ORIGINAL ARTICLE

Comparison of different formulas in Panoptix intraocular lens power calculations using Pentacam Oculus AXL

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ABSTRACT

Purpose: To evaluate and compare the predictability of different formulas for multifocal intraocular lens (IOL) power calculation using a new optical biometer (Pentacam Oculus AXL).

Materials and Methods: This retrospective study included 70 eyes of 38 patients who underwent uneventful phacoemulsification with multifocal IOL (AcrySof IQ PanOptix) implantation. IOL power calculations were performed using Pentacam Oculus AXL optical biometer. Postoperative actual refractive errors and errors predicted by the Barrett Universal II, Olsen, SRK/T, Holladay 1, Hoffer Q and Haigis formulas were analyzed. The mean estimation error (EE), mean absolute estimation error (AEE) and the percentage of eyes within ±0.50 and ±1.00 D of target refraction of for each of six formulas were calculated and compared in three groups formed based on the axial length(AL) (Group 1: <22.5mm, Group 2: 22.5-24mm, Group 3: >24mm).

Results: In overall study group, the smallest mean AEE was provided by Barrett Universal II formula, with no statistically significant difference (p=0.23). The highest percentage of eyes within ±0.50 and ±1.00 D of target refraction was also found by using Barrett Universal II (78% and 95%). SRK/T provided smallest mean AEE for group 1(p=0.42). In Group 2, the smallest mean AEE was obtained by using Barrett Universal II (p=0.10). In group 3, Haigis provided smallest mean AEE (p=0.14).

Conclusions: Based on the Pentacam Oculus AXL biometric data, better results obtained using SRK/T formula in eyes with short AL. Barrett Universal II formula can be preferred in eyes with moderate AL, and Haigis formula in eyes with long AL.

Keywords: Pentacam Oculus AXL, axial length, multifocal IOL power, calculation formulas.

INTRODUCTION

The technological advancements in the field have elevated the postoperative refractive expectations of individuals undergoing cataract surgery. Hence, precise calculation of intraocular lens (IOL) power holds paramount significance in achieving the desired postoperative target refraction, thereby fulfilling patients' expectations of spectacle independence, including those related to presbyopia. To this end trifocal IOLs are used worldwide and satisfying results have been demonstrated.[1,2] One of them AcrySof IQ PanOptix TFNT0 IOL (Alcon Laboratories, Inc, Fort Worth, Texas, United States) is a non-apodized diffractive hydrophobic monoblock IOL with an ultraviolet filter and a bluelight filter.[3] Sustaining precision and uniformity in postoperative refractive outcomes necessitate continual dedication. In addition to advancements in surgical technology and the quality of intraocular lenses (IOLs), the selection of the IOL power formula stands out as another influential factor impacting refractive outcomes following implantation. The calculation of IOL power involves preoperative measurements such as keratometric (K) values, axial length (AL), and the A constant of the IOL.[4-6] IOL power is estimated by means of several formulas.[4-6] Latest formulas show similar refractive outcomes with average AL.[5,6] Nevertheless, in eyes characterized by either a short or long AL, the precision of these formulas may fluctuate,

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leading to deviations from the intended postoperative refractive target.[7,8] Formulas such as Holladay 1, Hoffer Q, SRK/T, calculates the estimated IOL power using AL, K value, and a constant as variables.[9] Latest formulas such as Olsen, Haigis and Barrett Universal II use additionally the anterior chamber depth (ACD).[10]

Researches have demonstrated that applanation and immersion ultrasound biometry may yield inaccurate axial length (AL) measurements, contingent upon globe compression and off-axis evaluation.[5-7] This issue has been mitigated with the advent of optical biometry, significantly reducing IOL power calculation challenges associated with AL measurement errors.[6] The Pentacam AXL (Oculus, Germany), introduced in 2018, represents a novel device incorporating optical biometry capabilities in addition to corneal measurements. Utilizing a combination of Scheimpflug camera and partial coherence interferometry, it facilitates AL measurements and IOL power calculation essential in cataract and refractive surgery. The device employs blue LEDs (475 nm, UV-free) as its light source.[11]

The aim of this study is to evaluate and compare the predictability and accuracy of six IOL power calculation formulas (Barrett Universal II, SRK/T, Holladay 1, Hoffer Q, Olsen Raytracing and Haigis) for trifocal IOL power calculation using the Pentacam AXL optical biometer.

MATERIALS AND METHODS

Subjects enrolled in this retrospective study were patients who underwent uneventful phacoemulsification (cataract or refractive lens exchange surgery) with panoptix IOL implantation at Ophthalmology Department of Bahçelievler Medipol Hospital, Istanbul, Turkey between June 15, 2022 and March 30, 2023. Surgeries were performed by the same surgeon (F.K.). The study was explained to each patient and written informed consent was obtained. The study project was approved by Institutional Ethical Board of Istanbul Medipol University. All research and data collection adhered to the tenets of the Declaration of Helsinki.

The study enrolled individuals with accurate Pentacam AXL biometry measurements of high quality and post-cataract surgery best-corrected visual acuities (BCVA) exceeding 20/40. Exclusion criteria comprised additional ocular pathologies aside from cataracts (e.g., corneal opacities, retinal pathology), a history of traumatic or uveitic cataracts, prior intraocular or corneal surgeries (e.g., refractive or glaucoma surgeries), intraoperative complications (e.g., anterior or posterior capsule ruptures, vitreous loss, or zonule dehiscence), and postoperative complications (e.g., tilted or decentrated intraocular lens). Patients with corneal astigmatism ≥ 1.25 were excluded, with a preference for toric trifocal intraocular lenses for such cases. The study also included patients with systemic diseases like diabetes or rheumatic diseases that do not induce complications in the anterior or posterior segment of the eye.

Preoperatively all patients had a complete examination including manifest refraction, BCVA testing, intraocular pressure (IOP) measurements with applanation tonometry, slit lamp, and dilated fundus examinations. Each patient underwent biometry measurement on Pentacam AXL optical biometer (Oculus, Germany) by the same examiner. After carefully positioning of patient, optical biometer was focused as determined by a clear view of anterior segment. IOL power was calculated using the Barrett Universal II, SRK/T, Holladay 1, Hoffer Q, Olsen Raytracing and Haigis formulas. The power of the implanted IOL was calculated by using the Barrett Universal II formula. The goal in IOL power selection was a value that would provide a postoperative refraction nearest to plano, staying on the side of myopia.

All phacoemulsification and intraocular lens (IOL) implantation procedures were uniformly conducted by the same surgeon (F.K.) under topical anesthesia, employing a consistent surgical technique and protocol. A standard phacoemulsification was executed through a 2.8 mm temporal clear corneal incision, and the monoblock foldable hydrophobic acrylic multifocal IOL (AcrySof IQ PanOptix TFNT0 IOL) was precisely inserted into the capsular bag using an injector system. By the end of first postoperative month, ophthalmological examination was carried out for all patients. Postoperative objective refractive error was measured by using Topcon KR 800 autorefractometer (Topcon, Tokyo, Japan). Uncorrected visual acuity (UCVA) and BCVA were also evaluated.

The estimation error (EE) was defined as the difference between the postoperative objective refractive error (spherical equivalent) and the preoperative refractive error predicted by the Pentacam AXL using different formulas (Barrett Universal II, SRK/T, Holladay 1, Hoffer Q, Olsen Raytracing and Haigis) for the power of IOL implanted. The absolute estimation error (AEE) was defined as the absolute value of the EE. For example, if postoperative objective error is -0.50 D and preoperative predicted error is -0.14 D, the EE is calculated as -0.50-(-0.14) = -0.36 D. The AEE (the absolute value of EE) is [-0.36] = 0.36 D.

Percentage of eyes within target refraction of ±0.50 D, and ±1.00 D were determined for each formula.

The Friedman Anova (Comparing Multiple Related Samples) test was used to evaluate differences in mean EE and mean AEE between six formulas in entire study group. This assessment was repeated also in three groups formed based on the axial length (AL) (Group 1: < 22.5 mm, Group 2: 22.5 – 24 mm, Group 3: > 24 mm). Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 12.0 (SPSS Inc, Chicago, Illinois, USA). *P* values <0.05 were considered to be statistically significant.

RESULTS

70 eyes of 38 patients were included in this study. The mean patient age was 64.3± 9.2 years (range, 44-76 years). The mean K value was 42.82 ± 1.72D (range, 40.22 - 46.43D). The mean AL was 23.5 ± 1.1 mm (range, 20.54 - 26.48 mm). Characteristics of patients are shown in Table 1.

Table1: *Characteristics of patients and preoperative measurements.*

Parameter	**Mean ± SD**	**Range**
Age, *years*	64.3 ± 9.2	44 -76
Sex, *n of patients (%)* Male Female	 21 (%55) 17 (%45)	–
Laterality, *n (%)* Right eye Left eye	 38 (%54) 32 (%46)	–
K value, *D*	42.82 ± 1.72	40.22 - 46.43
ACD, *mm*	3.18 ± 0.41	2.39 - 4.48
Axial length, *mm*	23.5 ± 1.1	20.54 - 26.48
IOL power, *D*	22.5 ± 3.01	11- 27.5

SD=standard deviation, K= mean corneal power, D= diopters, IOL= intraocular lens, ACD= anterior chamber depth

The results of overall study group (n=70) concerning the EE, AEE, and percentages of eyes within target refraction for six formulas are shown in Table 2. In overall study group, the smallest mean AEE was obtained by using Barrett Universal II formula (0.36 ± 0.30), however there was no statistically significant difference in the mean AEEs predicted by the six formulas (p=0.23). Regarding the comparison of mean EEs, mean EE predicted by Haigis was non-significantly higher than other formulas (p=0.12). There was no significant difference between the mean EEs of other formulas. The highest percentage of eyes within ± 0.50 and ± 1.00 D of target refraction was also found by using Barrett Universal II (78% and 95%).

In Group 1 (n=15), mean AL was 22.09 ± 0.48 mm (range, 20.42 - 22.43 mm). The results of this group are shown in Table 3. The smallest mean AEE was calculated by using SRK/T (0.45 ± 0.42) comparing with other six formulas, however the difference was not statistically significant (p=0.42). There was also no significant difference of mean EE between six formulas (p=0.18). The SRK/T and Hoffer Q predicted more eyes with EE within ±0.50 (80%) and SRK/T and Barrett Universal II predicted more eyes with EE within ±1.00 D of target refraction compared to other formulas (93%).

In Group 2 (n=39), mean AL was 23.16 ± 0.32 mm (range, 22.65 - 23.85 mm). The results of this group are presented in Table 4. The smallest mean AEE was obtained by using Barrett Universal II (0.37 ± 0.31). However, no significant difference of mean AEE was found between six formulas (p=0.21). There was also no significant difference of mean EE between six formulas (p=0.10). The Barrett Universal II formula predicted more eyes with EE within ±0.50 and ±1.00 D of target refraction when compared to other formulas (89% and 97%).

In Group 3 (n=16) mean AL was 24.72 ± 0.79 mm (range,

Table 2: *Comparison of mean absolute estimation error (AEE), estimation error (EE), and percentage of eyes within target refraction (EWTR) between five formulas in overall study group (n=70).*

	Barrett Universal II	**Olsen**	**Haigis**	**Hoffer Q**	**SRK/T**	**Holladay 1**	**P* value**
Mean AEE±SD (range), ***D***	0.36 ± 0.30 (0.04-1.77)	0.37 ± 0.32 (0.03-1.81)	0.44 ± 0.35 (0.02 - 1.73)	0.41± 0.34 (0.2 - 2.22)	0.41 ± 0.34 (0 - 1.87)	0.39 ± 0.33 (0.03-1.82)	0.23
Mean EE±SD (range), ***D***	0.06 ± 0.57 (-1.72 - 1.33)	0.07± 0.50 (-1.73 - 1.28)	0.09 ± 0.56 (-1.77 - 1.34)	0.07 ± 0.57 (-2.08 - 1.28)	0.08 ± 0.53 (-1.80 - 1.08)	0.07 ± 0.52 (-1.82 -1.1)	0.12
EWTR ±0.50 D*(%)*	78	77	77	72	72	75	
EWTR ±1.00 D *(%)*	95	92	88	90	92	92	

**The Friedman Anova (Comparing Multiple Related Samples) test.*

Table 3: *Comparison of mean absolute estimation error (AEE), estimation error (EE), and percentage of eyes within target refraction (EWTR) between five formulas in Group 1 (AL< 22.5 mm, n=15).*

	Barrett Universal II	Olsen	Haigis	Hoffer Q	SRK/T	Holladay 1	P value*
Mean AEE±SD (range), *D*	0.52 ± 0.48 (0.08 -2.08)	0.53 ± 0.55 (0.08 -2.03)	0.54 ± 0.43 (0.06 - 1.76)	0.49 ± 0.51 (0.06 – 1.93)	0.45 ± 0.42 (0.05 - 1.72)	0.47 ± 0.41 (0.07 - 1.85)	0.42
Mean EE±SD (range), *D*	-0.32 ±0.85 (-0.9 - 1.04)	-0.38 ±0.96 (-0.85-1.09)	-0.40 ± 1.1 (-1.16 – 1.18)	-0.28 ± 0.71 (-0.82 - 0.88)	-0.18 ± 0.62 (-0.54 – 0.82)	-0.21 ± 0.64 (-0.62 - 0.83)	0.18
EWTR ±0.50 D *(%)*	73	66	60	80	80	73	
EWTR ±1.00 D *(%)*	93	86	80	86	93	86	

* *The Friedman Anova (Comparing Multiple Related Samples) test.*

Table 4: *Comparison of mean absolute estimation error (AEE), estimation error (EE), and percentage of eyes within target refraction (EWTR) between five formulas in Group 2 (AL 22.5 - 24 mm, n=39).*

	Barrett Universal II	Olsen	Haigis	Hoffer Q	SRK/T	Holladay 1	P value*
Mean AEE ± SD (range), *D*	0.37 ± 0.31 (0.07 - 1.29)	0.41 ± 0.52 (0.08 - 1.37)	0.40 ± 0.34 (0.06 - 1.31)	0.44 ± 0.29 (0.08 - 1.27)	0.42 ± 0.25 (0 .1- 1.32)	0.41 ± 0,33 (0.06 - 1.35)	0.21
Mean EE ± SD (range), *D*	0.13 ± 0.49 (-0.73 - 1.32)	0.17 ± 0.34 (-0.74 - 1.29)	0.18 ± 0.43 (-0.78 - 1.42)	0.19 ± 0.45 (-0.88 - 1.44)	0.12 ± 0.18 (-0.80 - 1.37)	0.09 ± 0.15 (-0.76 - 1.46)	0.10
EWTR ± 0.50 D *(%)*	89	84	79	79	82	84	
EWTR ± 1.00 D *(%)*	97	92	89	87	89	92	

* *The Friedman Anova (Comparing Multiple Related Samples) test.*

24.13 - 26.82 mm). The results of this group are presented in Table 5. Although there was no significant difference of mean AEE between six formulas (p=0.14), the smallest mean AEE was calculated by using Haigis (0.28 ± 0.29). Regarding the comparison of mean EEs, there was no significant difference between the mean EEs of six formulas (p=0.16). The highest percentage of eyes within ±0,50 was found by using Haigis (87%) and ±1,00 D of target refraction was also found by using Barrett Universal II, Haigis, Hoffer Q and SRK/T (100%).

DISCUSSION

Achieving the desired refractive target is achievable through the selection of an appropriate lens diopter based on biometric formulas. The Alcon Acrysof IQ PanOptix lenses are frequently employed for this purpose. Careful evaluation of the accuracy of each biometric formula specific to this lens type is crucial to prevent refractive deviations, taking into account both patient expectations and the high cost of lenses.

Table 5: *Comparison of mean absolute estimation error (AEE), estimation error (EE), and percentage of eyes within target refraction (EWTR) between five formulas in Group 3 (AL > 24 mm, n=16)*

	Barrett Universal II	Olsen	Haigis	Hoffer Q	SRK/T	Holladay 1	P value*
Mean AEE ± SD (range), *D*	0.29 ± 0.44 (0.04 - 0.87)	0.36 ± 0.45 (0.05 - 0.97)	0.28 ± 0.29 (0.04 - 0.78)	0.38 ± 0.61 (0.08 - 0.85)	0.33 ± 0.14 (0.09 - 0.91)	0.39 ± 0.26 (0.08 - 0.93)	0.14
Mean EE ± SD (range), *D*	-0.1 ± 0.45 (-0.52 - 0.88)	0.12 ± 0.42 (-0.77 - 0.78)	0.04 ± 0.42 (-0.63 - 0.78)	0.18 ± 0.51 (-0.79 - 0.79)	-0.05 ± 0.35 (-0.60 - 0.81)	0.25 ± 0.59 (-0.59 – 0.92)	0.16
EWTR ± 0.50 D *(%)*	81	81	87	75	81	75	
EWTR ± 1.00 D *(%)*	100	93	100	100	100	93	

* *The Friedman Anova (Comparing Multiple Related Samples) test.*

No studies have been found to date that compare the accuracy of formulas in calculating intraocular lens (IOL) power for AcrySof IQ PanOptix IOLs using Pentacam Oculus AXL. This study evaluated six widely used and previously examined formulas, including Barrett Universal II, Olsen, Haigis, Hoffer Q, SRK/T, and Holladay 1.

The estimation error (EE) defines what extent the postoperative refraction is more hyperopic or myopic than predicted.[12] To compare the differences in the absolute estimation error (AEE) between formulas is simple, efficient, and less affected by outliers.[13] Percentages of eyes within prediction errors of ±0.50 D, ±1.00 D, are clinically important and might give a prediction about the patients' satisfaction.[14] We used these four parameters to compare and evaluate six formulas accuracy calculated by Pentacam AXL. Hayashi et al. reported that, although emmetropia is the primary target, slight myopia is a better refractive target than slight hyperopia.[15] Similarly, in our study, IOL power selection for refractive target was a value that would provide a postoperative refraction nearest to plano, staying on the side of myopia.

Achieving emmetropia is notably challenging in eyes with a shorter AL. In hyperopic eyes, the preferred centration axis for devices like trifocal intraocular lenses (IOLs), which is crucial for optimal centralization, was reported to be located inferonasally compared to eyes with a longer AL.[16,17] Multifocal lenses must be centered as closely as possible guided by pupil to present balanced light.[17] Aristodemou notified that; The accuracy of the IOL formulas has been troublesome, because of short distance between IOL and fovea.[12] Different studies reported different formulas to be optimal in short eyes. Hoffer Q,[18] Holladay 1[18,19] and Barrett Universal II[20] were reported to be the best formula in short eyes. Choi et al. reported that Holladay 1 and Hoffer Q showed better performance in short group.[21] Consistent with Eom et al.[22] they analyzed that shorter AL was associated with poor performance of the Barrett Unniversal II. Barrett Universal II uses extra input variables such as ACD, lens thickness and white to white, which represent anterior segment characteristics addition to AL and K. These anterior segment values are disproportional to the AL in small eyes when compared to eyes with normal AL. This disproportionality may cause inaccurate calculation of IOL power and inaccurate prediction when Barrett Universal II is used in short eyes. In our study, in short eyes (AL<22.5 mm) the smallest mean AEE was obtained by using SRK/T formula (0.45±0.42) compared to other formulas, however there was no statistically significant difference.

There are too many studies comparing formulas for IOL calculation in eyes with average AL or when evaluating overall eyes. Choi et al.[21] reported that Barrett Universal II was presenting the best results in overall eyes consistent with previous studies.[20,23,24] There are several other studies comparing accuracy of Barrett Universal II with other formulas and they concluded that, this formula was better for all types of eyes.[20,25] Cooke and Cooke, Kane et al. and Shajari et al. also reported that Barrett Universal II resulted in the lowest AEE in overall or eyes with average AL.[12,19,23]

Kane et al. identified Barrett Universal as having the highest percentage of eyes within ±0.50 D, and Shajari et al. reported Barrett Universal II as the most effective formula for eyes with intermediate axial length based on the mean of AEE.[19,23] Lawless et al. obtained better results by using Barrett Universal II rather than those with the Haigis.[26] Although there was no significant difference, in our study the smallest mean AEE was obtained by using Barrett Universal II (0.37 ± 0.31). The Barrett Universal II formula predicted more eyes with EE within ±0.50 and ±1.00 D of target refraction when compared to other formulas (89% and 97%).

Zhu et al. put forth inferior decentration of multifocal IOLs in myopic eyes.[27] They indicated the increasing discordance between IOL and capsular bag size. Several studies reported Barrett Universal II to have more accuracy than other formulas in myopic eyes.[28,29] Two other studies evaluating the accuracy of new generation formulas also reported that performance of Barret Universal II was more satisfying than other formulas.[30,31] In our study, although there was no significant difference of mean AEE between six formulas, the smallest mean AEE was calculated by using Haigis (0.28 ± 0.29) in eyes with long AL and Barrett Universal II was the second (0.29 ± 0.44). The highest percentage of eyes within ±0,50 was found by using Haigis (87%) and ±1,00 D of target refraction was also found by using Barrett Universal II, Haigis, Hoffer Q and SRK/T (100%).

In conclusion, the Pentacam Oculus AXL optical biometer yields satisfactory refractive outcomes for Multifocal IOL calculation. While the mean AEE difference among the six formulas did not reach statistical significance, our study suggests a preference for the Barrett Universal II formula in eyes with moderate axial length based on the Pentacam Oculus AXL biometric data. Additionally, optimal outcomes may be achieved using the SRK/T formula for eyes with short axial length and the Haigis formula for eyes with longer axial length.

This study has limitations, including a small sample size of patients with short or long axial length (AL), a restricted follow-up duration, and potential biases associated with the retrospective design. Improved outcomes could be achieved through an expanded cohort of patients and a more extended follow-up period

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