Original Article

Comparative analysis of predictability and accuracy of American Society of Cataract and Refractive Surgery online calculator with Haigis-L formula in post-myopic laser-assisted *in-situ* keratomileusis refractive surgery eyes

Ramya Menon P, Madhu Shekhar, Sankarananthan R, Neha Agarwal, CA Dhanya, Hiruni K Wijesinghe[1]

Purpose: The aim of this study was to compare the predictability and accuracy of the American Society of Cataract and Refractive Surgery (ASCRS) online calculator with the Haigis-L formula for intraocular lens (IOL) power calculation in post myopic laser-assisted *in-situ* keratomileuses (LASIK) eyes undergoing cataract surgery and also to analyze the postoperative refractive outcome among the ASCRS average, maximum and minimum values. **Methods:** A retrospective study was conducted on post myopic LASIK eyes which underwent cataract surgery between June 2017 and December 2019. IOL power was calculated using both Haigis-L & ASCRS methods. Implanted IOL power was based on the ASCRS method. The expected postoperative refraction for IOL power based on the Haigis-L formula was calculated and compared with the Spherical Equivalent (SE) obtained from the patient's actual refraction. Prediction error (PE) & Mean Absolute Error (MAE) was calculated. Intragroup analysis of ASCRS values was done. **Results:** Among the 41 eyes analyzed, pre-operative and post-operative mean best-corrected visual acuity was 0.58 ± 0.21 and 0.15 ± 0.26 logMAR, respectively. In the ASCRS method, 36 (87.8%) and 40 (97.6%) eyes had PE within ± 0.5D and ± 1.0 D, respectively, whereas, in the Haigis-L method, 29 (70.7%) eyes, and 38 (92.7%) eyes had PE within ± 0.5D and ± 1.0 D, respectively. Among the ASCRS subgroups, ASCRS average, maximum and minimum values had 83%, 80.6%, and 48.8% eyes with SE within ± 0.5D, respectively. **Conclusion:** ASCRS method can be considered as an equally efficient method of IOL power calculation as the Haigis-L method in eyes which have undergone post myopic LASIK refractive surgery. ASCRS maximum & average values gave better emmetropic results.

Key words: ASCRS calculator, cataract, LASIK, post myopic refractive surgery

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Patients undergoing laser refractive corneal surgeries are increasing worldwide in their quest to achieve emmetropia. The majority of these patients develop cataracts later in life & they expect uncorrected emmetropic vision after cataract surgery. Commonly used Intraocular lens (IOL) power calculation formulae in eyes that have undergone previous myopic refractive surgery underestimate the IOL power resulting in postoperative unintentional hyperopia.[1] Thus, predicting an accurate IOL power in these eyes remains a challenge.

Laser *in-situ* keratomileuses (LASIK) is one of the widely performed types of refractive surgery. The two major sources of prediction errors in IOL power calculation after refractive surgery are altered keratometry values and error in the calculation of the estimated lens position (ELP) by the commonly used third and fourth-generation IOL power formulae.[1] These two errors are cumulative resulting in the high hyperopic surprises. Several studies have reported different methods to calculate IOL power for eyes that have undergone refractive surgeries. Methods that use pre-operative keratometry (K) & change in manifest refraction (ΔMR) are Clinical history, Feiz/Mannis & Corneal bypass method. Formulas using no previous data are Shammas L, Haigis L, Double K, Holladay 1, Barrett True K, etc.[2] Few popular methods include the Haigis-L method, the American Society of Cataract and Refractive Surgery (ASCRS) average method, and the clinical history method.[3]

Haigis L, a regression formula based on statistics, is a part of the built-in software of IOL Master. Corneal power is calculated by inputting IOL Master Biometry such as axial length (AXL), anterior chamber depth (ACD) & keratometry. It is one of the popular methods of IOL power calculation after refractive surgery. In this method, using an IOL Master 700, the corneal radius is measured in mm (r meas) and the Haigis-L algorithm generates a corrected corneal radius (r corr) from which average corneal power in keratometric diopters is derived, which is then used by the regular Haigis formula to calculate the IOL power.[4]

Department of Cataract and IOL Services, Aravind Eye Hospital, [1]Consultant in Glaucoma, Aravind Eye Hospital, Madurai, Tamil Nadu, India

Correspondence to: Dr. Madhu Shekhar, Cataract and IOL Services, Aravind Eye Hospital and Post Graduate Institute of Ophthalmology, Madurai - 625 020, Tamil Nadu, India. E-mail: madhushekhar93@gmail.com

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The ASCRS post-refractive IOL calculator is a free online calculator with 13 IOL power calculation methods for patients with prior myopic refractive surgery that enables to automatically generate a range of IOL power predictions by entering historical data (pre- and post- LASIK/photorefractive keratectomy (PRK) refraction), biometry measurements, and K measurements.[2,5] All calculator methods can be divided into 3 groups according to whether the refractive surgery data are known, partly known, or not known.[3] ASCRS calculator is available on the website of the ASCRS (http://iol.ascrs.org/). This online calculator has 3 modules: IOL power calculation for eyes with (a) previous myopic laser *in situ* keratomileuses (LASIK) or excimer laser photorefractive keratectomy (PRK), (b) with previous hyperopic LASIK or PRK, and (c) with previous radial keratotomy (RK).[6] This method uses various formulae incorporated in software like the Double-K method, Holladay 1, Shammas-PL, Haigis-L, OCT-based, and Barrett True K formula. IOL power is calculated for all these formulae from which it gives minimum, maximum, and average IOL power values. This calculator can be used even if only basic information like Keratometry readings, AXL, ACD, and Lens thickness (LT) are available.

It is difficult to arrive at a consensus regarding which formula to be chosen in order to get a better postoperative result. In our study, we retrospectively analyzed the post myopic LASIK eyes which had undergone cataract surgery in which the ASCRS online calculator was utilized for IOL power calculation & compared it with the Haigis-L method to evaluate the predictability and accuracy of the ASCRS calculator in assessing IOL power compared to Haigis-L.

We also performed an intra-group comparison among the ASCRS average, maximum, and minimum values available on an online calculator, to assess which value gave better post-operative refraction in post myopic LASIK eyes.

Methods

Patients

After obtaining ethical committee clearance, a retrospective study was conducted on post myopic LASIK corneal refractive surgery patients undergoing cataract surgery between June 2017 and December 2019 in tertiary eye care in South India. The study adhered to the tenets of the declaration of Helsinki. Data on demography, duration between refractive and cataract surgery, biometry, pre, and postoperative uncorrected, and best-corrected visual acuity were retrieved from electronic medical records. Forty-one eyes of 41 patients with a history of prior uneventful bilateral myopic LASIK corneal refractive surgery that have undergone uneventful phacoemulsification for immature cataract were included in the study. Unilateral corneal refractive surgeries, hyperopic corneal refractive surgeries, post-PRK/RK eyes, and patients with anisometropia were excluded from the study.

Methods of IOL power calculation:

Keratometry, axial length, anterior chamber depth, lens thickness, and white to white measurements were calculated using IOL Master 700 (Carl Zeiss Meditec AG, Jena, Germany). All these parameters, target refraction, A constant of the lens along with patients details were fed in an online ASCRS calculator which is available at http://iol.ascrs.org/.[6] The calculator uses various formulae and gives three values 1) Minimum IOL power, 2) Maximum IOL power and 3) Average IOL power.

IOL power was also calculated using the Haigis-L method. The decision for IOL power implantation was done by a single surgeon considering the ASCRS formula and Haigis-L method. All cases were performed by a single surgeon & had undergone temporal clear corneal phacoemulsification with 2.2 mm incision with implantation of foldable Alcon acrylic IOL Model No SA60AT or Aspheric IOL Model No SN60WF. Written informed consent was taken from all patients prior to surgery.

Refraction was performed on day one & one-month post-cataract surgery in all eyes. However, the refraction at one month was considered for analysis.[7,8]

Postoperative refraction (R) for a proposed IOL power (I) can be computed as given below:

If IOL power used (P) is greater than 14D, R = (P-I)/1.25.

If IOL power used (P) is less than 14D, R = P-I.[9]

According to this calculation, the expected post-operative refraction for IOL power based on the Haigis-L formula was calculated and this value was compared to the postoperative Spherical Equivalent (SE) obtained from the patient's actual refraction. The IOL power formula in which the patient had minus/myopic post-operative spherical equivalent was assumed to be a better option compared to those with hyperopic correction. The IOL prediction error was calculated as follows:

$\Delta R = Ractual - Rexp$

ΔR: IOL prediction arithmetic error

Ractual: Refractive error that was attained one month after cataract surgery, converted to spherical equivalent

Rexp: Expected refraction that was calculated by IOL calculation formula

The percentage of prediction refractive error within ± 0.5D and ± 1.0 D of the target was calculated. A high percentage of refractive error within ± 0.5D and ± 1.0 D means the calculation method has a high degree of accuracy. The effect of axial length on prediction error was also analyzed in eyes with axial length <26 mm and >26 mm.[10]

MAE was calculated for ASCRS & Haigis-L formula. The MAE was defined as the absolute value of the difference in the refractive error calculated as given below.[11]

$MAE = \Sigma |Ractual - Rexp| / n$

n: number of patients

An analysis of ASCRS minimum, maximum & average values given in the calculator was also done and the percentage of eyes with prediction error within ± 0.5D & ± 1D among these values was analyzed.

Statistical analysis

The normality of the data was checked using the Shapiro-Wilk test and box plot. Visual acuity (Snellen's equivalent) was converted into logMAR and mean & median logMAR visual acuity was presented. Wilcoxon sign rank test was used

to find out the significant difference between baseline and follow-up uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA). *P* value <0.05 considered as statistically significant. All statistical analysis was done by using statistical software STATA 14.0 (TX, USA).

Results

A total of 41 eyes of 41 patients were included in the study, among which 23 (56.10%) were males and 18 were females (43.90%) with a mean age of 47.97 ± 8.95 years. The mean duration between corneal refractive surgery for myopic correction and cataract surgery was 14.09 ± 5.37 years with a range of 4 to 25 years.

The mean K reading was 38.88 ± 2.05D which ranged from 35.23 D to 44.50D. The mean axial length was 28.02 ± 2.71 mm which showed a range of 23.40 mm to 34.93mm. The mean IOL power calculated by the Haigis-L method was 16.13 ± 5.11D ranging from 6.00 D to 24.50D. The mean IOL power calculated by the ASCRS method was 16.35 ± 4.84D ranging from 6.50 D to 24.00 D.

Mean preoperative and postoperative visual acuity (UCVA & BCVA) was measured in Snellen's chart and converted to logMAR. Nine patients (21.95%) had a logMAR visual acuity of less than 0.3 (Snellen VA <6/12). It was seen that the difference between the baseline and postoperative visual acuity was statistically significant with a *P* value of less than 0.001 [Table 1].

Post-operative spherical equivalent calculated based on 1-month post-operative refraction was analyzed for ASCRS & Haigis-L method. In the ASCRS method, 28 eyes (68.3%) attained a target refraction of zero, seven eyes (17.07%) had a myopic result & six eyes (14.63%) had a hyperopic result. In the Haigis-L method, 21 (51.22%) eyes had zero postop spherical equivalents, only one (2.44%) eye showed a myopic result & 19 (46.34%) eyes had a hyperopic result.

In the ASCRS method, 36 (87.8%) eyes had PE within ± 0.5D & 40 (97.6%) eyes within ± 1.0 D. In the Haigis-L method, 29 (70.7%) eyes had PE within ± 0.5D; 38 (92.7%) eyes within ± 1.0 D. The comparison of the prediction error of ASCRS and Haigis-L within the range ± 0.50 D & ± 1.00 D showed a *P* value of 0.217 and 0.175, respectively, which was not statistically significant. Only one patient (2.44%) had a postop spherical equivalent of -1.25D with the ASCRS method, whereas two patients (4.88%) had a postop refractive error above ± 1D in the Haigis-L method [Fig. 1].

Table 1: Baseline & post-operative uncorrected and best corrected visual acuity of 41 eyes

Visual Acuity	Mean (SD)	logMAR median (Snellen's VA)	IQR	*P*[S]
UCVA				
Baseline	1.13 (0.34)	1.08 (5/60)	0.60-1.78	<0.001
Post-op	0.22 (0.28)	0.18 (6/9)	0-0.48	
BCVA				
Baseline	0.58 (0.21)	0.60 (6/24)	0.30-0.78	<0.001
Post-op	0.15 (0.26)	0 (6/6)	0-0.48	

VA=visual acuity, UCVA:Uncorrected Visual Acuity, BCVA:Best Corrected Visual Acuity, *n*:number of eyes, SD:Standard deviation, IQR:Inter Quartile Range, S - Sign Rank test

In the eyes with axial length <26mm, the ASCRS, and Haigis-L method showed similar results with 10 eyes (24.4%) and 9 eyes (21.9%) with PE within ±0.5D and ±1 D, respectively, which was not statistically significant with a *P* value of 0.612. In the eyes with axial length >26 mm, in the ASCRS method 26 eyes (63.4%) and 30 eyes (73.2%) showed a PE within ±0.5D and ±1D, respectively. In the Haigis-L method, 20 eyes (48.8%) and 29 eyes (70.7%) showed a PE within ±0.5D and ±1D, respectively. The difference was not statistically significant with a *P* value of 0.18 in eyes with PE within ±0.5D and 0.15 in eyes with PE within ±1D.

MAE for ASCRS method was 0.04 ± 0.36 & for Haigis-L method was 0.33 ± 0.52 [Fig. 2]. There was no statistically significant difference in the MAE between the ASCRS & Haigis-L formula with a *P* value of 0.65. The median absolute error of the ASCRS method was zero with interquartile range (IQR) from -0.62 to 0.37 & Haigis-L was 0.29 with an IQR from -0.15 to 0.97.

In our study, 21 eyes had an implanted IOL power with ASCRS average value, 14 eyes with maximum value, and six eyes with minimum value. The prediction error of ASCRS minimum, maximum, and average values within ± 0.5D and ± 1.0D was calculated and is given in Fig. 3. The percentage of eyes who achieved emmetropic, myopic & hyperopic refraction among these three groups is represented in Fig. 4.

Discussion

Our study evaluated the accuracy & predictability of the ASCRS online calculator compared with the Haigis-L formula for calculating IOL power in post myopic LASIK patients. The majority of the patients had a postoperative visual acuity better than logMAR 0.3 (Snellen visual acuity >6/12). Nine patients fell short of this level of which one patient had Retinitis pigmentosa associated macular pathology. Two patients had myopic macular degeneration, of which one patient was status post scleral buckling surgery. Four patients had high myopia associated amblyopia. One patient had a residual spherical power of + 1.0D in which ASCRS minimum value was implanted. We could have avoided this hyperopic surprise if we had taken the ASCRS maximum value.

One month postoperative spherical equivalent evaluation showed that in the ASCRS method a greater number of patients (68.3%) achieved target refraction compared to the Haigis-L method (51.22%). In the ASCRS method, 17.07% of patients had a myopic tendency whereas, in the Haigis-L method, only 2.44% showed a myopic tendency. The hyperopic tendency was slightly higher in the Haigis-L method. MAE calculated for the ASCRS formula was found to be better than the Haigis-L formula. But the difference in MAE was not statistically significant. On analyzing the refractive outcome based on ASCRS average, minimum and maximum values, ASCRS maximum and average values gave a better post-operative emmetropic refraction. The hyperopic tendency was least with ASCRS maximum value in our study. The wide range of axial lengths did not appear to have a significant influence on the refractive prediction error of ASCRS and Haigis-L formula in our study.

IOL power calculation is a clinical challenge in patients who have undergone previous corneal refractive surgeries as there is

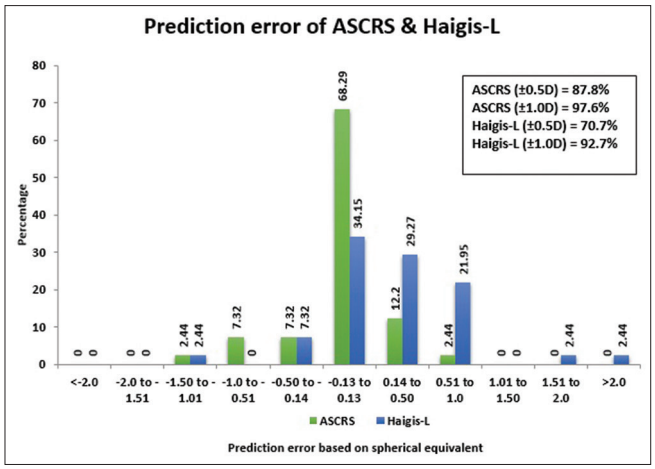

Figure 1: Prediction error of ASCRS & Haigis-L method

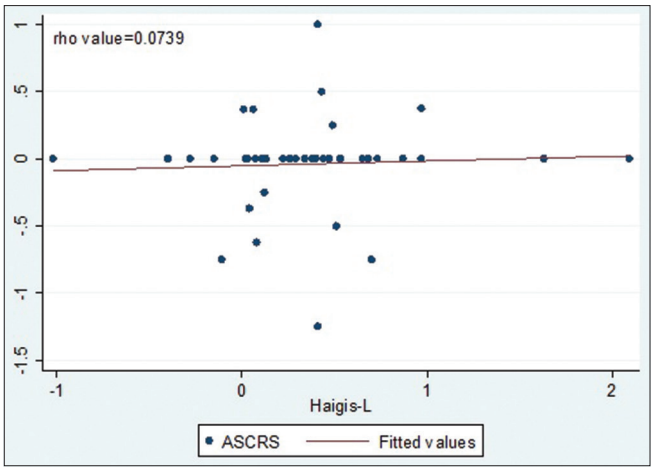

Figure 2: Scatter plot of MAE for ASCRS & Haigis-L methods

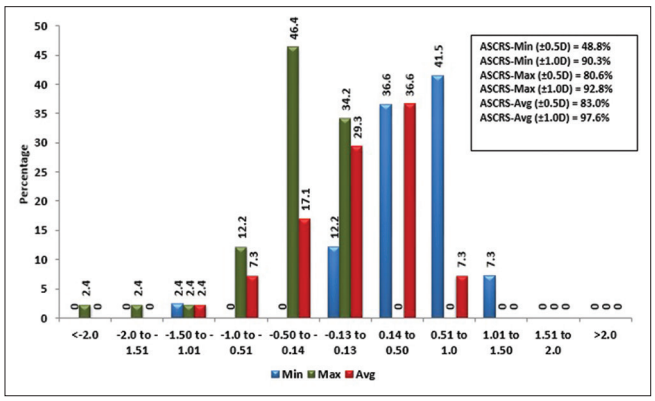

Figure 3: Prediction error of ASCRS minimum, maximum & average values

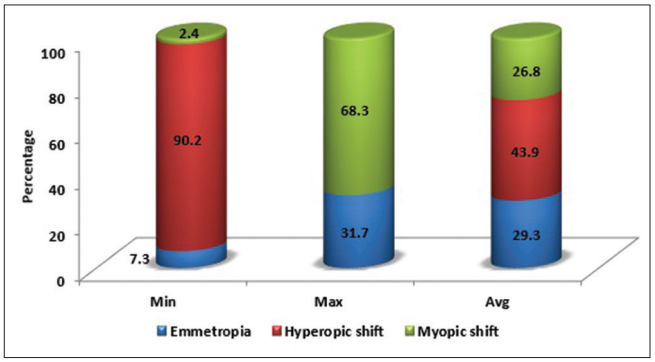

Figure 4: Refractive outcome of ASCRS average, maximum & minimum values

an increased risk of refractive surprises. Several strategies have been proposed to overcome the errors in IOL power calculations that can be grouped into five categories: (1) methods that require pre-refractive surgery data; (2) methods that calculate corneal power from post-refractive measurements; (3) using current corneal measurements with adjustment of IOL power; (4) direct measurements of the anterior and posterior cornea after refractive surgery; (5) intraoperative IOL power determination.[12]

In a meta-analysis done by Chen *et al*., Haigis-L was chosen as the control method to compare with other calculation combinations as Haigis-L is one of the most popular methods for IOL power calculation after refractive surgery. It is also the only method with a fixed combination that uses only 1 formula, the Haigis. In our study also we have considered the Haigis-L method as a control for comparison with the ASCRS method.[3]

Wang *et al*. evaluated the accuracy of various methods of IOL power prediction using the ASCRS IOL power calculator after previous myopic LASIK or PRK eyes.[13] They also evaluated the performance of the average (mean) IOL power displayed on the online IOL calculator & showed that the average method had the smallest absolute mean IOL prediction error, the smallest variance, and the highest percentage of eyes within ± 0.50 D of the refractive prediction error. In this study, percentage of eye with prediction error within ± 0.5D & ± 1.0D in ASCRS average method was 72% & 93%, respectively; in Haigis-L method it was 60% & 94%, respectively. Haigis *et al*. reported 61% of eyes with PE within ± 0.50 D and 84% within ± 1.00 D for Haigis-L formula.[4] A meta-analysis done by Li *et al*. showed that the percentage of refractive prediction error within ± 0.50 D calculated by Haigis-L was significantly lower than the ASCRS average whereas no statistically significant difference was found in PE within ± 1.0D.[1] Our study obtained a comparable or better result in comparison with these studies.

A study on comparison of intraocular lens power calculation methods after myopic laser refractive surgery without previous refractive surgery data done by Yang *et al*. showed that in ASCRS average method the PE within ± 0.5D was 45% & within ± 1.0D was 66% whereas in Haigis-L method PE within ± 0.5D was 40% & within ± 1.0D was 68%. They also showed that the ASCRS minimum method as a better choice in IOL power prediction in eyes without previous myopic laser surgery data.[14] In contrast to this, our study got a better IOL power prediction with ASCRS average and maximum methods.

In a study done by Tang *et al*., and OCT-based IOL formula was developed, and the MAE of postoperative refraction was compared with that for the Haigis-L formula.[15] They analyzed 16 patients, out of which 14 (87.5%) had prediction error within ± 0.1D. They also found that there was no statistically significant difference in the MAE between the OCT-based calculation and the Haigis-L formula similar to our study.

Most of the current studies have evaluated various methods of IOL power calculation in post-refractive surgery patients with the different formulae available in ASCRS.[3,11,13,14,16] In our study we evaluated the accuracy of IOL power predicted by the ASCRS online calculator with the Haigis-L formula instead of comparing individual formulae available in the ASCRS online calculator. Our study also throws light on which among the ASCRS minimum, maximum, average values would give a better post-operative refractive outcome in post myopic LASIK eyes.

The limitation of this study includes its retrospective design & small sample size. We excluded post-RK, PRK & hyperopic LASIK patients to avoid the introduction of confounding factors. We also limited the ASCRS true average value to that of Double K Holladay, Shammas-PL, Haigis-L, OCT-based, and Barrett True K No history methods instead of all the formulae available in the ASCRS calculator.

Conclusion

Our study showed that the ASCRS method of IOL power calculation can be considered as a better option or as an equally efficient method of IOL power calculation compared to Haigis-L in patients who have undergone myopic LASIK refractive procedure surgery and the results were satisfactory. Among the ASCRS minimum, maximum and average values, choosing the IOL power predicted by ASCRS maximum or average values resulted in the least refractive surprises whereas hyperopic tendency was more with the minimum value in post myopic LASIK eyes.

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Conflicts of interest

There are no conflicts of interest.

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