Optimizing intraocular lens power calculations in eyes with axial lengths above 25.0 mm

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PURPOSE: To evaluate the accuracy of refractive prediction of 4 intraocular lens (IOL) power calculation formulas in eyes with axial length (AL) greater than 25.0 mm and to propose a method of optimizing AL to improve the accuracy.

SETTING: Cullen Eye Institute, Baylor College of Medicine, Houston, Texas, USA, and Department of Ophthalmology, Goethe University, Frankfurt am Main, Germany.

DESIGN: Case series.

METHODS: Refractive prediction errors with the Holladay 1, Haigis, SRK/T, and Hoffer Q formulas were evaluated in consecutive cases. Eyes were randomized to a group used to develop the method of optimizing AL by back-calculation or a group used for validation. Further validation was performed in 2 additional data sets.

RESULTS: The optimized AL values were highly correlated with the IOLMaster AL (R^2 from 0.960 to 0.976). In the validating group, the method of optimizing AL significantly reduced the mean numerical errors for IOLs greater than 5.00 diopters (D) from +0.27 to +0.68 D to −0.10 to −0.02 D and for IOLs of 5.00 D or less from +1.13 to +1.87 D to −0.21 to +0.01 D, respectively (all $P<.05$). In 2 additional validation data sets, this method significantly reduced the percentage of eyes that would be left hyperopic.

CONCLUSIONS: The proposed method of optimizing AL significantly reduced the percentage of long eyes with a hyperopic outcome. Updated optimizing AL formulas by combining all eyes from the 2 study centers are proposed.

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With current technology, for eyes with axial lengths (AL) from 22.0 to 25.0 mm, modern intraocular lens (IOL) power calculation formulas give accurate outcomes. However, for long eyes, current formulas tend to select IOLs of insufficient power, leaving patients with postoperative hyperopia.[1–6]

Inaccurate measurement of preoperative AL has been reported to be the main reason for postoperative refractive error in axial high myopia.[7] The incidence of posterior staphyloma increases with increasing AL. Ultrasonic biometric methods can produce errors in the presence of a posterior staphyloma by giving a falsely longer AL as a result of eccentric measurements to the depth of the staphyloma rather than to the fovea. Optical coherence biometry permits more accurate measurements when posterior staphylomata are present; because the patient fixates along the direction of the measuring beam, the instrument is more likely to display an accurate AL to the center of the macula. However, consistent hyperopic errors were reported across all 3 methods of biometry (A-scan, B-scan, and optical) in a study by MacLaren et al.[2] that evaluated the accuracy of biometry in eyes with

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negative-powered or zero-powered IOLs using the SRK/T formula. This indicates that eliminating or minimizing the adverse impact of posterior staphylomata on IOL calculations does not prevent hyperopic surprises in long eyes.

The purpose of this study was to evaluate the accuracy of refractive prediction of 4 IOL power calculation formulas (Holladay 1, Haigis, SRK/T, and Hoffer Q) in eyes with an AL greater than 25.0 mm and to propose a method of optimizing AL to improve the prediction accuracy.

PATIENTS AND METHODS

Patients

Institutional Review Board approval was obtained for this study. Consecutive cases with an AL of more than 25.0 mm that had cataract extraction and IOL implantation by the same surgeon (D.D.K.) at Cullen Eye Institute, Baylor College of Medicine, Houston, Texas, USA, from October 2002 to October 2005 were reviewed. The inclusion criteria were (1) implantation of an Acrysof SA60AT, Acrysof SN60AT, or Acrysof MA60MA posterior chamber IOL (all Alcon Laboratories, Inc.), (2) biometric measurements by partial coherence interferometry (IOLMaster, Carl Zeiss Meditec, Inc.), (3) no previous ocular surgery or intraoperative or postoperative complications, and (4) postoperative corrected distance visual acuity of 20/30 or better. All patients had phacoemulsification through a small temporal clear corneal incision (3.0 to 3.2 mm). The surgeon chose the power of the implanted IOL based on the Holladay 1 formula.

Evaluation of the Accuracy of Refractive Prediction Errors

Four IOL power calculation formulas (Holladay 1, Haigis, SRK/T, and Hoffer Q) were evaluated in this study. Refractive prediction error was calculated as the difference between the actual refractive outcome postoperatively and the predicted refraction (Actual refraction − Predicted refraction). A positive refractive prediction error indicates a hyperopic refractive outcome. To assess the extent of hyperopic refractive surprises in these eyes, the mean numerical error (MNE) and percentage of eyes with positive prediction error that would have left patients with postoperative hyperopic outcome were calculated for the 4 formulas. Postoperative refraction was obtained 3 weeks or more postoperatively.

To avoid the offset errors due to systematic errors in biometry, surgical technique, and/or the formula, lens constants in each formula were optimized retrospectively by obtaining an MNE of zero. Lens constants for the Holladay 1, SRK/T, and Hoffer Q formulas were optimized using the IOLMaster device. The 3 constants (a0, a1, and a2) of the Haigis formula were optimized using multiple regression analysis described by Haigis et al.[8] The mean absolute error (MAE) of the refractive prediction (Actual refraction − Predicted refraction) using the optimized constants was also calculated.

Developing the Method of Optimizing Axial Length

The eyes were randomized and divided into 2 groups. Group 1 was used to develop the method of optimizing AL, and Group 2 was used to validate the optimizing AL method.

For each eye with each IOL power calculation formula, the optimized or ideal AL using the manufacturer's lens constants, which produces a refractive prediction error of zero, was back-calculated. The rationale for using manufacturers' constants in method development is that they serve as standard lens constants for all surgeons. Regression analysis was used to assess the association between the optimized ALs and original IOLMaster ALs.

Validating the Method of Optimizing Axial Length

The accuracy of the method of optimizing AL was assessed in Group 2. Using the regression equations developed above for each eye with each IOL power calculation formula, the optimized AL was calculated and then used in each IOL power calculation formula to predict the refractive error. The MNE and MAE values using the optimized AL and manufacturer's constants were then calculated.

To determine whether the method of optimizing AL is better than the method of optimizing the lens constants with original IOLMaster AL, the MAE values using the optimized AL and manufacturer's lens constants were also compared with those using the IOLMaster AL and optimized lens constants.

Additional Validation of Method of Optimizing Axial Length

To evaluate the accuracy of the method of optimizing AL, 2 additional validating data sets were included.

Data Set from Another Center Consecutive cases with Acrysof MA60MA IOL implantation by the same surgeon (T.K.) from another center (Department of Ophthalmology, Johann Wolfgang Goethe University, Frankfurt am Main, Germany) were reviewed. Biometry was also performed with the IOLMaster device. All patients had uneventful refractive lens exchange using standard phacoemulsification through a 3.0 to 3.5 mm unsutured temporal or on-axis posterior limbal tunnel incision.

Recent Data Set from Cullen Eye Institute Consecutive cases with AL greater than 25.0 mm that had cataract extraction and IOL implantation by the same surgeon (D.D.K.) from November 2005 to April 2008 were reviewed.

Statistical Analysis

Because MAE values do not have normal distribution, log transformation of the MAE values was performed; the transformed values were used for statistical analysis. The Student *t* test was used to assess the differences of MNE and MAE in transformed log values between formulas and groups, and regression analysis was used to assess the association between the optimized ALs and the IOLMaster ALs. The chi-square test was performed to compare the number of eyes with hyperopic outcomes between groups. Bonferroni correction was used for multiple comparisons. All statistical analyses were performed using SPSS software (version 11.5, SPSS, Inc.); a *P* value less than 0.05 was considered statistically significant.

RESULTS

In the main data set used to develop and validate formulas, 94 eyes of 69 patients met the inclusion criteria. The mean age of the patients was 62 years ± 11 (SD) (range 34 to 88 years) (Table 1). Group 1 and Group 2 each comprised 47 eyes.