Original Article

Comparison of Hill Radial Basis Activation Function-2, Barrett Universal II, and Ladas Super Formula Intraocular Lens Power Calculation Formulas

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Abstract

Purpose: This study aimed to compare the predictability and accuracy of different formulas for calculating the power of Tecnis ZCB00 intraocular lenses (IOLs) in patients undergoing cataract surgery.
Patients and Methods: A retrospective comparative analysis was conducted at Basir Eye Clinic, Tehran, Iran, involving 491 eyes of 491 patients who underwent cataract surgery with Tecnis ZCB00 IOL insertion. Biometry data were entered into calculators for SRK/T, Hill Radial Basis Activation Function-2 (Hill RBF- 2), Barrett Universal II, and Ladas Super Formula. Tecnis ZCB00 IOL was implanted for all patients with the power calculated by SRK/T formula. The mean refractive prediction error was compared between Hill RBF- 2, Barrett Universal II, and Ladas Super Formula.
Results: The mean refractive prediction error when considering the IOL power calculations using the Ladas Super Formula, Hill RBF-2, and Barrett Universal II were 1.07 ± 1.11, 0.97 ± 0.82, 1.21 ± 1.04, respectively ($P < 0.01$). Also, there was a significant difference between the formulas when accessing patients with short axial length (worst results with Barrett Universal II, $P < 0.01$), medium axial length (best results with Hill RBF-2, $P < 0.01$) and long axial length (worst results with Barrett Universal II, $P < 0.01$).
Conclusion: For TECNIS® ZCB00 IOLs, the calculation of IOL power yielded the highest mean refractive prediction error with the Barrett Universal II formula.

Keywords: Intra Ocular Lens; Power Calculation; TECNIS® ZCB00; Cataract Surgery; Predictability; Accuracy.

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Introduction

Cataract, a leading cause of blindness, is a prevalent medical condition characterized by the opacity of the lens [1]. Surgical intervention is the primary treatment for cataract, involving the removal of the opaque lens and implantation of an intraocular lens (IOL) [2]. Globally, cataract surgery is the most commonly performed ophthalmic surgical procedure, with IOL insertion being performed in over 20 million surgeries a year worldwide [3].

To determine the appropriate IOL power for each patient, preoperative measurements of ocular characteristics such as eye length, anterior chamber depth, and the corneal radius are obtained through optometry [4]. These measurements are utilized in various formulas employed by surgeons to estimate the required IOL power [5]. Numerous efforts have been made to enhance the accuracy of the IOL power calculation, resulting in the development of newer generation formulas [6]. Despite these advancements, a consensus has yet to be reached regarding the most accurate formula for predicting the required IOL power, and different formulas are recommended in various studies [7].

The Sanders- Retzlaff- Kraff / Theoretical (SRK/T) formula, introduced in 1990, has been widely employed for predicting IOL power [8]. While it remains widely accepted and exhibits comparable prediction accuracy to other formulas, the SRK/T formula has demonstrated some non-physiological behaviors [9]. The Hill-Radial Basis Function (Hill-RBF) formula represents an alternative mathematical approach that predicts IOL power without involving the calculation of effective lens position (ELP) [10]. Fifth-generation formulas, such as the Barrett Universal II formula, incorporate additional parameters like corneal white-to-white (WTW) measurements into the ELP calculation [11].

In this study, our aim was to compare Hill RBF- 2, Barrett Universal II, and Ladas Super Formula when using TECNIS® ZCB00 Intraocular Lens implantation in cataract surgery. By determining the formula with superior predictive capabilities, we can enhance postoperative results and patient satisfaction.

Patients and Methods

Patients

This retrospective comparative analysis involved 491 eyes of 491 patients who underwent uneventful cataract surgery with implantation of a TECNIS® ZCB00 monofocal lens (Johnson & Johnson Surgical Vision, Irvine, CA) at Basir Eye Clinic, Tehran, Iran. Exclusion criteria included corrected distance visual acuity worse than 20/40, prior refractive surgery, and posterior capsule opacification.

The study protocol received approval from the institutional ethics committee, and it adhered to the clinical research standards outlined in the Declaration of Helsinki.

IOL calculation

All preoperative biometric measurements were made using the Zeiss IOLMaster® 700 version 1.90.12.05 (Carl Zeiss Meditec AG, Jana, Germany) and Lenstar® LS 900 version i9.6.3.0 (Haag-Streit, Koeniz, Switzerland). For all patients prior to their IOL implantation, biometry data were entered into calculators for SRK/T, Hill RBF-2, Barrett Universal II, and Ladas Super Formula. We used online calculators for the Hill RBF-2 formula, available at http://rbfcalculator.com/online/index.html, the Barrett Universal II formula, available at https://calc.apacrs.org/barrett_universal2105/, and the Ladas Super Formula, available at http://iolcalc.com/. Tecnis ZCB00 IOL was implanted for all patients with the power calculated by SRK/T formula. The recommended A-constant provided by each formula's website for the TECNIS® ZCB00 monofocal lens was utilized during calculations. If a formula required a K-index, a value of 1.3375 was used. Follow-up distance testing using a Snellen visual acuity chart was performed at 6 meters and the final postoperative manifest refractions according to distance testing were obtained. The refractive prediction error (difference between the predicted manifest refraction outcomes and the actual postoperative manifest refraction outcomes) were compared between Hill RBF- 2, Barrett Universal II, and Ladas Super Formula. To further analyze the results, we categorized the eyes into three groups based on their axial length: short (≤ 22.00 mm), medium (> 22.00 mm and < 25.00 mm), and long (≥ 25.00 mm).

Statistical analysis

Statistical analysis was performed using SPSS version 25 (Armonk, NY: IBM Corp.). A p-value of less than 0.05 was considered statistically significant. A repeated measures linear model was used to compare each pair of formulas in both the entire population and each subgroup. The Greenhouse-Geisser test of within-subjects effect was used to assess the overall significance of the differences among all formulas.

Results

A total of 491 eyes belonging to 491 patients who underwent cataract surgery with IOL insertion were included in this study (51.33% male, 48.67 % female) (Table 1). The mean age of the patients was 64.53 ± 10.8 years, all of whom were of Iranian ethnicity. There were 102 patients with short, 287 patients with medium, and 102 patients with long axial length.

Comparison of refractive prediction error in the entire axial length range

The mean actual refractive prediction error using SRK/T formula was 0.41 ± 0.41 diopters. The mean refractive prediction error when considering the IOL power calculations using Ladas Super Formula, Hill RBF-2, and Barrett Universal II were 1.07 ± 1.11, 0.97 ± 0.82, and 1.21 ± 1.04 diopters, respectively ($P < 0.01$) (Table 2).

Table 1: Demographic findings of patients evaluated in the study

Groups / Variable	Short axis (n = 102)	Medium axis (n = 287)	Long axis (n = 102)	Total
Sex (M/F)	42/60	153/134	44/58	239/252
Mean age	61.32 ± 9.5	62.78 ± 11.3	69.49 ± 11.6	64.53 ± 10.8
Axial length	21.90 ± 0.52	23.21 ± 0.40	24.89 ± 1.10	23.22 ± 1.16

Table 2: Comparison of the mean refractive prediction error between the different IOL power calculation formulas

Mean Absolute Error	LADAS	Hill-RBF	BARRET	P Value*
Total	1.07± 1.11	0.97 ± 0.82	1.21 ± 1.04	< 0.01
Short Axial Length	1.05 ± 0.10	1.04 ± 0.10	1.37 ± 0.14	< 0.01
Medium Axial Length	1.24 ± 0.07	0.960 ± 06	1.17 ± 0.07	< 0.01
Long Axial Length	1.28 ± 0.13	0.65 ± 0.06	0.64 ± 0.06	< 0.01

*Based on t test

Comparison of refractive prediction error for short axial length eyes

The mean refractive prediction error when considering the IOL power calculations using Ladas Super Formula, Hill RBF-2, and Barrett Universal II were 1.05 ± 0.10, 1.04 ± 0.10, and 1.37 ± 0.14, diopters, respectively (P < 0.01) (Table 2).

Comparison of refractive prediction error for medium axial length eyes

The mean refractive prediction error when considering the IOL power calculations using Ladas Super Formula, Hill RBF-2, and Barrett Universal II were 1.24 ± 0.07, 0.960 ± 0.06 and 1.17 ± 0.07 diopters for Ladas Super Formula, Hill RBF, and Barrett Universal II, respectively (P < 0.01) (Table 2).

Comparison of refractive prediction error for long axial length eyes

The mean refractive prediction error when considering the IOL power calculations using Ladas Super Formula, Hill RBF-2, and Barrett Universal II were 1.28 ± 0.13, 0.65 ± 0.06, and 0.64 ± 0.06 diopters for Ladas Super Formula, Hill RBF, and Barrett Universal II, respectively (P < 0.01) (Table 2).

Discussion

The first formula for calculating the power of intraocular lenses (IOLs) was described by Fedorov in 1967 [12,13]. Subsequently, newer formulas were developed to improve the accuracy of predicting refractive outcomes. However, despite these advancements, there is still no consensus on the most accurate formula for preoperative IOL power calculation [14].

The earlier, first-generation formulas relied on a single constant to predict the postoperative position of the IOL [6]. In contrast, the third and fourth generation formulas were developed with the aim of calculating the IOL position more accurately [15]. The third-generation formulas, such as Holladay 1, SRK/T, and Hoffer Q, incorporate keratometry values [16]. SRK/T, formulated by Retzlaff in 1990, is an example of a third-generation formula that takes into account the axial length and the corneal curvature radius [17]. On the other hand, fourth-generation formulas, including Holladay 2, incorporate additional factors such as lens thickness and corneal diameter [18]. In 2015, the LADAS super formula was published as a newer generation of formulas. It combines elements from various formulas,

including Hoffer Q, Holladay 1, Holladay 1 with Koch adjustment, Haigis, and SRK/T [19].
These different generations of formulas were selected in this study for comparison. The differences in the predictive accuracy of IOL calculation formulas can be influenced by various factors, including the type of intraocular lens (IOL) used. In our study, we used a single type of IOL for all the patients included. Using this single type of IOL, we observed that across the entire axial length range the difference in mean refractive prediction error when using Ladas Super Formula, Hill RBF-2, and Barrett Universal II was statistically significant with Barrett Universal II showing the highest mean error. This trend was consistent in eyes with a short and long axial length.
In contrast to our results in a recent study conducted by Roberts et al., [20] the authors evaluated the performance of the Holladay II, SRK/T, Barrett Universal II IOL, Hoffer Q and Hill RBF formulas in 400 patients. They reported that, compared to other IOL power calculation formulas across all axial lengths, the Barrett Universal II formula provided the lowest risk of refractive surprise (deviation of more than 1 diopter from the predicted error). Similarly, Kane et al., [21] reported that the Barrett Universal II formula was the most accurate predictor of postoperative refraction when compared to third and fourth generation formulas including Hill-RBF, FullMonte, Ladas Super Formula, and Holladay 1. Aristodemou et al., [22] conducted a study on a larger sample size of 8108 eyes and evaluated the optimized Hoffer Q, Holladay 1, and SRK/T formulas. They found that in long eyes, the SRK/T formula had the lowest mean refractive prediction error compared to the other formulas. However, for medium and short eyes, there were no statistically significant differences in mean refractive prediction error for axial lengths ranging from 21.50 to 23.49 mm [13].
The differences in results between studies can be attributed to variations in study design, patient populations, sample sizes, specific IOL types used, and other factors. Additionally, different studies may utilize different evaluation criteria and statistical analyses, which can contribute to variations in reported outcomes. These variations in results highlight the complex nature of IOL power calculations and the influence of different factors on predictive accuracy. It's important for surgeons to consider multiple factors, including patient characteristics, surgical techniques, and the specific type of IOL, when selecting the most appropriate formula for their practice.

Conclusion

For TECNIS® ZCB00 IOLs, the calculation of IOL power yielded the highest mean refractive prediction error with the Barrett Universal II formula.

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Footnotes and Financial Disclosures

Conflict of interest:

The authors have no conflict of interest with the subject matter of the present manuscript.