Int J Ophthalmol, Vol. 12, No. 6, Jun.18, 2019 www.ijo.cn
Tel: 8629-82245172 8629-82210956 Email: ijopress@163.com

· Clinical Research ·

Effect of lens constants optimization on the accuracy of intraocular lens power calculation formulas for highly myopic eyes

Jia-Qing Zhang, Xu-Yuan Zou, Dan-Ying Zheng, Wei-Rong Chen, Ao Sun, Li-Xia Luo

State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou 510060, Guangdong Province, China

Correspondence to: Li-Xia Luo. State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou 510060, Guangdong Province, China. luolixia@mail.sysu.edu.cn

Received: 2018-07-21 Accepted: 2018-11-30

Abstract

● AIM: To evaluate the effect of different lens constant optimization methods on the accuracy of intraocular lens (IOL) power calculation formulas for highly myopic eyes.

● METHODS: This study comprised 108 eyes of 94 consecutive patients with axial length (AL) over 26 mm undergoing phacoemulsification and implantation of a Rayner (Hove, UK) 920H IOL. Formulas were evaluated using the following lens constants: manufacturer's lens constant, User Group for Laser Interference Biometry (ULIB) constant, and optimized constant for long eyes. Results were compared with Barrett Universal II formula, original Wang-Koch AL adjustment method, and modified Wang-Koch AL adjustment method. The outcomes assessed were mean absolute error (MAE) and percentage of eyes with IOL prediction errors within ±0.25, ±0.50, and ±1.0 diopter (D). The nonparametric method, Friedman test, was used to compare MAE performance among constants.

● RESULTS: Optimized constants could significantly reduce the MAE of SRK/T, Hoffer Q, and Holladay 1 formulas compared with manufacturer's lens constant, whereas the percentage of eyes with IOL prediction errors within ±0.25, ±0.50, and ±1.0 D had no statistically significant differences. Optimized lens constant for long eyes alone showed non-significant refractive advantages over the ULIB constant. Barrett Universal II formula and formulas with AL adjustment showed significantly higher accuracy in highly myopic eyes (*P*<0.001).

● CONCLUSION: Lens constant optimization for the subset of long eyes reduces the refractive error only to a limited extent for highly myopic eyes.

● **KEYWORDS:** high myopia; cataract; intraocular lens power; lens constant optimization; prediction error

DOI:10.18240/ijo.2019.06.10

Citation: Zhang JQ, Zou XY, Zheng DY, Chen WR, Sun A, Luo LX. Effect of lens constants optimization on the accuracy of intraocular lens power calculation formulas for highly myopic eyes. *Int J Ophthalmol* 2019;12(6):943-948

INTRODUCTION

High myopia has become a global public health issue with its notably increased prevalence, especially in Asia[1]. Increasing number of patients with cataracts have eyes with an axial length (AL) greater than 26 mm. However, the intraocular lens (IOL) power calculated using most of the 3rd or 4th generation formulas lack precision when directly applied for these patients. This results in uncorrected refractive errors, especially hyperopia, which in turn negatively affects the patient's quality of life after IOL implantation[2-3].

Some approaches were proposed to reduce prediction error and improve visual quality for highly myopic eyes, including targeting a moderate amount of myopia, using new generation of formulas, optimizing lens constant, and adjusting the AL as Wang-Koch recommended[4-5]. Lens constant optimization and Wang-Koch AL adjustment are methods that can effectively eliminate the systematic prediction error of IOL formulas. Whether there is a need to optimize lens constant for atypical eyes is still controversial[6]. Will optimizing lens constant using data only from the subset of patients with long eyes further improve refractive outcomes for highly myopic eyes, compared with that using data from all eyes? We present a comparison of IOL power calculation formulas using different lens constants in eyes with AL longer than 26.0 mm in order to find the best optimization for the postoperative refractive results.

SUBJECTS AND METHODS

Ethical Approval All procedures adhered to the tenets of the Declaration of Helsinki of the World Medical Association. Ethical approval was provided by the Ethics Committee of Zhongshan Ophthalmic Center (2018KYPJ101). Informed consent was waived due to the retrospective nature of the study.

Patient Selection Data from consecutive patients undergoing uneventful phacoemulsification cataract surgery and in-the-bag IOL implantation of 1-piece hydrophilic acrylic IOLs (920H, Rayner, Hove, UK) by the surgeons (Zheng DY and Chen WR) from September 2016 to March 2018 were collected and reviewed. Inclusion criteria were restricted to eyes with AL greater than 26 mm; this biometric measurement was performed using a partial coherence interferometry (PCI) device (IOLMaster 500, Carl Zeiss Meditec, Jena, Germany). Cases for which parameters were unattainable using PCI were excluded from the study. Eyes that had undergone previous surgery or trauma and those with preexisting ocular diseases that may affect the ability to undertake accurate biometry or refraction (postoperative best-corrected visual acuity less than 20/40) were excluded. Post-operative subjective refraction was performed by the optometrist at least 6wk after surgery.

Data Collection Patients' basic information and preoperative biometric data, including AL, anterior chamber depth (ACD), keratometry values, data of surgery, and IOL power inserted, were extracted from electronic medical records. The IOL power and stable postoperative spherical equivalent (SE) were entered into the IOLMaster device, and a built-in optimization program provided optimized lens constants. Lens constants for long eyes were optimized following the steps described in the IOLMaster manual in detail. The manufacturer's constants were derived from the A-constant and ACD-constant provided by the lens manufacturer[7-8]. User Group for Laser Interference Biometry (ULIB) constants, optimized based on comprehensive data from multiple surgical centers, were downloaded from the website (www.ocusoft.de/ulib/c1.html) on April 29, 2018[9]. The SRK/T[10], Hoffer Q[11], Holladay 1[12], and Haigis[7] formulas using different lens constants were evaluated. Results were compared with Barrett Universal II formula[13], original Wang-Koch AL adjustment method[4], and modified Wang-Koch AL adjustment method[5]. The predicted postoperative SEs were recalculated based on the actual IOL power implanted.

Evaluation of Parameters The following results were evaluated: 1) mean arithmetic SE prediction error (ME). ME is calculated as the mean difference between the predicted and actual postoperative refractive SE. A negative value significantly different from zero represents a more myopic outcome than the predicted one, whereas a positive error indicates more hyperopic results; 2) mean and median absolute SE prediction error (MAE and MedAE), which are defined as the mean and median of the absolute differences between formula-predicted values and actual refractive outcomes; 3) percentage of eyes with IOL prediction error within ±0.25, ±0.50, and ±1.0 D of target refraction. A formula that is associated with a higher percentage of prediction errors within a certain range indicates greater accuracy.

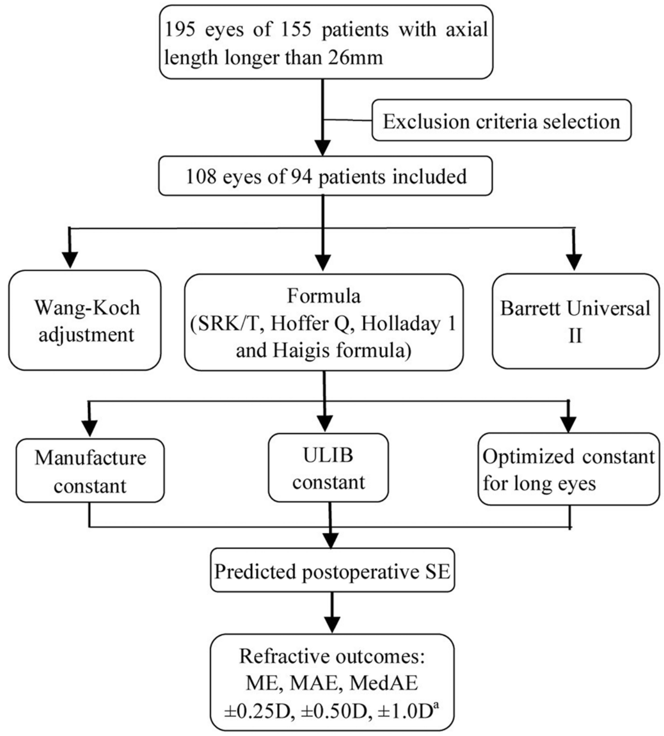

Figure 1 Flow diagram ULIB: User Group for Laser Interference Biometry; SE: Spherical equivalent; ME: Mean arithmetic SE prediction error; MAE: Mean absolute SE prediction error; MedAE: Median absolute SE prediction error. [a]Percentage of refractions within ±0.25 D, ±0.50 D or ±1.0 D of prediction.

Statistical Analysis Kolmogorov-Smirnov test was used to determine whether the data were normally distributed. The one-sample *t*-test or Wilcoxon signed rank test was used to determine whether the mean arithmetic error was significantly different from zero across the constants used. Refractive outcomes obtained using manufacturer's lens constant, ULIB constant, and optimized constant for long eyes were compared. The nonparametric method, Friedman test, was used to compare MAE performance among constants. The Cochran *Q* test was performed to compare the percentages of eyes with IOL prediction error within ±0.25, ±0.50, and ±1.0 D of target refraction. Statistical analysis was performed using SPSS software (version 23.0; IBM, Chicago, IL, USA). The Bonferroni correction was performed for multiple comparisons. A *P* value of less than 0.05 was considered statistically significant.

RESULTS

Figure 1 shows the flow chart of the study. A total of 108 eyes of 94 patients with AL longer than 26 mm were recruited. Table 1 shows preoperative demographic characteristics of the study population. Nine patients received negative-power IOLs. The mean follow-up time was 88d (range, 43-124d). Lens constants used for Rayner 920H in the study are shown in Table 2.

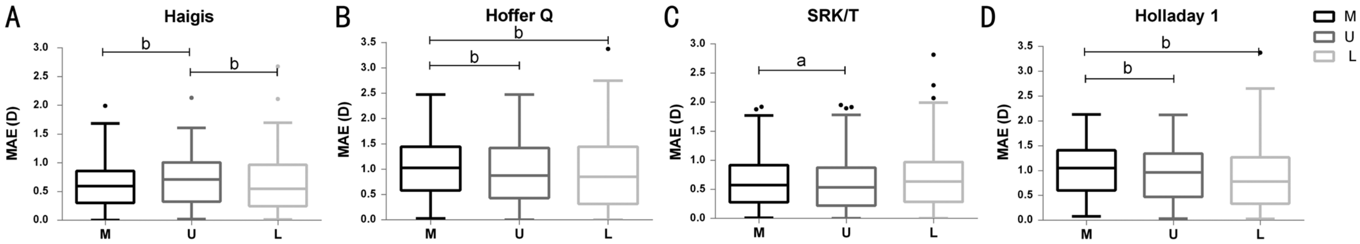

Figure 2 Boxplot of mean absolute prediction error with IOL calculation formulas MAE: Mean absolute SE prediction error; M: Manufacturer's lens constants; U: User Group for Laser Interference Biometry method; L: Optimized lens constants for long eyes. $^{a}P<0.01$; $^{b}P<0.001$.

Table 1 Preoperative demographic characteristics of sample included

Parameters	Mean±SD	Range
Age (y)	57.46±12.56	22-77
AL (mm)	29.15±2.31	26.06-36.37
SimK (D)	43.85±1.62	40.32-49.24
ACD (mm)	3.51±0.39	2.42-4.34
IOL power (D)	7.94±5.35	-7-18.5
Corneal astigmatism (D)	1.22±0.73	0.2-3.38

SD: Standard deviation; SimK: Simulated keratometry; D: Diopter; ACD: Anterior chamber depth; IOL: Intraocular lens.

Table 2 Lens constants used for Rayner 920H in the study

Parameters	Manufacture const	ULIB const	Optimized const for long eyes
SRK/T A const	118.0	118.3	119.7
Haigis			
a0	1.283	1.02	2.217
a1	0.4	0.4	0.4
a2	0.1	0.1	0.1
Hoffer Q pACD	4.97	5.21	6.75
Holladay 1 SF	1.22	1.41	2.96

Const: Lens constant; ULIB: User Group for Laser Interference Biometry method.

Figure 2 shows the boxplots of MAE of formulas with different lens constant. Compared with manufacturer's lens constant, the ULIB constant significantly reduced the MAE of SRK/T, Hoffer Q, and Holladay 1 formulas, and the optimized lens constant for long eyes significantly reduced the MAE of Hoffer Q and Holladay 1 formulas. No statistically significant differences were observed between the ULIB constant and optimized lens constant for long eyes. The MAE of Haigis formula with ULIB constant was significantly higher than that for the other constants ($P<0.0001$).

Table 3 summarizes postoperative refractive error of IOL calculation formulas. Without AL adjustments, formulas combined with manufacturer's lens constant and ULIB constant had a positive arithmetic mean error, different from zero with statistically significance. There were no statistically significant differences between percentages of eyes within certain prediction errors of formulas combined with different constants without AL adjustments. Both the ME of Barrett Universal II formula and formulas with original Wang-Koch AL adjustment were equal to zero statistically. The ME of formulas with modified Wang-Koch AL adjustment had a positive arithmetic mean error, statistically significantly different from zero. Barrett Universal II formula and formulas adjusted with both Wang-Koch methods had the significantly lower MAE and the higher percentage of prediction error within certain range than formulas without AL adjustment ($P<0.001$). No significant difference was found between Barrett Universal II formula and formulas with original or modified Wang-Koch AL adjustment in terms of MAE and percentages of eyes within certain prediction errors.

DISCUSSION

This study was designed and performed to investigate the effects of different lens constants on the accuracy of IOL power calculation formulas in a given series of highly myopic eyes, using a single IOL model.

Numerous factors, such as different IOL types, biometry devices, and surgical technique, can result in systematic prediction errors of IOL formulas. IOL constants like A-constants are variables introduced to lens power calculation in order to fine-tune the results. Constants given by lens manufacturers are meant for an average measurement set-up and always considered as default. Lens constant optimization is a mathematical method used to reduce the arithmetic mean error to zero by adjusting the lens constants, thereby eliminating the systematic myopic or hyperopic prediction error. The SRK/T, Hoffer Q, and Holladay 1 formulas belong to the 3rd generation 2-variable formulas, and their IOL power prediction curve involves simply changing the position in combination with different constants. The Haigis formula is the 4th generation formula using three constants (a0, a1, and a2). The a0 constant sets the position of the IOL power prediction curve. The a1 and a2 constants are related to the preoperative ACD and AL, respectively. Therefore, the IOL power prediction curve of the Haigis formula will change both the position and shape if the lens constant is optimized based on large pooled data. That in normal eyes the effectiveness of

Table 3 Postoperative refractive error of IOLs formulas

Formulas	ME	MAE	SD	MedAE	Max Error	±0.25 D (%)[a]	±0.50 D (%)[a]	±1.0 D (%)[a]
Haigis (M)	0.51[b]	0.64	0.45	0.59	1.99	21.30	42.59	77.78
Haigis (U)	0.64[b]	0.71	0.44	0.71	2.13	22.22	34.26	75
Haigis (L)	0	0.65	0.51	0.55	2.68	25.00	46.30	76.85
Hoffer Q (M)	1.01[b]	1.07	0.65	1.03	2.48	12.96	22.22	49.07
Hoffer Q (U)	0.89[b]	0.99	0.67	0.88	2.48	13.89	27.78	55.56
Hoffer Q (L)	0	0.99	0.76	0.85	3.38	22.22	33.33	58.33
Holladay 1 (M)	0.97[b]	1.03	0.53	1.05	2.13	9.26	19.44	48.15
Holladay 1 (U)	0.88[b]	0.95	0.56	0.97	2.12	12.96	25.93	50.93
Holladay 1 (L)	0	0.89	0.65	0.78	3.38	19.44	32.41	59.26
SRK/T (M)	0.51[b]	0.68	0.49	0.57	1.92	22.22	43.52	78.70
SRK/T (U)	0.42[b]	0.64	0.51	0.54	1.95	26.85	48.15	79.63
SRK/T (L)	0	0.72	0.56	0.64	2.82	21.30	40.74	76.85
Holladay 1-AL	-0.01	0.40	0.34	0.34	2.09	42.59	74.07	96.30
Holladay 1-AL^2	0.14[b]	0.36	0.29	0.34	1.58	43.88	75.51	96.94
SRK/T-AL	-0.10	0.45	0.38	0.37	1.90	39.81	67.59	93.52
SRK/T-AL^2	0.22[b]	0.41	0.31	0.33	1.49	32.94	69.41	95.29
Barrett Universal II	0.07	0.42	0.39	0.33	2.58	38.53	71.56	94.50

ME: Mean refractive prediction error; MAE: Mean absolute refractive prediction error; SD: Standard deviation of the refractive prediction error; MedAE: Median refractive absolute error; Max error: Maximum refractive prediction error; M: Manufacturer's lens constants; U: User Group for Laser Interference Biometry method; L: Optimized lens constants for long eyes; AL: Original Wang-Koch axial length adjustments; Holladay 1-AL^2: Holladay 1 with modified Wang-Koch axial length adjustments which included 98 eyes with an axial length greater than 26.5 mm; SRK/T-AL^2: SRK/T with modified Wang-Koch axial length adjustments which included 85 eyes with an axial length greater than 27.0 mm. [a]Percentage of refractions within ±0.25, ±0.50 or ±1.0 D of prediction; [b]$P<0.05$.

optimized lens constant is better than that of manufacture lens constant has been supported by several studies and numerous authors have recommended the use of the optimized lens constant[14-16]. The ULIB constants were optimized based on a large number of preoperative and postoperative clinical data in different surgical centers without differentiating AL. The ULIB constants are published and freely available on the website and have been frequently used worldwide.

Currently, as patients have higher expectations in terms of postoperative visual quality, there are still challenges remaining for more complex eyes, such as eyes that had previously undergone refractive surgery[17], those with an AL shorter than 22 mm (short eyes)[18], and those with an AL longer than 26 mm (long eyes), resulting in low or negatively powered IOLs implantation[19]. There is a need to optimize the way we calculate IOL power for these atypical eyes. Since we cannot simply change the A-constant because it affects the calculation for all kinds of eyes equally, we could separately optimize constants for atypical eyes. Theoretically, in this way we could come up with the best outcomes that formulas might provide for each kind of atypical eyes, such as long eyes. To our knowledge, there are no studies comparing the two constants optimization method only for atypical eyes. Our results show that lens constant optimization based on long eyes demonstrates limited improvement on the accuracy of IOL formulas for high myopic eyes. No significant difference was found between ULIB constant and optimized lens constant for long eyes in terms of MAE and percentages of eyes within certain prediction errors. Therefore, it is not necessary to optimize lens constants for long eyes alone. Choosing an appropriate IOL formula or optimization method would be more beneficial.

Adjustment for AL has been advocated to correct systemic errors in ultrasound biometry for short and long eyes[20-21]. The Wang-Koch AL adjustment method was validated for use in 2011 in optical biometry. A modified version was published in November, 2018, developed from a larger dataset and using ULIB constants. Only Holladay 1 and SRK/T formula were included in modified version with AL restriction. Holladay 1 formula with modified AL adjustment was recommended to use in eyes longer than 26.5 mm and the latter was recommended to use in eyes longer than 27.0 mm. It is an effective method of handling the selection of IOL power for high to extreme axial myopia by adjusting the AL in a linear fashion. The approach was based on the hypothesis that systemic error occurs in long eyes when optical biometry uses only a single refractive index to convert the length of optical path to AL. The original Wang-Koch AL correction has shown remarkable improvements in postoperative refractive results in long eyes and has effectively reduced the incidence of postoperative hyperopic shift[22-23].

In our study, formulas with AL adjustment reduced MAE and increased the percentage of eyes with prediction error within a certain range significantly. The Holladay 1 formula with either original or modified Wang-Koch AL adjustment achieved favorable postoperative refractive outcomes compared with the currently proposed benchmark standards, with 73% and 96% of the postoperative cataract refractive outcomes lying within ±0.5 D and ±1.0 D of the target, respectively[24]. Our study is the first to evaluate the accuracy of modified AL adjustment method. Our results show that the modified version has a lower MAE and a higher percentage of prediction error within ±0.5 D and ±1.0 D than the original one, but with no statistical significance. However, the modified version has a tendency towards hyperopia whereas the ME of original version was nearly equal to zero. The original Wang-Koch AL adjustment alone has almost eliminated the hyperopic error in IOL formula prediction for highly myopic eyes for all formulas. Combining the Wang-Koch AL adjustment with constant optimization for long eyes resulted in obvious overcorrection. The predicted refractive outcomes in such combination were clearly toward myopia, with decreased MAE and percentage within a certain range (data not shown). Therefore, it is neither recommended nor necessary to combine these two methods.

Based on thick lens models and the paraxial ray tracing theory, considering the position of principal planes when a low-power positive IOL changes to a negative one, the Barrett Universal II formula was one of the most accurate formulas for long eyes, as was showed in a recent meta-analysis[25]. Therefore, the Barrett Universal II formula has a unique advantage in extremely long eyes that require a low dioptric power IOL. For surgeons' convenience, the calculation for Barrett Universal II formula is offered on the website for free[26] and it is not necessary to optimize the AL or the constant. Our results show that Barrett Universal II formula demonstrates similar accuracy to formulas with Wang-Koch AL adjustment, consistent with previous researches[19,27].

Our study has some limitations. First, the retrospective design itself is defective. Therefore, we continuously included patients who met the inclusion criteria to avoid a selection bias. Two independent researchers (Zhang JQ and Zou XY) input data separately. A third researcher (Sun A) verified the accuracy of the data to avoid mistakes in data transcription. Second, postoperative subjective refraction was performed by multiple opticians. Interobserver variability may introduce measurement errors. Uniform training in the hospital may minimize the impact of this bias on the study. Finally, the optimization of the Haigis formula was restricted by the small sample size. Only the a0 constant was optimized. The a1 and a2 constants were retained at the default value as they need data from more than 250 subjects to be optimized. Studies with larger sample sizes are needed to assess the accuracy of the Haigis formula with different constants.

Further studies should address the effectiveness of constants optimized separately for short eyes or eyes that had previously undergone refractive surgery. We can also try to optimize IOL calculations for specific ALs, but doing so is far more complicated than just adjusting IOL constant or AL in a linear way. More variables should take into account, such as keratometry, ACD, preoperative refraction, the size of capsular bag, *etc*. Some formulas, such as the Hill-RBF[28] and Ladas Super formula[29], use a sophisticated computer-based statistical model based on the large library data set in order to find relationships not otherwise evident in theoretical approaches. These formulas will evolve over time as more information is incorporated and will bring us further in the field of lens power calculation.

In conclusion, our results suggest that lens constant optimization based on long eyes alone did not show additional benefits for highly myopic eyes than using optimized constant based on all eyes. Both the original Wang-Koch AL adjustment method and the Barrett Universal II formula have favorable postoperative refraction outcome, while the modified Wang-Koch AL adjustment method has a tendency towards hyperopia and a similar prediction accuracy.

ACKNOWLEDGEMENTS

Foundation: Supported by National Natural Science Foundation of China (No.81770905). The funding organization had no role in the design or conduct of this research.

Conflicts of Interest: Zhang JQ, None; **Zou XY,** None; **Zheng DY,** None; **Chen WR,** None; **Sun A,** None; **Luo LX,** None.

REFERENCES

1 Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, Wong TY, Naduvilath TJ, Resnikoff S. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016;123(5):1036-1042.

2 Geggel HS. Comparison of formulas and methods for high myopia patients requiring intraocular lens powers less than six diopters. *Int Ophthalmol* 2018;38(4):1497-1504.

3 Zhang Y, Liang XY, Liu S, Lee JW, Bhaskar S, Lam DS. Accuracy of intraocular lens power calculation formulas for highly myopic eyes. *J Ophthalmol* 2016;2016:1917268.

4 Wang L, Shirayama M, Ma XJ, Kohnen T, Koch DD. Optimizing intraocular lens power calculations in eyes with axial lengths above 25.0 mm. *J Cataract Refract Surg* 2011;37(11):2018-2027.

5 Wang L, Koch DD. Modified axial length adjustment formulas in long eyes. *J Cataract Refract Surg* 2018;44(11):1396-1397.

6 Wang L, Koch DD, Hill W, Abulafia A. Pursuing perfection in intraocular lens calculations: III. Criteria for analyzing outcomes. *J Cataract Refract Surg* 2017;43(8):999-1002.

7 Haigis W, Lege B, Miller N, Schneider B. Comparison of immersion ultrasound biometry and partial coherence interferometry for intraocular lens calculation according to Haigis. *Graefes Arch Clin Exp Ophthalmol* 2000;238(9):765-773.

8 Holladay JT. International intraocular lens and implant registry 2003. *J Cataract Refract Surg* 2003;29(1):176-197.

9 User Group for Laser Interference Biometry. Optimized IOL constants for the Zeiss IOLMaster calculated from patient data on file (last revision Oct 31,2016). Available at: www.ocusoft.de/ulib/c1.html. Accessed on May 26, 2018.

10 Retzlaff JA, Sanders DR, Kraff MC. Development of the SRK/T intraocular lens implant power calculation formula. *J Cataract Refract Surg* 1990;16(3):333-340.

11 Hoffer KJ. The Hoffer Q formula: a comparison of theoretic and regression formulas. *J Cataract Refract Surg* 1993;19(6):700-712.

12 Holladay JT, Prager TC, Chandler TY, Musgrove KH, Lewis JW, Ruiz RS. A three-part system for refining intraocular lens power calculations. *J Cataract Refract Surg* 1988;14(1):17-24.

13 Barrett GD. An improved universal theoretical formula for intraocular lens power prediction. *J Cataract Refract Surg* 1993;19(6):713-720.

14 Nemeth G, Nagy A, Berta A, Modis L Jr. Comparison of intraocular lens power prediction using immersion ultrasound and optical biometry with and without formula optimization. *Graefes Arch Clin Exp Ophthalmol* 2012;250(9):1321-1325.

15 Aristodemou P, Knox Cartwright NE, Sparrow JM, Johnston RL. Intraocular lens formula constant optimization and partial coherence interferometry biometry: refractive outcomes in 8108 eyes after cataract surgery. *J Cataract Refract Surg* 2011;37(1):50-62.

16 Madge SN, Khong CH, Lamont M, Bansal A, Antcliff RJ. Optimization of biometry for intraocular lens implantation using the Zeiss IOLMaster. *Acta Ophthalmol Scand* 2005;83(5):436-438.

17 Wang L, Tang M, Huang D, Weikert MP, Koch DD. Comparison of newer intraocular lens power calculation methods for eyes after corneal refractive surgery. *Ophthalmology* 2015;122(12):2443-2449.

18 Gökce SE, Zeiter JH, Weikert MP, Koch DD, Hill W, Wang L. Intraocular lens power calculations in short eyes using 7 formulas. *J Cataract Refract Surg* 2017;43(7):892-897.

19 Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. *Ophthalmology* 2018;125(2):169-178.

20 Norrby S, Lydahl E, Koranyi G, Taube M. Reduction of trend errors in power calculation by linear transformation of measured axial lengths. *J Cataract Refract Surg* 2003;29(1):100-105.

21 Norrby S, Lydahl E, Koranyi G, Taube M. Clinical application of the lens haptic plane concept with transformed axial lengths. *J Cataract Refract Surg* 2005;31(7):1338-1344.

22 Abulafia A, Barrett GD, Rotenberg M, Kleinmann G, Levy A, Reitblat O, Koch DD, Wang L, Assia EI. Intraocular lens power calculation for eyes with an axial length greater than 26.0 mm: comparison of formulas and methods. *J Cataract Refract Surg* 2015;41(3):548-556.

23 Popovic M, Schlenker MB, Campos-Möller X, Pereira A, Ahmed IIK. Wang-Koch formula for optimization of intraocular lens power calculation: evaluation at a Canadian center. *J Cataract Refract Surg* 2018;44(1):17-22.

24 Behndig A, Montan P, Stenevi U, Kugelberg M, Zetterström C, Lundström M. Aiming for emmetropia after cataract surgery: swedish national cataract register study. *J Cataract Refract Surg* 2012;38(7): 1181-1186.

25 Wang Q, Jiang W, Lin T, Zhu Y, Chen C, Lin H, Chen W. Accuracy of intraocular lens power calculation formulas in long eyes: a systematic review and meta-analysis. *Clin Exp Ophthalmol* 2018;46(7):738-749.

26 Barrett Universal II Formula. Available at: http://www.apacrs.org/barrett_universal2/; 2017 Acessed on 18.07.10.

27 Roberts TV, Hodge C, Sutton G, Lawless M, contributors to the Vision Eye Institute IOL Outcomes Registry. Comparison of Hill-radial basis function, Barrett Universal and current third generation formulas for the calculation of intraocular lens power during cataract surgery. *Clin Exp Ophthalmol* 2018;46(3):240-246.

28 Hill WE. Hill-RBF calculator version 2.0. Available at: http://rbfcalculator.com/online/index.html. Accessed on October 25, 2018.

29 Ladas JG, Siddiqui AA, Devgan U, Jun AS. A 3-D "super surface" combining modern intraocular lens formulas to generate a "super formula" and maximize accuracy. *JAMA Ophthalmol* 2015;133(12):1431-1436.