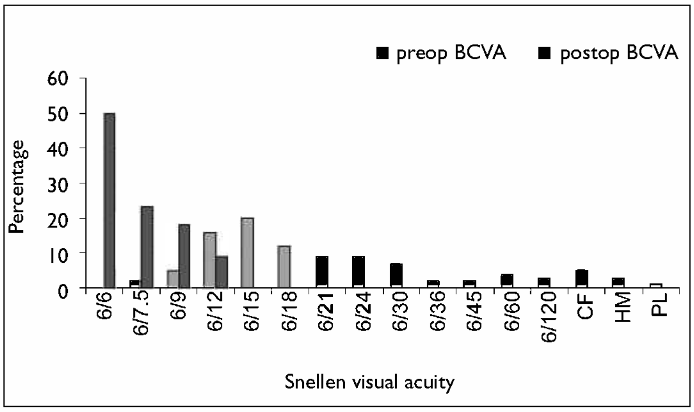

Fig. 2 Bar chart shows the comparison of pre- and postoperative visual acuity with spectacles correction.

emmetropia; AL = axial length (mm); K = average keratometer reading (D); A = specific constant for each lens type and manufacturer. A modification of the SRK formula, the SRK II formula, aimed to improve the predictability in cases of eyes with AL < 22 mm and > 24.5 mm.[7] In SRK II, for eyes with AL between 22 mm and 24.5 mm, no modification was required of the SRK formula. With increasing patient expectations, the accurate calculation of IOL power and the identification of possible factors affecting this predictability are crucial in ensuring the desired postoperative refractive results.

METHODS

This is a retrospective review of 100 cases of uncomplicated phacoemulsification surgery with in-the-bag IOL implantation that were performed in SNEC during the period from January to September 2005. To limit the variability between surgeons, we audited the cases performed by only two surgeons. Only cataract surgery performed using the phacoemulsification method was included due to its small incision, hence reducing the surgical variability and minimising the cylindrical error induced.[8] All the IOLs used were of the posterior chamber type and the lens choice was surgeon dependent. MA60BM and YA60BB are three-piece lenses with acrylic optic and polymethylmethacrylate (PMMA) haptics made by Alcon Laboratories Inc, USA and Hoya Corporation, Japan, respectively. SI40NB and LI61SE are three-piece lenses with silicone optic and PMMA haptic made by Advanced Medical Optics Inc, USA and Bausch and Lomb Inc, USA, respectively. SN60AT is a single piece acyllic lens made by Alcon Laboratories Inc, USA.

Eyes with normal AL, i.e. ≥ 22.5 mm and < 24.5 mm, were included in the study. ALs were measured preoperatively using the Sonomed A2500 contact A-scan ultrasonography method by a team of technicians. Multiple AL measurements were routinely performed for each patient and the most reproducible reading as computed by the machine was used. Keratometry (K) was performed using the KR-8100 automated keratometer which gives the K reading in the horizontal and vertical meridians. The average of these K readings was used for IOL calculation. The IOL power was subsequently decided by the surgeon who performed the surgery. Eyes with previous intraocular surgeries or macular pathology and postoperative best corrected visual acuity (VA) of less than 6/12 on Snellen acuity visual chart were excluded.

Table III. Difference between the actual and predicted refractive errors and variance of outcome of spherical equivalence.

Difference	No. (%)
Between actual and predicted refraction (D)*	+0.25 ± 0.67 (−1.58 to +1.80) [0.669]
Within ± 0.5 D	45 (45)
Within ± 1.0 D of predicted refractive refractive error	83 (83)
Between −1.0 D and −1.5 D (outcome more myopic than predicted)	2 (2)
Between −1.5 D and −1.75 D	1 (1)
Between +1.0 D and +1.50 D (outcome more hyperopic than predicted)	12 (12)
Between +1.5 D and +2.0 D	2 (2)

* Expressed as mean ± standard deviation (range) [standard error of the mean].

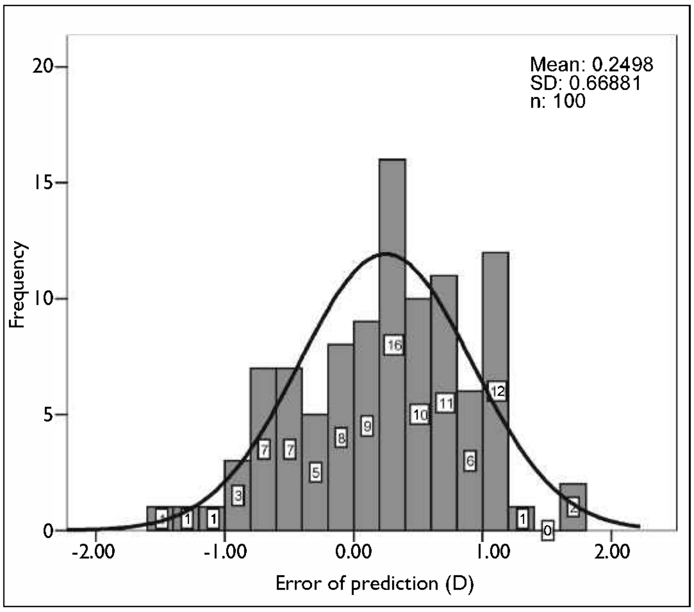

Fig. 3 Histogram shows the range of errors of prediction postoperation.

Patients with poor postoperative best corrected VA were excluded to ensure as accurate a refraction measurement as possible. Only one eye was recruited from each patient into the study. Patients must have completed at least one month of follow-up postsurgery and have had either auto or manual refraction performed.

Consecutive patients were selected from our cataract surgery database and the relevant information was subsequently obtained from the patient's case notes. Data captured include demographical data such as the patient's age, gender and race, pre- and postoperative uncorrected and best corrected VA, mean K reading, AL, type and power of IOL implanted, predicted refractive error and actual spherical equivalent of postoperative refractive error and complications of surgery, if any. The error of prediction was defined as the difference between the observed and the predicted refraction (observed minus predicted value in D). A "negative" prediction error indicated that the actual refractive outcome was more myopic than the predicted refractive target. Similarly, a "positive" prediction error means that the actual refractive outcome was more hyperopic than the predicted refractive target. Analysis of the mean error and standard error of the mean was performed using the Statistical Package for Social Sciences version 13.0 (SPSS Inc, Chicago, IL, USA). The correlation between prediction error and AL, mean K, mean preoperative corneal astigmatism, IOL power and age of the patient was made using the Pearson's and Spearman's rank correlation coefficient.

Based on the error of prediction, we divided the eyes into two groups: those with high and those with low predictability. Eyes with high predictability had errors of prediction of ≤ 0.5 D of the target refraction. Eyes with low predictability had errors of prediction of > 0.5 D. A test of the normality of the data distribution was performed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. AL, preoperative corneal astigmatism, mean K, IOL power and patient's age in the low and high predictability groups were compared using both the parametric independent samples *t*-test and non-parametric Wilcoxon Signed-ranks test. Laterality of the operated eye, surgeon and patient's gender in the two groups were compared using the Pearson's chi-square test. The race distribution was compared using the Fisher's exact test. A comparison between the groups of different IOL was made using the one-way ANOVA. Further analysis between the groups of IOL used was made using the parametric student *t*-test or non-parametric test depending on the normality of the data. A p-value of ≤ 0.05 was taken as significant.

RESULTS

A total of 267 case notes were reviewed, of which 100 patients (50 from each of the two surgeons) met the inclusion criteria and were analysed. The reasons for exclusion of the 167 eyes were as follows: long AL ≥ 24.5 mm (n = 51), short AL < 22 mm (n = 33), postoperative refraction not performed (n = 36), macular pathology (n = 17), previous retinal surgery or combined retina and cataract surgery (n = 11), usage of non-SRK II formula (n = 5), extracapsular cataract extraction (n = 1), phacomorphic glaucoma (n = 1) and posterior capsule rupture complication (n = 1); ten eyes were lost to follow-up and one patient was deceased. The demographic data of the patients is shown in Table I. Various IOLs were used in this study based on availability and the surgeon's choice. The distribution was as follows: acrylic MA60BM lens (n = 71), silicone SI40NB lens (n = 25), acrylic YA60BB lens (n = 2) and one each of silicone LI61SE and acrylic SN60AT lenses.

Both preoperative uncorrected and best corrected VAs ranged from 6/12 to perception of light. Postoperative uncorrected VA ranged from 6/6 to 6/45 (72% 6/12 or better). 73% of postoperative best-corrected VA was 6/7.5 or better. Figs. 1 and 2 show the comparison between the pre- and postoperative VAs without and with spectacle correction, respectively. The mean K reading, mean AL and mean IOL power implanted are shown in Table II. The error of prediction (actual postoperative refractive error minus refractive target) ranged from −1.58 D to +1.80 D. The mean error was +0.25 ± 0.67 D. The majority of patients (83%) were within 1 D of the predicted refractive error (Table III and Fig. 3). The prediction error between the two surgeons was compared using the Pearson's chi-square test and was not found to be statistically significant ($p = 0.452$). The AL had a negative correlation with the prediction error (Pearson's correlation coefficient, $r = -0.444$) (Fig. 4). The IOL power was positively correlated with the prediction error (Spearman's correlation coefficient, $r = 0.384$) (Fig. 5).

Comparisons were made between the high (45 eyes) and low (55 eyes) predictability groups. The high predictability group had a lower mean K reading, less preoperative corneal astigmatism, younger age, smaller IOL power and slightly longer AL than the low predictability group, but these differences were not statistically significant (Table IV). The difference between the two groups in terms of racial and gender distribution, laterality of eye operated and surgeon were also not statistically significant (Table V). The prediction error between the different types of IOL was compared using the one-way ANOVA and was significant at a p-value of 0. Multiple comparisons between the groups using the Bonferroni method were not possible as two of the groups had fewer than two cases. The silicone SI40NB lens had less prediction error (n = 25, mean of −0.18 ± 0.66 D) as compared to the acrylic MA60BM lens (n = 71, mean of +0.43 ± 0.57 D). Further comparisons were not made with the YA66BB, LI61SE or SA60AT lenses due to their small sample sizes.

DISCUSSION

This study focused only on eyes with normal ALs, i.e. between 22.5 mm and 24 mm, for which SRK II had been shown to be reliable and comparable to the theoretical formulas, such as SRK/T, Holladay and Hoffer Q.[9,10]

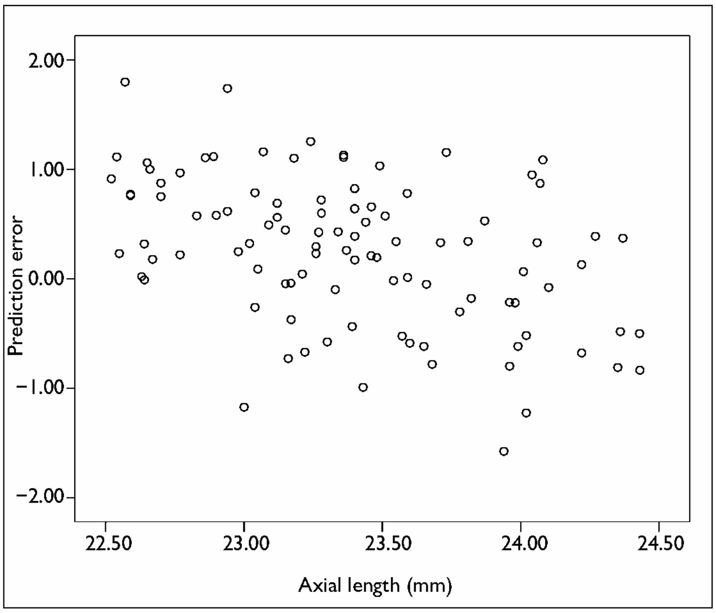

Fig. 4 Scatter plot of prediction error versus axial length showing a negative correlation.

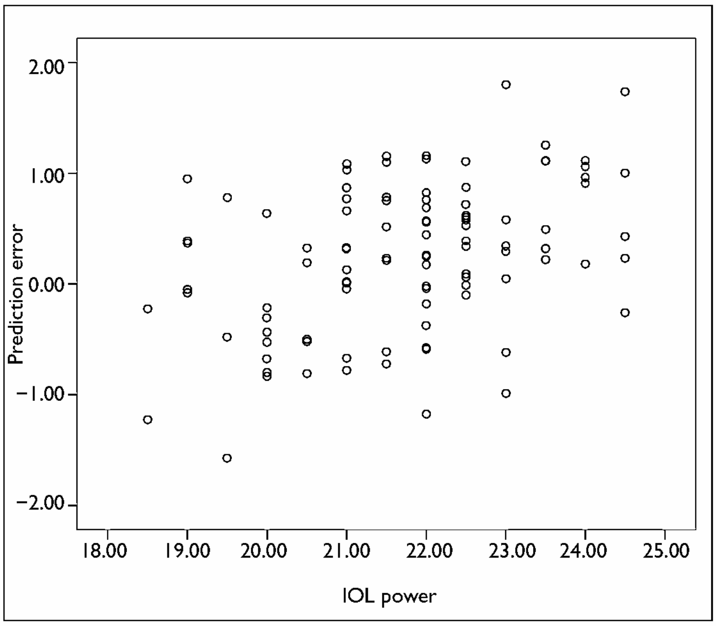

Fig. 5 Scatter plot of prediction error versus IOL power showing a positive correlation.

Our study revealed a mean error of prediction of +0.25 ± 0.67 (range −1.58 to +1.80) D, which is comparable to previous studies by Olsen et al[11] for ALs 22.5–24.5 mm (+0.41 ± 0.91 D, range −2.28 to +2.96 D) and Sanders et al[9] in an unselected group of ALs (mean absolute error 0.65). Standard error of mean was 0.669 in our study and is also comparable to previous studies by Sanders et al, who reported a standard error of mean of 0.86.[9]

The variance of outcome of spherical equivalence postoperatively in our series was 45%, 83% and 100% for ≤ 0.5 D, ≤ 1.0 D and < 2.0 D, respectively. Sanders et al used a data set of 990 unselected cases from multiple

Table IV. Continuous data: a comparison of the low and high predictability groups.

Parameter	Mean ± SD		Independent samples *t*-test p-value	Mann-Whitney U test p-value
	Group A (n = 45)	Group B (n = 55)		
Axial length (mm)	23.45 ± 0.51	23.33 ± 0.52	0.272	0.305
Preop corneal astigmatism (D)	+0.79 ± 0.52	+0.99 ± 0.70	0.107	0.153
Mean keratometry (D)	43.86 ± 1.32	44.01 ± 1.24	0.560	0.417
Patient's age at operation (years)	66.51 ± 9.95	69.84 ± 8.81	0.08	0.089
IOL power (D)	+21.71 ± 1.63	+21.82 ± 1.40	0.724	0.802

Table V. Categorical data: a comparison of the high and low predictability groups.

Parameter	No. (%)		Pearson's chi-square test p-value	Fischer's exact test p-value
	HP group	LP group		
Gender			0.189	
Male	17 (37.8)	28 (62.2)		
Female	28 (50.9)	27 (49.1)		
Surgeon			0.315	
A	25 (50)	25 (50)		
B	20 (40)	30 (60)		
Eye			0.466	
Right	18 (40.9)	26 (59.1)		
Left	27 (48.2)	29 (51.8)		
Race				0.862
Chinese	38 (45.2)	46 (54.8)		
Malay	3 (42.9)	4 (57.1)		
Indian	2 (66.7)	1 (33.3)		
Others	2 (33.3)	4 (66.7)		

HP: high predictability; LP: low predictability

surgeons and reported variances of 29%, 79% and 95.3% for < 0.5 D, 1.0 D and 2.0 D, respectively (76% of the patients in that study had ALs between ≥ 22 and < 24.5 mm).[9] Retzlaff et al used an unselected data set of 1,677 cases from multiple surgeons and reported variance rates of 48%, 77% and 96.4%,[12] whereas Hoffer published a case series of 450 unselected cases from a single surgeon with rates of 57%, 88% and 99%.[13] However, the variance of spherical equivalence is not directly comparable between our studies and the above-mentioned ones due to the different composition of ALs between the studies.

A significant number of patients (n = 36) were excluded from the study due to insufficient postoperative refractive data. These patients may represent a group who had good uncorrected postoperative VA and were satisfied with their vision without spectacles correction such that they did not require refraction to be performed. The accuracy of biometry using SRK II in predicting postoperative refractive error may have been underestimated in our study due to the exclusion of this group of patients with good postoperative visual outcome. Within the ALs of 22.52 mm and 24.43 mm in our study, we found that the longer AL eyes tend to have a refractive outcome more myopic than predicted and vice versa for the shorter AL eyes. This corresponded with our findings on the correlation between IOL power and prediction error. The longer AL eyes would require an IOL with less power. We did not find any correlation between prediction error and patient's age, mean K and preoperative corneal astigmatism.

We divided the patients into two groups based on the error of prediction. The high predictability group had 45 eyes with prediction error ≤ 0.5 D whereas the low predictability group had 55 eyes with prediction error > 0.5 D. A comparison of the various parameters was made between these two groups. There were no significant differences in the patient's age, gender, race or laterality of the operated eye between the two groups. It was also not shown to be surgeon dependent. The ALs, mean preoperative K, mean preoperative corneal astigmatism and IOL power were not statistically different in the two groups. In our study, the prediction error was less with SRK II formula when using the SI40NB silicone lens as compared to the MA60BM acrylic lens. However, it is difficult to draw a definite conclusion due to the small sample size in the SI40NB arm (n = 25) as compared to the MA60BM arm (n = 71). Overall, the sample size was rather small once sub-analysis was performed.

In our study, the applanation ultrasound biometry was performed by a team of technicians, and this could introduce some variability in the AL measurement. Furthermore, the ultrasound applanation method of measurement is liable to measurement error due to compression of the cornea, hence giving a shorter than true value of AL. A non-contact method for AL measurement, such as the use of partial optical coherence interferometry or immersion ultrasonography, may have been more accurate.(14-16) A comparison between pre- and postoperative AL and corneal K would have been useful as both these parameters were used in the SRK II calculation of IOL power. Analysing the difference in pre- and postoperative values will provide us with a clue of the likely source of error in calculation.

The A constant used in the SRK II formula calculation varies depending on the IOL used. It is a constant provided by the manufacturer of the lenses and is related to the anterior chamber depth (ACD) of that IOL in an average eye. The IOL position in the capsular bag varies depending on the IOL design and the angulation between its haptic and optic, hence the differing A constant for the different lenses. As the A constant is calculated based on an average eye, we would expect that as the AL moves towards the extreme of shorter or longer eyes, the A constant used would be inaccurate. In our correlation plot, we have also shown that the prediction error did increase as we moved towards the two extremes of the normal AL ranges. Newer formulae such as SRK/T, Holladay and Hoffer Q use an optimised ACD constant which has been reported to improve accuracy in very short and long AL eyes.(17,18) The newer formulae were not used in our retrospective study as SRK II has been shown in previous studies to be reliable for normal length eyes and was routinely used in our practice for this AL range.

In conclusion, the accuracy of SRK II in the prediction of refractive outcome in normal ALs as shown in our study was good and comparable with those found in the literature. There was a negative correlation between AL and prediction error even within the range of normal AL eyes. No difference was found in preoperative corneal astigmatism, mean K, AL, age or gender of the patient, laterality of the operated eye and IOL power between the low and high predictability groups.

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