Original Article

Comparison of applanation ultrasound biometry with optical biometry for intraocular lens power estimation in cataract surgery and their impact on prediction error

ABSTRACT

Aim: The aim of this study is to determine the agreement between applanation ultrasound biometry (AUB) and optical biometry using Lenstar 900 for precataract surgery axial length measurement and intraocular lens (IOL) power estimation and their effect on postoperative refractive outcomes. **Methods:** A case record-based retrospective study of 229 eyes which underwent phacoemulsification with foldable IOL, in a private hospital setting was done. All the eyes were evaluated using AUB and optical biometry for IOL power prediction. The IOL power was chosen based on the optical biometry and the final refraction was used to calculate the prediction error (PE) for both optical and ultrasound biometry. The concordance coefficient and Bland Altman's limits of agreement were determined to examine the disagreement between the two technologies. **Results:** The mean axial length ± standard deviation (SD) in the study eyes by ultrasound was 23.46 ± 1.01 mm and 23.57 ± 0.99 mm by optical biometry (P = 0.19). The axial length of 4.37% of eyes could not be measured by optical biometry. The mean IOL power prediction ± SD in the study eyes by ultrasound was 20.98 ± 2.68 D and 20.89 ± 2.85 D by optical biometry (P = 0.72). The mean ± SD absolute value of the refractive PE was 0.32 ± 0.44 D (median 0.25, interquartile range: 0.75–0). All eyes achieved a postoperative visual acuity of 6/18 or better including 204 (89.87%) that had a visual acuity of 6/6. One hundred and sixty-four eyes (71.62%) eyes had a postoperative spherical equivalent of 0 to ± 0.5D at 30 days. Two hundred and twenty eyes (96.07%) had a postoperative spherical equivalent of 0 to ± 1.0 D. **Conclusions:** The findings of the study prove that carefully done AUB is comparable to optical biometry and should not be a deterrent in providing the best possible refractive outcomes in a majority of our cataract patients. To ensure that these results are replicable on a wider scale will necessitate adequate training of personnel in the art and science of biometry.

Keywords: Intraocular lens power calculation, Lenstar 900, optical biometry, prediction error, ultrasound biometry

INTRODUCTION

Optical biometry and improved choices of formulas have changed cataract surgery from a predominantly sight-restoring surgery to a refractive surgery. However, refractive cataract surgeries are only a small proportion of the total cataract surgeries performed in India.[1,2]

A properly done ultrasound biometry provides good results with monofocal intraocular lenses (IOLs), which is the most frequently performed surgical procedure for sight restoration in age-related cataract.[2] Nearly 87% of patients can achieve a target postcataract surgery refraction within ± 1D, with proper selection of IOL power calculation formulas, good axial length measurements of the eye, and optimization of IOL constants.[3,4]

Norrby has previously reported on the influence of variability of input parameters on the refractive outcome and the final prediction error (PE).[5] Inaccuracies in axial

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length measurements can contribute up to 17% of the errors.[3,5] Optical biometry is the current gold standard for measuring axial length, however, a review of literature reveals that equivalence and not superiority has been established in most studies if actual visual outcomes are considered.[6,7] While this is true for eyes which fall within the normal range of anatomical parameters, eyes which are longer or shorter than normal do better with optical biometry, as do postrefractive surgery eyes and eyes with silicone oil.[8] Optical biometry has several disadvantages. About 10% to 15% of eyes cannot be measured with conventional partial coherence interferometry (PCI) technology[4,9] and about 2.42% of eyes cannot be measured due to dense opacities in the media even with the latest Swept-Source OCT-based biometers.[4] In addition to this, the cost of investment and maintenance of these machines are prohibitive and unaffordable for most hospital settings in India other than large corporate hospitals and Medical Colleges.

We designed a study to compare the concordance of optical coherence biometry (OCB) and contact or applanation ultrasound biometry (AUB) for the preoperative measurement of axial length and IOL power prediction before cataract surgery by phacoemulsification with foldable IOL implantation.

METHODS

The study protocol used a case record-based retrospective analysis that adhered to the tenets of the Declaration of Helsinki. The sample size for the study was estimated as 229 eyes based on a two-sided alpha of 0.05, a power of 90%, and a delta of 0.05. The case records of consecutive patients with age-related cataract who underwent standardized phacoemulsification with foldable IOL implantation by a single surgeon (MP) at the study institute between June 2019 and June 2020, were retrieved for the study. The study excluded patients with intra- or post-operative surgical complications, associated ocular pathologies such as zonular dialysis and posterior staphylomas, history of previous trauma or injuries to the eye, postrefractive surgery eyes, eyes with silicone oil, and patients requesting toric and multifocal IOLs.

All the patients were evaluated preoperatively by the surgeon MP. Preoperative assessment included uncorrected and best-corrected visual acuity, slit-lamp examination after dilatation of the eyes, IOP by applanation tonometry, and fundus evaluation with 90D lens. Biometry was done at least 2 days prior to surgery on pristine cornea before dilatation. Both AUB and OCB were performed by a single operator, the surgeon MP. The OCB was performed first followed by Manual Keratometry before instilling any drops in the eye. Following this, a drop of 0.5% proparacaine was instilled in the eye and AUB performed with special focus on the position of the probe in relation to the eye. Care was taken to align the probe with the visual axis. The output graph was given attention and only good quality scans were accepted for IOL power calculations. Optical biometry was performed using the Lenstar LS 900 (Haag Streit AG) following the manufacturer's recommendations. The Lenstar LS 900 is an optical biometer based on the principle of optical low coherence reflectometry. Manual keratometry was performed with the Appasamy Keratometer (Appasamy Associates, Chennai). AUB was done with the Echorule PRO Ultrasound Biometer (Biomedix Optotechnik and Devices, Bengaluru).

The target postoperative refractive status was emmetropia to −0.5 D myopia in all cases and the final IOL power selection was based on IOL power optimization and input from the optical biometer. The A Constant suggested by the IOL manufacturer was used to calculate the IOL power. The prediction by SRK/T formula was chosen as it is the most widely used IOL power estimation formula in practice today. Patients were operated by a 2.2 mm on axis limbal incision, 5 mm capsulorhexis, nucleus removal by phacoemulsification, and in the bag IOL implantation. Phacoemulsification was performed using catarhex phacoemulsification systems (Orteli. Switzerland). Three types of aspheric monofocal IOLs were used, Acrysof IQ (SN60WF), (Alcon, Fort Worth, TX. USA), Matrix Acrylic (403) (Medennium, Inc., Irvine California), and Technis (ZCB00) (Abbot Medical Optics, Illinois, USA).

Postoperatively, patients were examined at 1 day, 7 days, and 30 days after surgery. The objective refraction on the 13th day was collated from case sheets and converted to spherical equivalent for this study. The PE was calculated from the difference between the predicted refraction suggested by the instrument and the actual subjective postoperative refraction at 30 days.[10] The mean and median absolute value of the PE was estimated.

Lin's concordance correlation[11] coefficient for agreement on a continuous measure obtained by two persons or methods was used to determine the agreement between ultrasound and optical biometry for axial length and IOL power prediction. The concordance correlation coefficient combines measures of both precision and accuracy to determine how far the observed data deviates from the line of perfect concordance (i.e., the line at 45

degrees on a square scatterplot). Lin's coefficient increases in value as a function of the nearness of the data's reduced major axis to the line of perfect concordance (the accuracy of the data) and of the tightness of the data about its reduced major axis (the precision of the data). The Pearson correlation coefficient (r) is the measure of precision; the bias-correction factor is the measure of accuracy and the concordance correlation coefficient is expressed as the product of the measure of precision and the measure of accuracy. A concordance correlation coefficient <0.90 is considered as poor concordance, 0.90–0.95 as moderate, 0.95–0.99 as substantial, and 0.99 as almost perfect. The Bland and Altman's limits of agreement (LOA) were also determined to examine patterns of disagreement between the ultrasound and optical biometry measurements.[12] The correlation between difference and mean was also determined for the ultrasound and optical biometry measurements. A value near zero implies concordance.[13] The refractive PE was determined based on the postoperative spherical equivalent and the predicted spherical equivalent and the mean and median absolute value were estimated. At the study institute, the operating surgeon aims for a predicted spherical equivalent between 0 and −0.5D postoperatively and based it on the optical biometry measurements.

RESULTS

The study included 229 eyes that were assessed by ultrasound-based biometry and optical biometry. The mean age ± standard deviation (SD) of participants in the study was 66.30 ± 8.24 (median 67.00 years, interquartile range [IQR]: 61–72 years) and 116 (50.66%) were females. The study included 108 (47.16%) left eyes. The distribution of systemic and ocular comorbidity in the study population is presented in Table 1. Most of the operated eyes (n = 140, 61.14%) had a preoperative visual acuity of 6/24–6/60 [Table 2]. The mean axial length ± SD in the study eyes by ultrasound was 23.46 ± 1.01 mm and 23.57 ± 0.99 mm by optical biometry (P = 0.19). The axial length of 4.37% of eyes could not be measured by optical biometry and we used the axial length measured by US for further calculations. The mean IOL power prediction ± SD in the study eyes by ultrasound was 20.98 ± 2.68 D and 20.89 ± 2.85 D by optical biometry (P = 0.72). Table 3 presents the measure of concordance correlation coefficient for axial length and prediction of IOL power by ultrasound and optical biometry method in the study eyes. The concordance correlation coefficient of ultrasound and optical biometry for axial length and IOL power prediction was substantial for all preoperative visual acuity categories [Table 4]. The LOA, the mean difference, and the paired differences plotted against pair-wise means for axial length [Figure 1] and IOL power prediction was determined [Figure 2]. The mean ± SD absolute value of the refractive PE was −0.32 ± 0.44 D (median −0.25, IQR: −0.75–0). The mean ± SD absolute value of the refractive PE was −0.30 ± 0.48 D in the 54 study eyes with an axial length >24 and −0.34 ± 0.51D in the eight eyes with an axial length <22. All eyes achieved a postoperative visual acuity of 6/18 or better including 204 (89.87%) that had a visual acuity of 6/6. One hundred and sixty-four eyes (71.62%) eyes had a postoperative spherical equivalent of 0 to ± 0.5D at 30 days. Two hundred and twenty eyes (96.07%) had a postoperative spherical equivalent of 0 to ± 1.0 D. Sixty eyes (26.20%) had a postoperative spherical equivalent between −0.5D and −1.5D, and five (2.18%) eyes had a postoperative spherical equivalent between +0.5 D and +1.0D.

DISCUSSION

Cataract extraction with IOL implantation is the commonest surgical procedure performed in India. AUB is the most

Table 1: Systemic and ocular comorbidity in the study population

Comorbidity	*n* (%)
Diabetes	96 (41.92)
Hypertension	129 (56.33)
Thyroid disorders	33 (14.41)
Dyslipidaemia	87 (37.99)
Corneal disorders	7 (3.06)
Glaucoma	7 (3.05)
Retina	14 (6.11)

Table 2: Distribution of preoperative visual acuity in the study eyes

Preoperative visual acuity	*n* (%)
6/6-6/18	46 (20.09)
6/24-6/60	140 (61.14)
Worse than 6/60	43 (18.78)

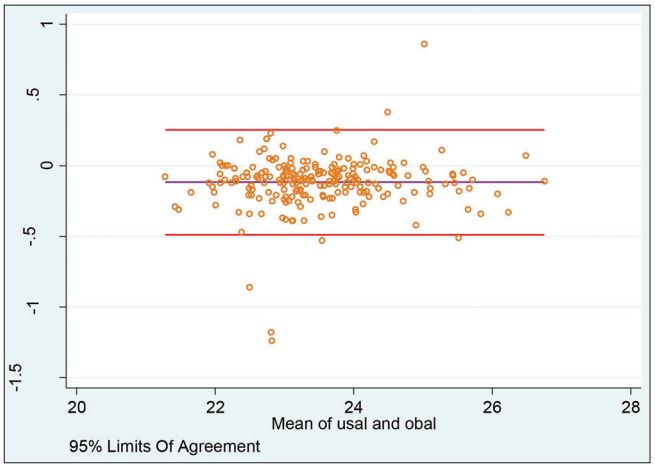

Figure 1: Limits of agreement between the ultrasound and optical biometry assessment of axial length

common technique used to measure the axial length of the eye for calculation of IOL power.[14] However, there is a general belief that optical biometry provides superior and more accurate IOL power prediction when compared to ultrasound biometry. Several studies have reported equivalence in postoperative refractive outcomes when the two technologies are compared.[7,15,16]

Previous studies have reported that optical biometry measurements cannot be estimated in approximately 10% of cases.[7,14] We could not measure the axial length using optical biometry in 4.37% of eyes in this study. The reason for this could be that dense cataracts were lesser in this study (preoperative visual acuity was <6/60 in 43 [18.78%] patients). Many of the studies comparing optical biometry with ultrasound biometry were designed to include only those cases in which optical biometry measurements were possible and this leads to a bias toward optical biometry.[15-17]

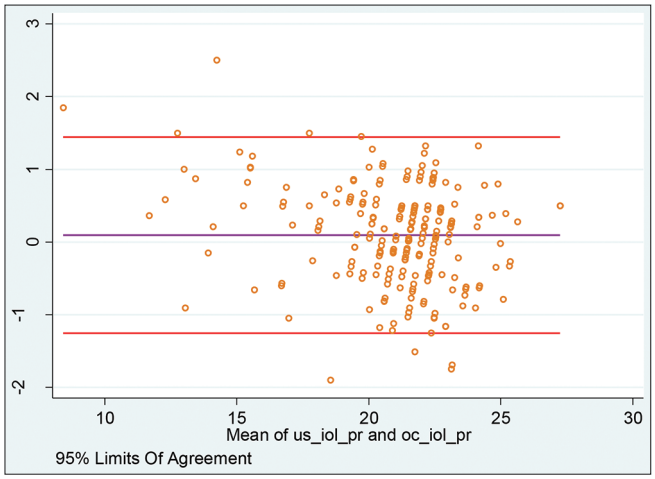

Figure 2: Limits of agreement between the ultrasound and optical biometry assessment of intraocular lens power prediction

This issue has been well documented by Raymond *et al.* who states that, "A group analysis that excludes PCI failures may cause serious bias and overestimate clinical effectiveness of the outcome measures."[7] The negative fallout of such a narrative is that ophthalmic centers are pushed into investing in a technology that does not offer tangible advantages for most patients compared to a tried and tested cheaper technology. The shift toward optical biometry has also led to laxity in training for good ultrasound A scan techniques, as the accuracy of A scan is highly dependent on obtaining a proper scan along the optical axis. A recent study that compared applanation biometry, immersion biometry, and optical biometry with IOL Master reported that only 46.4% of eyes were within ± 1 D with applanation biometry[18] and possibly demonstrates a lack of procedural or technical skill as all previous studies have shown far superior results in the range of 70.0% to 89.4%.[7,19]

The results of our study show comparable results for the measurement of axial length and IOL power calculation by ultrasound and optical biometry. The difference was not clinically significant as the effect of such a small difference (0.11 ± 0.02 mm) on IOL power calculation is negligible. Most (96.07%) of our patients achieved a postoperative spherical equivalent of 0 to ± 1.0 D and 71.62% achieved a spherical equivalent of 0 to ± 0.5 D. These results are comparable to outcomes in previous studies[7,19,20] and support the good postoperative results of both AUS and OCB in IOL power calculation.

Several studies have compared immersion ultrasound biometry with optical biometry and found that the results are comparable.[8,9,21] Immersion biometry has also been compared to contact biometry and found to have similar results in a study by Hennessy *et al*.[22] Immersion biometry is

Table 3: Concordance correlation coefficient for axial length and intraocular lens power prediction by ultrasound and optical biometry

	Axial length by ultrasound and optical biometry	IOL power by ultrasound and optical biometry
Pearson correlation coefficient	0.982	0.971
Bias correction factor	0.993	0.998
Concordance correlation factor (95% CI)	0.975 (0.969-0.982)	0.969 (0.961-0.976)
Bland-Altman 95% limits of agreement	−0.48 (0.22)	−1.256 (1.442)
Difference mean correlation	0.07	0.24

IOL – Intraocular lens, CI – Confidence interval

Table 4: Concordance correlation coefficient of ultrasound and optical biometry for axial length and intraocular lens power prediction by preoperative visual acuity

Preoperative visual acuity	Concordance correlation coefficient (95% CI)	
	Axial length	IOL power prediction
6/6-6/18	0.964 (0.943-0.983)	0.954 (0.928-0.980)
6/24-6/60	0.982 (0.976-0.988)	0.970 (0.961-0.980)
Worse than 6/60	0.959 (0.932-0.985)	0.970 (0.952-0.987)

IOL – Intraocular lens, CI – Confidence interval

theoretically more accurate but is rarely done due to technical difficulties in doing the procedure. It is also a messier process as it involves using a Prager shell filled with saline to be placed on the eye which is anesthetized prior to the procedure. Therefore, it was important to compare the commonly done contact or AUB with optical biometry to get a pragmatic idea of the real situation in clinical practice. Most studies were prospective with two cohorts assigned to either ultrasound biometry or optical biometry and doing a comparative study, instead of measuring the same eyes with both the technologies simultaneously.[7,15] This introduces avoidable errors and biases in patient selection and outcomes.[7]

The agreement between various types of optical biometry using different principles such as PCI, optical low-coherence interferometry, and swept-source OCT has been amply demonstrated by various studies.[4,19] Hence, it is reasonable to assume that the results of our study demonstrated with the Lenstar 900 can be extrapolated to other optical biometers with a similar degree of confidence. It is also interesting to note that unlike many studies we do not see significant difference in PEs between AUB and OCB in long and short eyes. However, as the number of cases of these outliers are less in this study, it may not feasible to draw definitive conclusions about these types of eyes without further research.

There is a definite space for optical biometry in the cataract surgery armamentarium, especially when dealing with postrefractive surgery eyes, premium IOLs, postvitrectomy, and silicone oil-filled eyes. However, to mandate the requirement of optical biometry for achieving good refractive results in all cataract surgery is not necessary. This is especially true in a country such as India where we have a wide range of clinical settings from the resource-poor rural hospitals which service a majority of our population to the large well-equipped hospitals in urban spaces. Wherever feasible it is advisable to have an optical biometer for IOL power calculations as inter-operator variability of these machines are minimal.[23] Hence, the major advantage is that resources spent on operator training can be minimized and hospitals with large turnover of patients will definitely benefit by giving consistent results with optical biometer. In contrast, the variability between an expert biometrist and a nonexpert operator in ultrasound biometry can be up to ten times when compared to optical biometry as shown by Goel *et al*.[24]

However, this cannot be a reason for poor refractive outcomes in cataract surgery for a large majority of our patients who do not have access to larger hospitals with the latest equipment. The reason for choosing ±1 D of postoperative PE as acceptable is because the patient can generally see well without glasses in this range. Anything beyond 2 D is a situation of unacceptable refractive error necessitating further interventions. An ultrasound biometer costs only one-tenth of the cost of an optical biometer and is invariably available in all types of surgical centers doing cataract surgery. Citing the lack of an optical biometer due to fiscal hurdles, for poor refractive outcomes cannot be acceptable in any kind of setting. This is what we have tried to demonstrate in this study. Giving sufficient training to optometrists and ophthalmologists to do a good ultrasound A scan can ensure that >90% of our patients achieve target refraction of ±1 D after cataract surgery. A system of performance audits and programs for skill enhancement training can optimize biometry results. Optical biometry will still be needed for patients with long or short eyes, postrefractive surgery eyes, and other situations listed earlier. Most of our towns and cities have multiple ophthalmic centers with this expensive equipment. A system of group practice or limited referral system can be arranged for patients for whom optical biometry is mandatory. However, the larger majority of patients can be managed efficiently with careful AUB.

The single operator measurements, surgery, and documentation are the strengths of this study. The retrospective nature of the study maybe considered a limitation. The surgeon was not masked to the results of the optical biometry and this may possibly have introduced a bias in the ultrasound measurements and the estimation of the final IOL power that was eventually used. The single center nature of the study can introduce selection bias and is another limitation. Further prospective studies from diverse medical settings can help to determine if the concordance between US biometry and optical biometry remains high in all situations.

CONCLUSIONS

This study has demonstrated the feasibility of achieving excellent postoperative refraction after cataract surgery using the IOL power predicted by optical biometry and ultrasound biometry. As the results from both technologies were closely matched, an argument for choosing ultrasound biometry without compromising on refractive outcomes can be made, especially for settings with fiscal disadvantages. However, it has to be emphasized that operators of ultrasound biometry have to be adequately trained and their performance periodically audited for optimum and consistent results.

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Conflicts of interest

There are no conflicts of interest.

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