Original Article

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# Prediction and Estimation of Postoperative Refractive Error in Phacoemulsification: Using Ultrasound A-Scan and Intra Ocular Lens Master

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## ABSTRACT

**Background:** This study aims to predict and estimate the postoperative refractive outcome in participants undergoing phacoemulsification using IOL Master and A-scan biometry.

**Methods:** A cross-sectional study was done where ninety eyes of 90 participants undergone phacoemulsification using SRK/T formula were included in longitudinal research. Each participant underwent axial length (AL) measurement by IOL Master and A-scan, and keratometry reading (k- reading) by manual TOPCON keratometer and automated keratometer on IOL master for IOL power calculation. All the pre-operative measurements between A-scan and IOL master and two keratometers were compared using paired-t tests. The four-week postoperative refractive error was estimated using univariate analysis and its prediction was compared with the ocular biometry parameters using quadratic regression.

**Results:** Preoperative findings were higher for AL and ACD by IOL master and A-scan (0.27±0.14mm; $p<0.001$, 0.14±0.31mm, $p<0.001$) respectively. The AL and K-reading were found to be strong predictors of IOL power calculation ($β$ = -1.07; $p<0.001$, $β$ = 0.75; $p<0.001$), respectively. The AL, K-reading were found to be strong predictors for four-week postoperative refractive error ($β$ = -1.563; p = 0.012, $β$ = 1.052; p = 0.012) where postoperative error was found to be higher (F = 7.521, $p<0.001$) in A-scan than IOL Master. For K-reading, the two keratometer's and for AL by A-scan and IOL Master's level of agreement (95% LoA) was comparable (-0.15 to 0.12mm and -0.01 to 0.54mm).

**Conclusions:** IOL Master is more reliable for ocular biometry and minimizes postoperative refractive error.

**Keywords:** Axial length; intraocular lens power; keratometry-reading; refractive error estimation; postoperative refractive error.

## INTRODUCTION

Accurate intraocular lens (IOL) power estimation is essential to minimize postoperative refractive error during cataract surgery.[1] Inaccurate AL calculations of 1mm lead to 2.8D postoperative error in 54% of cases.[2,3] The error in IOL power calculation between1.30D and1.60D, results in post-operative inaccuracy in each dioptre of keratometry.[4] Similarly, the A-scan is attributed for errors of 54% of the anticipated refractive error from AL, 8% from corneal power, and 38% from the prediction of postoperative ACD.[5] Optical biometry improves postoperative refraction by 16% on IOL power calculation.[6] For all these reasons, this study aimed to compare ocular biometry measurements by two methods in patients undergoing phacoemulsification to compare the effect on the accuracy of postoperative refractive error. To the best of our knowledge, there have been no reports regarding the postoperative refractive error prediction and variation in Nepalese eyes with Phacoemulsification surgery using A-scan and IOL Master.

## METHODS

A cross-sectional study was done where protocol registration number 19/2016 was used to obtain ethics approval for the study from the Institute of Medicine's Ethical Review Board. The research adhered to the principles outlined in the Declaration of Helsinki. After

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informed consent ninety consecutive participants over-40-year undergoing phacoemulsification were enrolled by using purposive sampling method in this prospective longitudinal study between November 2015 and October 2016. All the participants were recruited from the BPK Centre for Ophthalmic Studies, Institute of Medicine, Nepal. Participants with cataracts which could affect the IOL power measurement, IOL inserted on the ciliary sulcus, pre-operative corneal astigmatism greater than 3.00D, axial length less than 21mm and more than 26mm, refractive surgery, systemic complication affecting blood sugar level and high blood pressure during cataract surgery and participants unwilling to participate in the study were excluded.

The comprehensive eye examination was carried out which included intraocular pressure (IOP) measurement using a Goldmann-applanation tonometer, anterior segment examination with a slit lamp biomicroscope, and dilated fundus examination using a 90D lens (Volk, Japan). Each participant underwent an applanation ocular biometry using ultrasound A-scan (Quantel Medical Axis II PR, France) and an optical ocular biometry using an IOL Master (Carl Zeiss Meditec AG, Jena, Germany). Manual keratometry (Topcon Ophthalmometer, OM-4 class I, IEC601-I) was utilized to quantify corneal curvature in two primary meridians following the subjective alignment of the mires reflected from the central 3.4mm of the cornea utilizing the principle of reflection. The IOL power was calculated with an ultrasound A-scan using manual K-reading values that were acquired in the manual keratometer. Similarly, the IOL power was calculated automatically using the IOL master.

A-scan ultrasonography measures the intraocular distance between the internal limiting membrane and the anterior surface of the cornea using echo delay time with an accuracy of 100 to 200 µm and a longitudinal resolution of 200µm. In order to measure AL using A-scan, each eye of the participants must be anesthetized with a drop of topical anesthetic (4% xylocaine). The IOL master utilizes the principle of light reflection based on dual-beam partial coherence laser interferometry (PCI), which arranges six hexagon-shaped light points 2.3mm in diameter from the air/tear film interface to determine corneal surface curvature. IOL Master uses a fixation beam with a resolution of 12µm and precision of 5µm to measure the AL along the visual axis between the corneal vertex and the retinal pigment epithelium. After the modification of A-constant, Retzlaff and Kraff developed third-generation SRK/T formulae, where T stands for theoretical after empirically optimizing postoperative ACD prediction, retina thickness, AL correction factor and corneal refractive index. Using the SRK/T formula and A-constant of 118.0, the IOL power was computed in both ultrasound A-scan and IOL master. Subjective and objective refraction (Heine-Beta 200, Germany) were carried out preoperatively and after four weeks of cataract surgery.

The single optometrist measured each participant's biometrics and performed refractions of all the participants. The single senior experienced phaco and vitro-retinal surgeon performed phacoemulsification surgery with "Stop and Chop" techniques with foldable IOL in-the-bag implanted in the posterior capsular bag. The self-sealing 3.00mm superior temporal clear corneal incision was made during phacoemulsification surgery. Participants were reviewed first day, one week and four week after phacoemulsification surgery. All patients underwent uncorrected and best corrected visual acuity using Snellen's visual acuity chart. Objective refraction were performed in each visit and the refractive error were recorded in spherical equivalent. The confounding factors related to the accuracy of IOL power calculation included severity of nuclear sclerosis, preoperative refractive error and ACD were also investigated.

Patients were enrolled consecutively, and data were entered using statistical analyses with SPSS 25.0 (SPSS Inc., Chicago, IL). A statistically significant result was defined as $p<0.05$. The Shapiro-Wilk test was used to determine the normal distribution of all the parameters. A paired t-test was used to compare quantitative variables obtained from A-scan, manual keratometry and IOL master. The correlation between the manual keratometer and automated keratometer, and AL and ACD between A-scan and IOL Master was ascertained using Pearson's correlation at a 95% confidence level. A general linear model with a univariate analysis of variance was used to measure and predict postoperative refractive error. For IOL power and four weeks of postoperative refractive error, linear regression analysis was performed between predictors (K-reading and AL). Using the standardized coefficients (ß) with significance, an equation for the correlation between the variables was created. Bland-Altman plots were used to compare two devices in terms of AL agreement, where in mean differences were plotted against means, and a 95% limit of agreement (LoA) was utilized to assess potential bias between ultrasound A-scan and IOL master.

## RESULTS

Pre-operative evaluation for Phacoemulsification surgery was done in 90 subjects of 90 eyes, with mean age 68.61±8.5, having senile immature cataract where

41(45.00%) were taken for further analysis by IOL Master and 49(54.4%) by the A-scan. Among ninety participants enrolled in the study, 35(38.9%) were male and 55(61.1%) were female. Mean distant best corrected visual acuity by Snellen's fraction was converted into LogMAR units. The mean preoperative and postoperative best corrected visual acuity was 0.69±0.28LogMAR and 0.16±0.10LogMAR respectively. Maximum subjects had cataract of Nuclear Sclerosis(NSII), which was 23(25.6%). During cataract surgery, single surgeon selected for IOL power purposively and participants were divided into two groups: IOL Master (n = 41) and A-scan (n = 49). In the Shapiro-Wilk test, Keratometry-readings, ALs, ACD and IOL powers were distributed normally. **Table 1** summarizes the mean (95%CI) AL, ACD, and IOL power between A-scan and IOL master and keratometry reading between manual keratometer and IOL master, along with their 95% limit of agreement (LoA). For IOL Master ($R^2$ = 0.93; p<0.001) and A-scan ($R^2$ = 0.97; p<0.001), the coefficient of determinations was significant and predictable **(Table 2)**, suggesting AL and K-reading were the primary influencing factors for determining the postoperative refractive outcome. This study identified that IOL power calculation using A-scan had a higher predictability of postoperative refractive errors ($R^2$ = 0.297; p = 0.003) compared to that using IOL Master ($R^2$ = 0.125; p = 0.294) **(Table 3)**. Mean preoperative objective refractive error was -1.74±1.97D (range -6.00D to +4.25D). Participants in the IOL Master and A scan groups had similar estimation (p=0.809, p = 0.573) of four-week postoperative refractive errors of -0.74±0.55D and -0.74±0.06D, respectively **(Figure 1)**. The proportion of four weeks postoperative refractive error was in higher side and more myopic in participants using the ultrasound A-scan, compared with IOL master (**Table 4)**. This study found the spherical refractive error was more than astigmatism which reveal that the postop refractive error was more likely to be due to difference in IOL master and A-scan reading than site of incision. The quadratic regression showed that the four-week postoperative refractive error was noted significantly low (F = 1.135, p = 0.332) using IOL Master than using A-scan (F = 7.521, p = 0.001), even though IOL power being greater by 0.52D preoperatively with IOL Master **(Figure 2)**. **Figure 3** shows the 95% LoA for AL between IOL master and A-scan, which was -0.01 mm to 0.54mm and -0.15 mm to 0.12mm for both manual and automated K-reading.

**Table 1.Comparison of preoperative biometric features and limit of agreements (LoA) between ultrasound A-scan, manual keratometer and IOL Master.**

| | A-scan (n=90) [mean ± SD (95% CI)] | IOL Master (n=90) [mean ± SD (95% CI)] | Difference [mean ± SD (95% CI)] | p-value‡ | Pearson Correlation ( r) | 95%LoA |
|---|---|---|---|---|---|---|
| Axial length (mm) | 22.90±0.66 (21.47-24.65) | 23.16±0.67 (21.96-24.92) | 0.27±0.14 | <0.001 | 0.98 (p<0.001) | -0.01 to 0.54 |
| Keratometry[a] (mm) | 7.65±0.24 (7.15-8.19) | 7.64+0.25 (7.11-8.21) | -0.02±0.07 | 0.041 | 0.96 (p<0.001) | -0.15 to 0.12 |
| Anterior chamber depth(mm) | 2.91±0.43 (2.03-3.88) | 3.04±0.41 (2.04- 4.02) | 0.14±0.31 | <0.001 | 0.73 (p<0.001) | -0.45 to 0.74 |
| IOL power (D) | 21.36±1.90 (17.00-25.00) | 21.84±1.20 (17.00-25.50) | 0.48±0.64 | <0.001 | 0.95 (p<0.001) | -0.68 to 1.64 |

‡Mean difference using paired t-test, statistically significant at p<0.05 for 95% confidence interval.
SD = standard deviation, CI = confidence interval, mm = millimeter, D = Dioptre
[a]Mean keratometry reading obtained from an automatic keratometer in IOL Master, and a manual keratometer for ultrasound A-scan.

**Table 2. Regression between IOL master and ultrasound A-scan for preoperative keratometry-reading, axial length, anterior chamber depth.**

| Predictors | IOL master | | Ultrasound A-scan | |
|---|---|---|---|---|
| | Standardized Coefficients Beta (β) | p-value | Standardized Coefficients Beta (β) | p value |
| Preoperative mean keratometry[a] | 0.75 | <0.001* | 0.74 | <0.001* |
| Preoperative AL (mm) | -1.07 | <0.001* | -1.11 | <0.001* |
| Preoperative ACD (mm) | 0.01 | 0.64 | 0.39 | 0.24 |

Dependent Variable: Preoperative intraocular lens power calculation using IOL master and ultrasound A-scan, respectively;* Statistically significant at p<0.05 for 95% confidence interval

AL = axial length, ACD =anterior chamber depth, mm = millimeter

[a]Mean keratometry reading obtained from an automatic keratometer in IOL master, and a manual keratometer for ultrasound A-scan.

**Table 3. Regression between preoperative keratometry-reading, axial length, anterior chamber depth and intraocular lens power as a predictor of four weeks postoperative residual refractive error using IOL Master and ultrasound A-scan.**

| Predictors | IOL master | | Ultrasound A-scan | |
|---|---|---|---|---|
| | Standardized Coefficients Beta (β) | p-value | Standardized Coefficients Beta (β) | p-value |
| Preoperative mean keratometry[a] | 1.03 | 1.12 | 1.04 | 0.01* |
| Preoperative AL | -1.27 | 1.17 | -1.56 | 0.01* |
| Preoperative ACD | 0.28 | 0.11 | -1.15 | 0.37 |
| IOL power | -1.04 | 0.20 | -1.71 | 0.001* |

Dependent Variable: four weeks postoperative residual refractive error in which IOL power was selected from IOL master and ultrasound A-scan

* Statistical significant at p<0.05 for 95% confidence interval

[a]Mean keratometry reading obtained from an automatic keratometer in IOL Master and a manual keratometer for ultrasound A-scan.

**Table 4. Distribution of four week postoperative refractive error in participants with IOL master and A-scan group.**

| Range of SE | IOL master (n=41) | A-scan (n=49) |
|---|---|---|
| 0 to +0.50D | 1(2.4%) | 0(0.00%) |
| 0 to -0.50D | 10(24.4%) | 11(22.4%) |
| -0.55 to -1.00D | 27(65.9%) | 33(67.3%) |
| -1.25 to -1.50D | 3(7.3%) | 5(10.2%) |
| Abbereviation: D, diopter; n=number of eyes of participants; SE=spherical equivalent in Diopter | | |

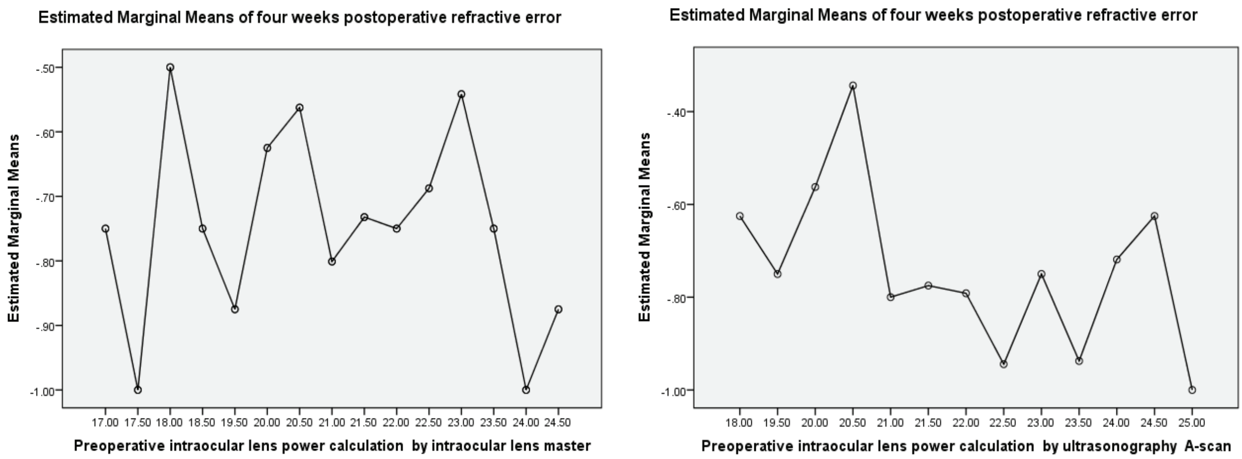


**Figure 1. Line plots showing the predicted residual refractive errors four weeks after cataract surgery and intraocular lens (IOL)power calculation for IOL master (F=0.639, p=0.81) and ultrasound A scan(F=0.88, p=0.57)**

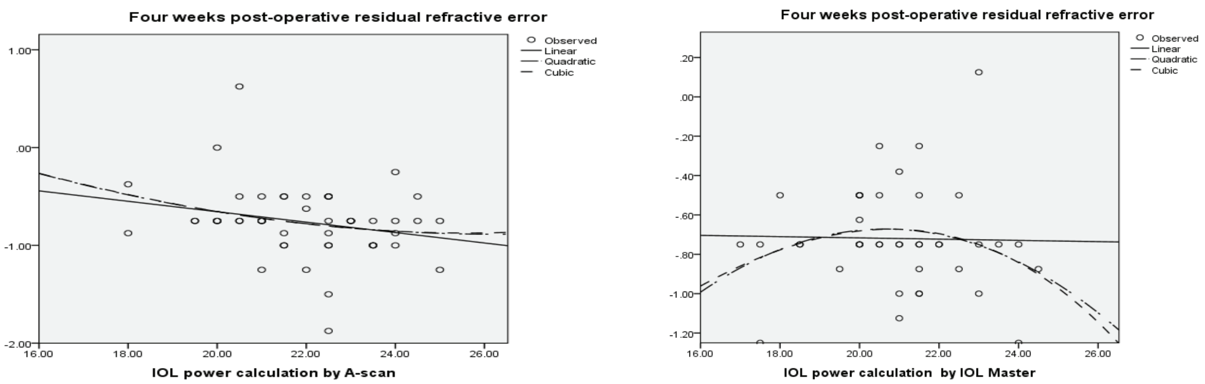


**Figure 2. Scatterplots showingquadratic regression between post-operative residual refractive errorsand intraocular lens (IOL) power calculations for ultrasund A scan (F=7.521, p<0.001) and IOL Master (F=1.135, p=0.332).**

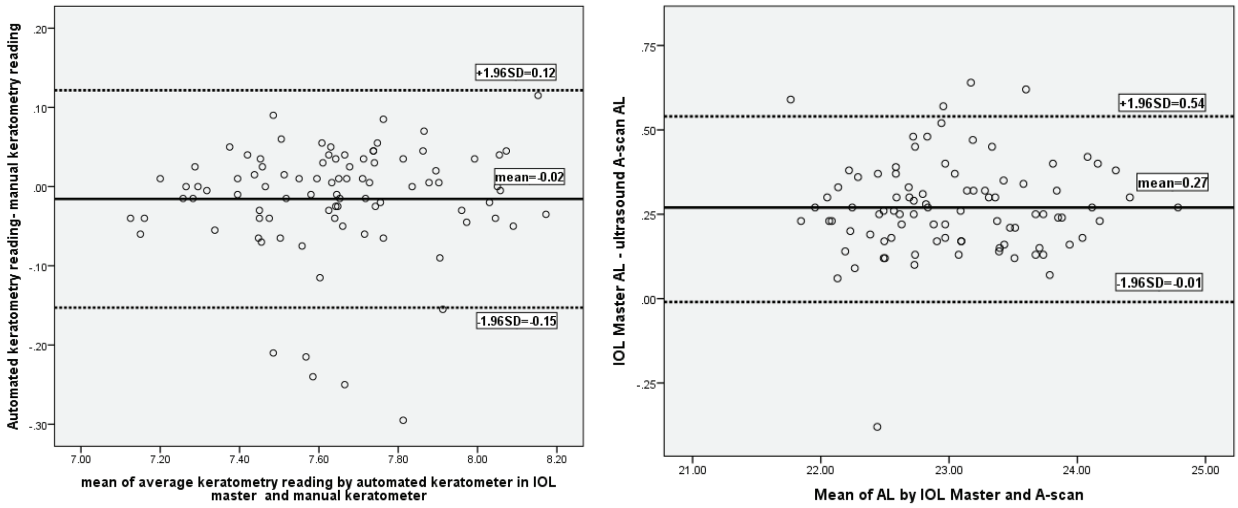


**Figure 3. Bland-Altman plot of axial length (AL) measurements using IOL master and ultrasound A-scan (95% LoA= 0.54 mm to -0.01mm) and keratometry-reading between manual keratometer for ultrasound A-scan and automated keratometer in IOL Master (95% LoA=-0.12mm to -0.15mm).**

## DISCUSSION

Accurate IOL power calculation and minimization of postoperative refractive error mainly depends on accurate measurement of AL, K-reading, IOL constant and assumed effective lens position.[7] Inaccurate prediction of lens position results in approximately 35% to 50% of the postoperative refractive error.[8] For every millimeter of measurement error in the anterior chamber depth (ACD), lead to the postoperative refraction is affected by approximately 1.0 D in myopic eyes, 1.50D in emmetropic eyes and 2.50D in hyperopic eyes. IOL master is the new technique for the ocular biometry measurements and IOL power calculation in clinical practice. This study compared validity and reliability of ocular biometry measurement between ultrasound A-scan and IOL master. In contrast to previous studies, this study used the IOL master and A-scan measurements as the basis to determine the IOL power, prediction and estimation of postoperative refractive error and variation of postoperative error based on K-reading and AL.

This study showed the good agreement for keratometry reading between manual keratometer and IOL master with a mean difference of -0.01±0.07mm. Previous studies also found a modest agreement of keratometry reading between automated and manual keratometer, with a mean difference of -0.02mm (95% confidence interval =-0.18 to +0.18mm).[9,10] The results may be due to manual keratometer have found to be measure steeper k-reading with greater variation than automated keratometer reading in IOL master. Manual keratometer assumes cornea is spherical around central 3.2mm zone and cannot determine as aspheric profile than IOL Master having central 2.3mm zone.[11] Similarly A-scan and IOL master showed good agreement for AL (mean difference 0.26±0.14mm) and the results were agreed with previous study where observed mean differences (0.56± 0.34mm; p<0.001) between A-scan and IOL master for AL was within the agreement range and varied from -0.09 to +0.69.[12-14] The reasons for good limit of agreement shown by IOL master and A-scan is may be due to cataract density. IOL master provides a good visualization image along the longitudinal scan, while A-scan provide an automatic tracing to ensure the ocular alignment fixation for AL measurement in immature cataract.[15,16]The K-reading difference between manual and automated keratometer and AL difference between A-scan and IOL master may be responsible for postoperative myopic error in higher proportion in participants with A-scan group than IOL master, and the study was also supported previously.[17] The postoperative refractive error within -1.00D and -1.50D were maximum in participants with A-scan than IOL master and the result was also supported previous study.[18-20] The lower proportion of postoperative error in IOL master group may be due to high resolution of IOL master and independent to operator bias.[21-27] In summary, this study has shown that biometry performed using the IOL master minimize the postoperative refractive outcome than A-scan. This study may be applicable in future research to compare postoperative refractive outcomes from biometry that has undergone optimization of A-constant in IOL master after refractive surgery. The limitation of this study was IOL Master could not take measurements in dense ocular media and the biometry in small, long eye was not considered in this study.

## CONCLUSIONS

The statistically significant differences in AL and K-reading for IOL power calculation signifies that values obtained by these different devices cannot be used interchangeably. IOL master have higher accuracy in IOL power calculation providing high resolution measurements and minimize the postoperative error.

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## CONFLICT OF INTEREST

There are no conflicts of interest.

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