Intraocular Lens Power Calculation Using IOLMaster and Various Formulas in Short Eyes

Young Rae Roh¹, Sang Mok Lee¹, Young Keun Han¹, Mee Kum Kim¹, Won Ryang Wee¹, Jin Hak Lee¹

¹Department of Ophthalmology, Seoul National University College of Medicine, Seoul, Korea
²Department of Ophthalmology, Seoul National University Boramae Hospital, Seoul, Korea
³Department of Ophthalmology, The Armed Forces Capital Hospital, Seongnam, Korea
⁴Department of Ophthalmology, Seoul National University Bundang Hospital, Seongnam, Korea

Purpose: To evaluate the predictability of intraocular lens (IOL) power calculations using the IOLMaster and four different IOL power calculation formulas (Haigis, Hoffer Q, SRK II, and SRK/T) for cataract surgery in eyes with a short axial length (AL).

Methods: The present study was a retrospective comparative analysis which included 25 eyes with an AL shorter than 22.0 mm that underwent uneventful phacoemulsification with IOL implantation from July 2007 to December 2008 at Seoul National University Boramae Hospital. Preoperative AL and keratometric power were measured by the IOLMaster, and power of the implanted IOL was determined using Haigis, Hoffer Q, SRK II, and SRK/T formulas. Postoperative refractive errors two months after surgery were measured using automatic refracto-keratometry (Nidek) and were compared with the predicted postoperative power. The mean absolute error (MAE) was defined as the average of the absolute value of the difference between actual and predicted spherical equivalents of postoperative refractive error.

Results: The MAE was smallest with the Haigis formula (0.37 ± 0.26 diopter [D]), followed by those of SRK/T (0.53 ± 0.25 D), SRK II (0.56 ± 0.20 D), and Hoffer Q (0.62 ± 0.16 D) in 25 eyes with an AL shorter than 22.0 mm. The proportion with an absolute error (AE) of less than 1 D was greatest in the Haigis formula (96%), followed by those in the SRK II (88%), SRK-T (84%), and Hoffer Q (80%).

Conclusions: The MAE was less than 0.7 D and the proportion of AE less than 1 D was more than 80% in all formulas. The IOL power calculation using the Haigis formula showed the best results for postoperative power prediction in short eyes.

Key Words: Intraocular lens power calculation, IOLMaster, Short eyes
diction is due in part to the chosen formula, particularly in eyes with very long or very short AL [8,9].

The Haigis formula incorporated in the IOLMaster predicts effective lens position with improved ACD prediction algorithms and has shown more accurate IOL power prediction results, even in extreme eyes [8-10]. However, few reports have compared the accuracies of the various IOL power formulas for cataract surgery using partial coherence interferometry for eyes of short AL less than 22.0 mm.

The purpose of the present study was to evaluate the predictability of IOL power calculations using the IOLMaster and four different IOL power calculation formulas (Haigis, Hoffer Q, SRK II, and SRK/T) for cataract surgery in eyes with a short AL less than 22.0 mm.

Materials and Methods

The present study was a retrospective comparative analysis which included 25 eyes from 17 patients with an AL shorter than 22.0 mm and that underwent uneventful phacoemulsification with IOL implantation from July 2007 to December 2008. Preoperative AL, keratometric power, and ACD were measured by the IOLMaster version 3.01.0294. The power of the implanted IOL was determined using Haigis, Hoffer Q, SRK II, and SRK/T formulas calculated by the IOLMaster software. Postoperative refractive errors two months after cataract surgery were measured using automatic refracto-keratometry (RKT-7700; Nidek, Hiroishi, Japan) and were compared with the predicted postoperative power. The mean absolute error (MAE) was defined as the average of the absolute value of the differences between the actual and predicted spherical equivalents (SE) of the postoperative refractive error.

Cataract surgery was performed by two surgeons (YKH and SML). Topical anesthesia with proparacaine hydrochloride (Alcaine; Alcon Labs, Fort Worth, TX, USA) or subtenon anesthesia with 3% lidocaine was administered prior to the operation. A clear corneal incision 2.75 mm in width was made using a microkeratome at the superior or temporal cornea according to the axis of astigmatism, and phacoemulsification was performed after continuous curvilinear capsulorhexis. Three types of IOLs were used in the present study, Sensar® (AR40e; Abbott Medical Optics, Los Angeles, CA, USA; five eyes in three patients), Akreos-AO® (MI60; Bausch & Lomb, Rochester, NY, USA; ten eyes in seven patients), and Tecnis® (ZA9003, Abbott Medical Optics; ten eyes in seven patients); IOL was selected based on only the operation date and was not influenced by any other factors.

Cases were excluded if a posterior capsular rupture occurred during cataract surgery, if the IOL was inserted into the sulcus, or if the AL could not be measured using the IOLMaster. Also excluded from the present study were patients who could not be observed for at least two months after surgery.

The differences in the MAE according to the four IOL calculation formulas in the three IOL groups were analyzed. Furthermore, the proportions with absolute errors (AE) less than 0.5 dioptries (D) and 1 D of the four IOL calculation formulas were estimated.

SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The Mann-Whitney U-test was used to compare differences in the AEs of the formulas. The ANOVA test was used for comparison of the AEs of the formulas according to the type of IOL. A statistically significant difference was defined as a p-value <0.05.

Results

A total of 25 eyes from 17 patients were included in the present study. One patient (one eye) was male and 16 patients (24 eyes) were female. The mean age was 70.6 ± 5.5 years (range, 61 to 80 years), and the mean follow-up period was 53.40 ± 15.71 months. The mean AL was 21.60 ± 0.41 mm (range, 20.41 to 21.94 mm). The ACD was 2.70 ± 0.36 mm (range, 2.07 to 3.34 mm).

The constants applied in the four formulas of the IOLMaster in three IOL subtypes are shown in Table 1. The MAE was smallest in the Haigis formula (0.37 ± 0.26 D), followed by those of the SRK/T (0.53 ± 0.25 D), SRK II (0.56 ± 0.20 D), and Hoffer Q (0.62 ± 0.16 D) formulas (Fig. 1). The proportion of AE less than 0.5 D was greatest in the Haigis formula (76%), followed by those in the SRK II (60%), SRK-T (60%), and Hoffer Q (48%) formulas. Additionally, the proportion of AE less than 1 D was greatest in the Haigis formula (96%), followed by those in the SRK II (88%), SRK-T (84%), and Hoffer Q (80%) formulas (Fig. 2). No statistically

---

Table 1. The constants used in the four formulas of the IOLMaster in three intraocular lens (IOL) subtypes

|                  | AMO Sensar AR40E | B&L Akreos AO MI60 | AMO Tecnis ZA9003 |
|------------------|------------------|--------------------|-------------------|
| Haigis           |                  |                    |                   |
| ACD constant     | 5.21             | 4.96               | 5.58              |
| A0 constant      | -2.918           | 0.78               | -1.43             |
| A1 constant      | 0.097            | 0.4                | 0.28              |
| A2 constant      | 0.317            | 0.1                | 0.238             |
| Hoffer Q         |                  |                    |                   |
| pACD constant    | 5.42             | 5.02               | 5.58              |
| SRK/T            |                  |                    |                   |
| A constant       | 118.7            | 118.1              | 118.9             |
| SRK II           | 118.8            | 118.3              | 119.2             |

ACD = anterior chamber depth.
significant discrepancies were observed in AE among the different IOL calculation formulas, except between the Haigis and the SRK-II formulas ($p = 0.028$, Mann-Whitney $U$-test) (Table 2).

There were no statistically significant differences among the AEs of the three IOL groups according to ANOVA analysis ($p$-values, 0.116 for Haigis; 0.059 for Hoffer Q; 0.065 for SRK/T; 0.311 for SRK-II). A positive correlation between the AL and the preoperative ACD (Fig. 3) was revealed, al-

though the coefficient of determination was low (linear regression analysis, $R^2 = 0.428$).

Discussion

The IOLMaster used in the present study is adapted to a non-contact method known as partial coherence interferometry. This method has a higher resolution [11,12] and more reproducible measurements [13] compared with those of standard ultrasound transducers. However, the IOLMaster has several shortcomings, particularly in cases of mature or hypermature cataract, severe posterior capsular opacity, or a posterior segment abnormality, such as vitreous hemorrhage, because the AL is impossible to measure [5].

In the Haigis formula, the MAE was smallest and the proportion of AE less than 0.5 D or 1 D was greatest in the present study. Though the Haigis formula showed the best predictability, the SRK II, SRK/T, and Hoffer Q formulas also showed good prediction accuracies.

MAE is often used as an indicator for the IOL formula prediction accuracy; however, the MAE did not show a resulting direction (myopic or hyperopic). For the exact interpretation of the MAE result, predicted error (PE), which was back-calculated by subtracting the predicted SE from the postoperative SE, may be helpful where negative PE values indicate the tendency for myopic shifts, and vice versa. In the present study, PE showed several myopic shifts and was smallest in the Haigis formula (-0.21 ± 0.22 D), followed by those of the SRK II (-0.41 ± 0.28 D), SRK/T (-0.45 ± 0.28 D), and Hoffer Q (-0.59 ± 0.28 D) formulas (Fig. 4). Only the Hoffer Q formula showed a significant difference in PE compared with that of the Haigis formula ($p = 0.020$, Mann-Whitney $U$-test). MAE and PE results consistently showed that the Haigis formula was the most accurate of the four formulas in eyes with an AL shorter than 22.0 mm.

In the previous reports using partial coherence interferometry, Haigis and Hoffer Q formulas have been shown to
exercise analysis, $R^2 = 0.428$), consistent with a previous report however, the coefficient of determination is low (linear regression for the Haigis formula being considered the most precise among the various formulas. The MAE and PE of Hoffer Q were the largest among the four formulas in the present study, a result contrary to those of previous reports and the common belief the Hoffer Q is a relatively good IOL-predicting formula, especially in short eyes [10,14]. The authors of the present study could not determine the reason for the errors with the Hoffer Q formula. A possible explanation is the lack of individualization of IOL constants, a shortcoming of the present study, considering that the standard deviation of the PE of the Hoffer Q formula was no larger than those of the other formulas, except the Haigis formula.

The retrospective nature, a relatively small sample number, three different IOL types and IOL constants which did not consider surgeon factors were limitations in the present study. Nevertheless, the present study showed the results of IOL power prediction in short ALs using the IOLMaster and the Haigis formula as the most precise among the various IOL formulas, though there was only statistical difference in comparison with SRK II formulas. Additionally, the results showed that the MAE was less than 0.7 D, and the proportion of the AE less than 1.0 D was greater than 80% in all four formulas using the IOLMaster.

In conclusion, the IOL power calculation using the IOLMaster showed relatively good postoperative IOL power prediction.
in short eyes with the Haigis, the Hoffer Q, the SRK-T, and the SRK II formulas. The Haigis formula showed the best results for postoperative power prediction in short eyes in which AL was less than 22.0 mm.

**Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

**References**

1. Kershner RM. Sutureless one-handed intercapsular phacoemulsification. The keyhole technique. *J Cataract Refract Surg* 1991;17 Suppl:719-25.
2. Olsen T, Dam-Johansen M, Bek T, Hjortdal JO. Evaluating surgically induced astigmatism by Fourier analysis of corneal topography data. *J Cataract Refract Surg* 1996;22:318-23.
3. Olson RJ, Crandall AS. Prospective randomized comparison of phacoemulsification cataract surgery with a 3.2-mm vs a 5.5-mm sutureless incision. *Am J Ophthalmol* 1998;125:612-20.
4. Kohnen T. Multifocal IOL technology: a successful step on the journey toward presbyopia treatment. *J Cataract Refract Surg* 2008;34:2005.
5. Lee AC, Quazi MA, Pepose JS. Biometry and intraocular lens power calculation. *Curr Opin Ophthalmol* 2008;19:13-7.
6. Drexler W, Findl O, Menapace R, et al. Partial coherence interferometry: a novel approach to biometry in cataract surgery. *Am J Ophthalmol* 1998;126:524-34.
7. Holladay JT. Refractive power calculations for intraocular lenses in the phakic eye. *Am J Ophthalmol* 1993;116:63-6.
8. Olsen T. Improved accuracy of intraocular lens power calculation with the Zeiss IOLMaster. *Acta Ophthalmol Scand* 2007;85:84-7.
9. Wang JK, Hu CY, Chang SW. Intraocular lens power calculation using the IOLMaster and various formulas in eyes with long axial length. *J Cataract Refract Surg* 2008;34:262-7.
10. MacLaren RE, Natkunarajah M, Riaz Y, et al. Biometry and formula accuracy with intraocular lenses used for cataract surgery in extreme hyperopia. *Am J Ophthalmol* 2007;143:920-31.
11. Findl O, Drexler W, Menapace R, et al. High precision biometry of pseudophakic eyes using partial coherence interferometry. *J Cataract Refract Surg* 1998;24:1087-93.
12. Schachar RA, Levy NS, Bonney RC. Accuracy of intraocular lens powers calculated from A-scan biometry with the Echolurometer. *Ophthalmic Surg* 1980;11:856-8.
13. Connors R 3rd, Boseman P 3rd, Olson RJ. Accuracy and reproducibility of biometry using partial coherence interferometry. *J Cataract Refract Surg* 2002;28:235-8.
14. Gavin EA, Hammond CJ. Intraocular lens power calculation in short eyes. *Eye (Lond)* 2008;22:935-8.
15. Terzi E, Wang L, Kohnen T. Accuracy of modern intraocular lens power calculation formulas in refractive lens exchange for high myopia and high hyperopia. *J Cataract Refract Surg* 2009;35:1181-9.
16. Chen MJ, Liu YT, Tsai CC, et al. Relationship between central corneal thickness, refractive error, corneal curvature, anterior chamber depth and axial length. *J Chin Med Assoc* 2009;72:133-7.
17. Olsen T. Calculation of intraocular lens power: a review. *Acta Ophthalmol Scand* 2007;85:472-85.
18. Kim SM, Choi J, Choi S. Refractive predictability of partial coherence interferometry and factors that can affect it. *Korean J Ophthalmol* 2009;23:6-12.