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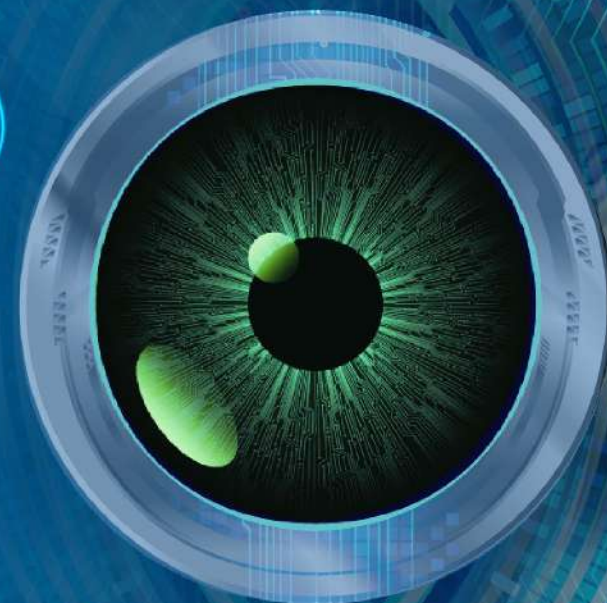
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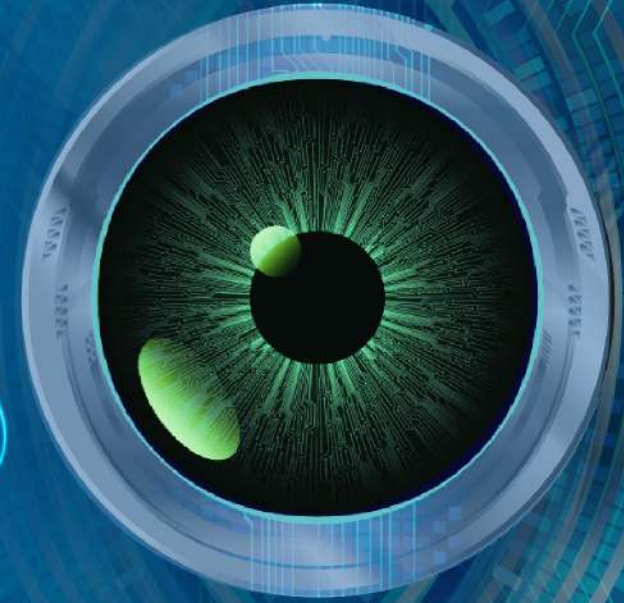
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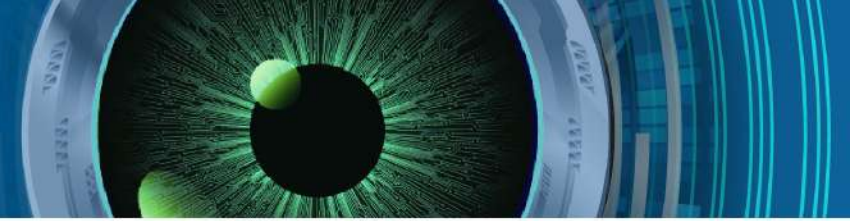


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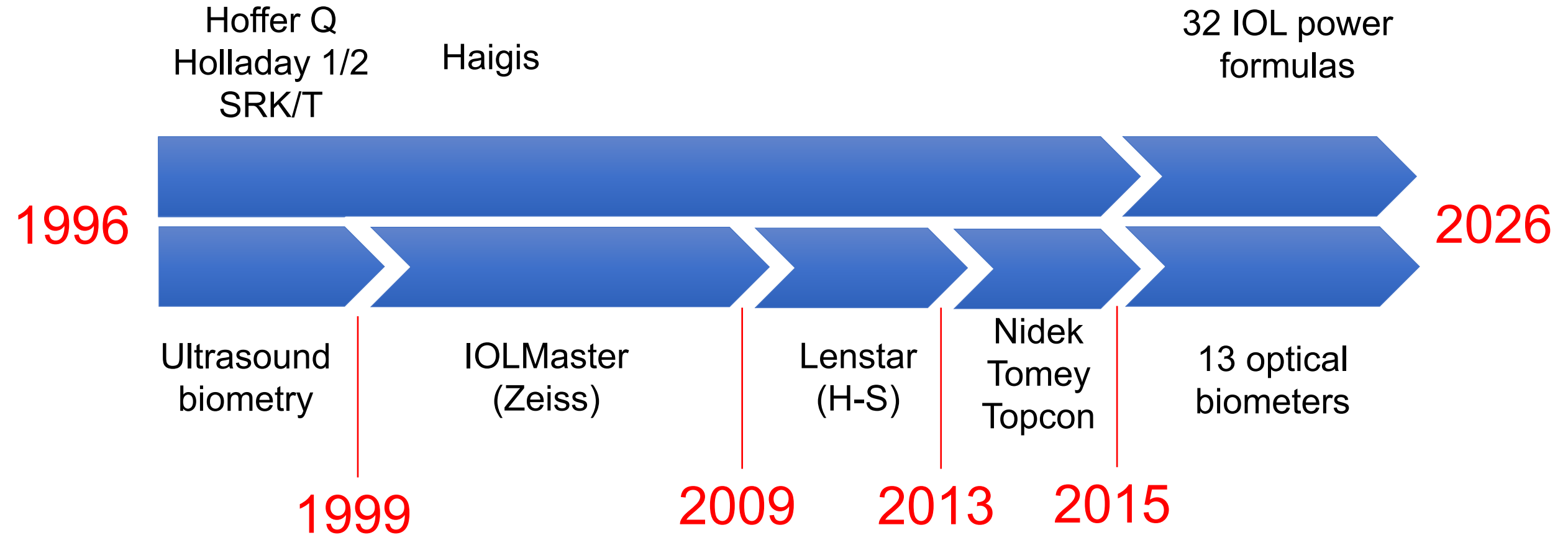
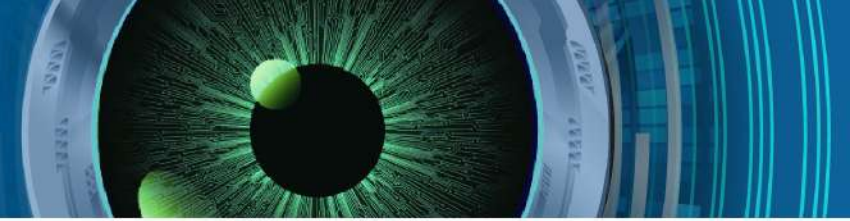


L'evoluzione della biometria delle lenti high-tech

Giacomo Savini
Studio Oculistico d'Azeglio, Bologna
IRCCS Fondazione Bietti, Roma



Shareholder	No relevant conflicts of interest to declare.
Grant / Research Support	No relevant conflicts of interest to declare.
Consultant	Medicel
Employee	No relevant conflicts of interest to declare.
Paid Instructor	Alcon
Speaker Bureau	Alcon, Moptim, SIFI, Thea, Zeiss
Other	CSO, SIFI



IOL power formula classifications

Giacomo Savini, MD, Kenneth J Hoffer, MD, FACS, Thomas Kohnen, MD, PhD

Traditionally, intraocular lens (IOL) power formulas have been classified into generations. First-generation formulas referred to the earliest vergence formulas independently developed by Gernet and Pyodkov. Second-generation formulas referred to a wide range of formulas listed by Sanders et al, like those by Donzis et al and Thompson et al as well as the first Olsen formula. According to other authors, second-generation formulas are those including factors that scaled the IOL axial position prediction based on axial length (AL), such as the original Hoffer formula with pACD, based on measured preoperative anterior chamber depth (ACD) (from corneal epithelium to the anterior lens surface). Third-generation formulas referred to formulas predicting the IOL position from keratometry (K) and AL, such as the Hoffer Q, Holladay 1, and SRK/T.¹⁻¹⁰ The confusion started with fourth-generation formulas, as these sometimes included both formulas, such as the Holladay 2, which predicted the IOL position from more than 2 preoperative parameters, and others, such as the Haigis formula, which predicted the IOL position from the AL and the preoperative ACD.¹¹

Widely, the classification into generations was replaced by a more descriptive classification in 2017, when Koch et al proposed 5 categories: (1) historical/refraction-based formulas, (2) regression formulas, (3) vergence formulas, (4) artificial intelligence (AI) formulas, and (5) ray tracing.¹² Since 2017, the number of IOL formulas for healthy unoperated eyes has dramatically increased, and we felt it is essential to provide an updated classification, which is shown in Figure 1. Given that the historical/refraction-based and the regression formulas are no longer used, we can still rely on the classification by Wang et al for the remaining formulas, which can be included in vergence formulas, AI methods, and ray tracing. Some of these categories now require different subcategories. The aim of this article is not to provide a detailed description of each formula and method but only to update their classification in an organized manner.

Vergence formulas should be defined as either thin lens or thick lens formulas. The former consider both the cornea and the IOL as infinitely thin dioptrics, whereas the latter take their thickness into consideration. In addition, both thin lens and thick lens formulas can take advantage of AI.

Therefore, the following 4 subcategories can be defined: (1) Thin lens vergence formulas without AI: these include the Haigis, Hoffer Q, Holladay 1, Holladay 2 (unpublished), and SRK/T.¹¹ In recent years, several formulas entered this subcategory: Castrop, Cooke K6 (unpublished), Panacea (unpublished), T2, and VRF and VRF-G (unpublished).¹³⁻¹⁵ (2) Thin lens vergence formulas with AI: these include the 3C calculator by Massimo Camellin, Umberto Camellin, Antonio Calossi (unpublished), Hoffer QST, Kane (unpublished), and Ladas AI super formula, whose structure is unpublished.¹⁶ (3) Thick lens vergence formulas without AI: EVO 2.0 by TK Yeo (unpublished) and the Naeser 2.¹⁷ (4) Thick lens vergence formulas with AI: the only formula in this subcategory is the Pearl-DGS, which was originally developed as a thin lens formula and then converted into a thick lens formula.¹⁸

Pure AI-based methods do not share any optical background but are data-driven only, using machine learning. The earliest method in this group was the Radial Basis Function, developed by Warren E. Hill, MD, and Haag-Streit (unpublished), whose latest evolution is v. 3.0. Recently, the Karmona and Nallasamy formulas, both developed using machine learning models, joined this subgroup.^{19,20}

Ray-tracing methods, which calculate the path of light rays based on Snell's law at each interface and the refractive index of each dioptric, can be classified into paraxial and exact methods. Exact ray tracing is not limited to the paraxial area, but also takes corneal asphericity and higher-order aberrations into account and can be calculated over different pupil diameters. In both paraxial and exact ray tracing, the exact design of the IOL is required, which is one of the major limitations of ray tracing, since IOL manufacturers are reluctant to provide these data.²¹ Different from vergence formulas, all input to ray-tracing power calculation should be true physical parameters and no adjustable parameters (eg, lens constants) should be used. The IOL power by paraxial ray tracing can also be calculated on Excel.²² The following subcategories can be defined: (1) Paraxial ray tracing with no AI: the Barrett Universal II (unpublished), O formula, Olsen formula, and Z-Calc by Zeiss (unpublished).²³⁻²⁵ (2) Paraxial ray tracing with AI: the only method using this approach is the Zeiss AI IOL Calculator (unpublished), which is not yet commercially available, but whose preliminary results have

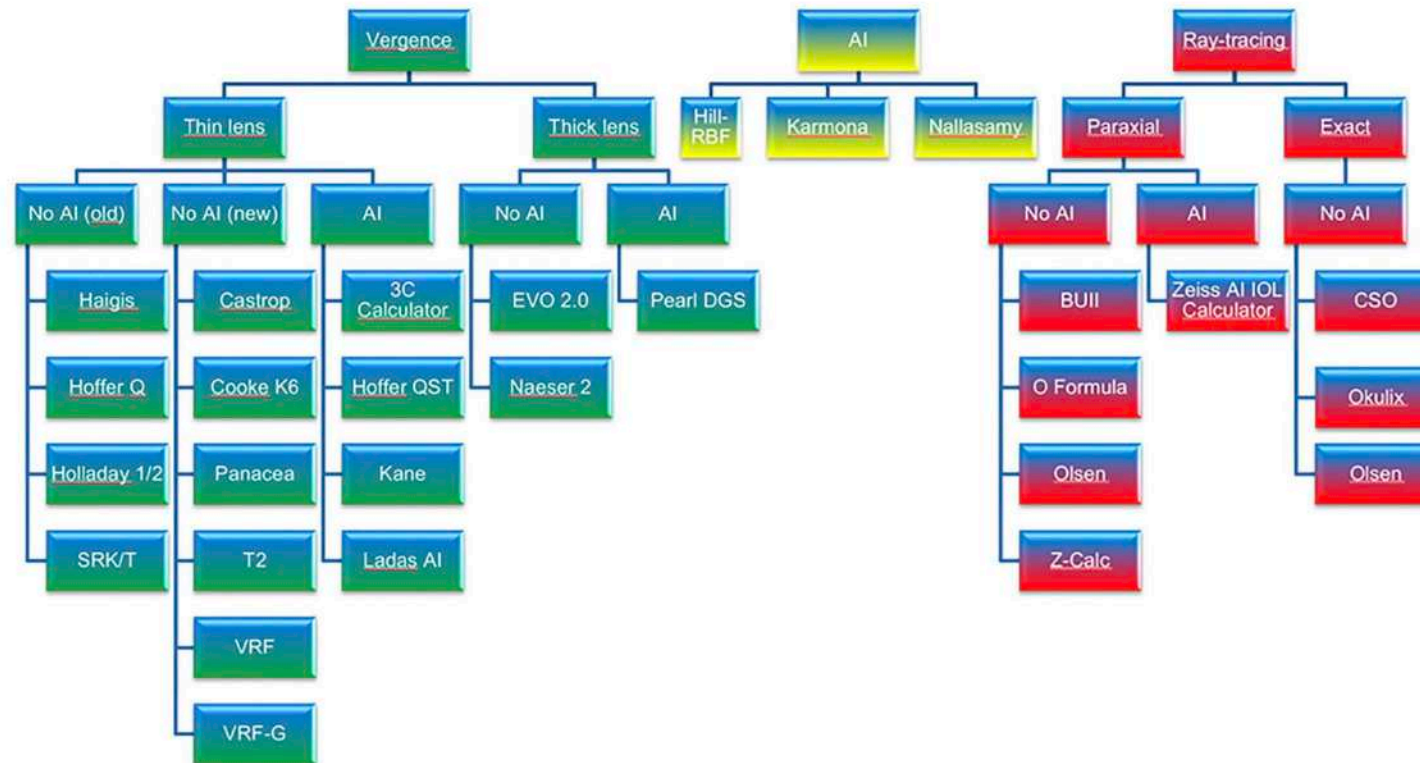


Figure 1. Classification of IOL power formulas.

From the IRCCS Belli Foundation, Rome, Italy (Savini); St. Mary's Eye Center, Santa Monica, California (Hoffer); Stein Eye Institute, Los Angeles, California (Kohnen); Department of Ophthalmology, Goethe-University, Frankfurt am Main, Germany (Kohnen).

The contribution of Belli Foundation was supported by Fondazione Roma and the Italian Ministry of Health.

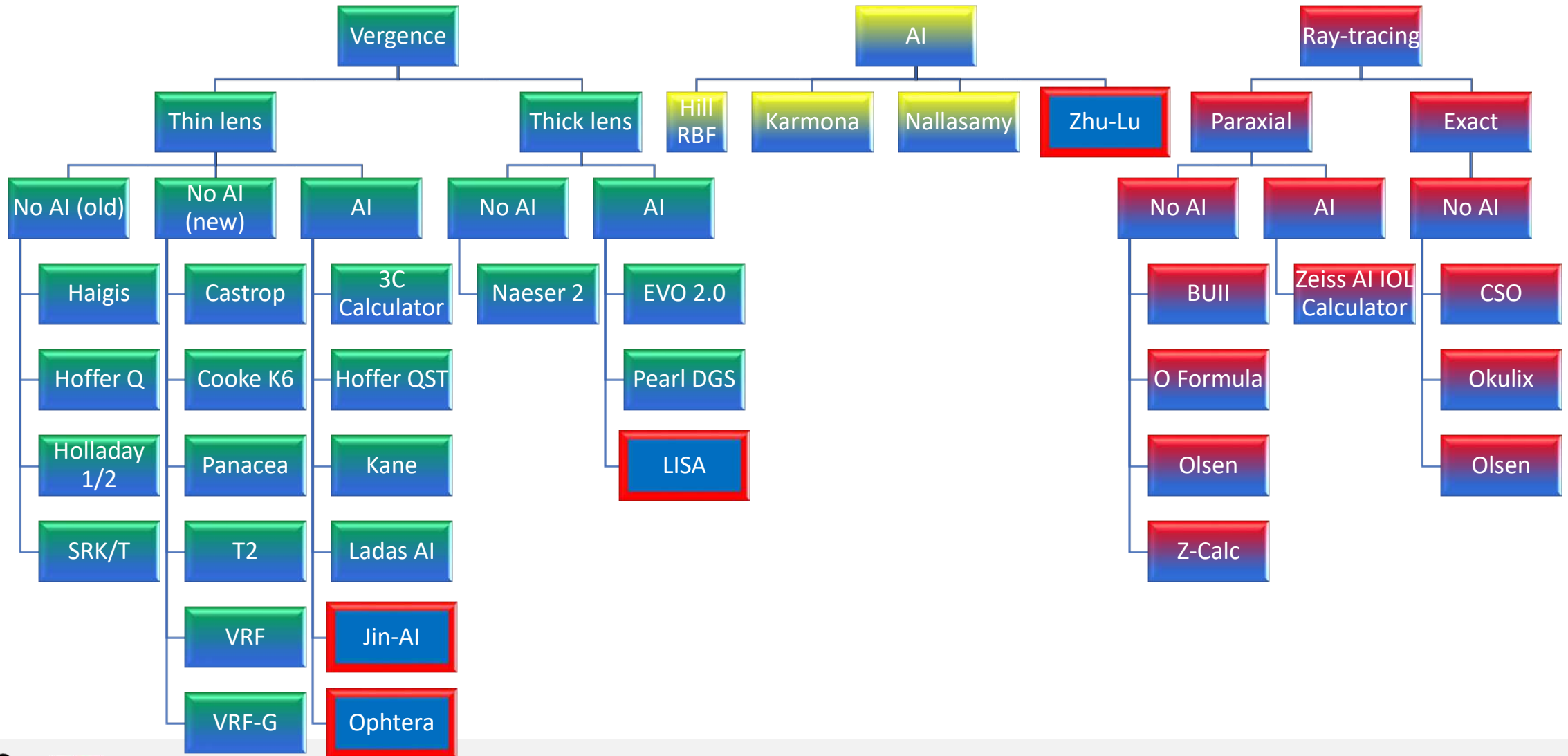
Corresponding author: Giacomo Savini, MD, Department of Ophthalmology, IRCCS Belli Foundation, Via Livorno 3, Rome 00196, Italy. Email: giacomo.savini@belli.it

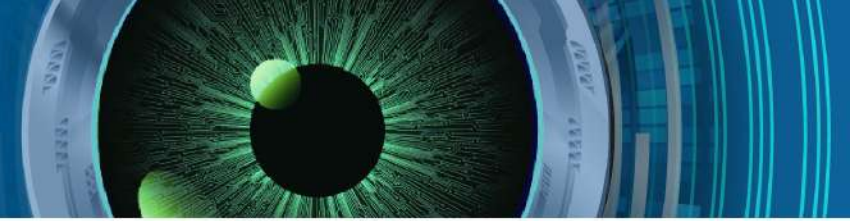
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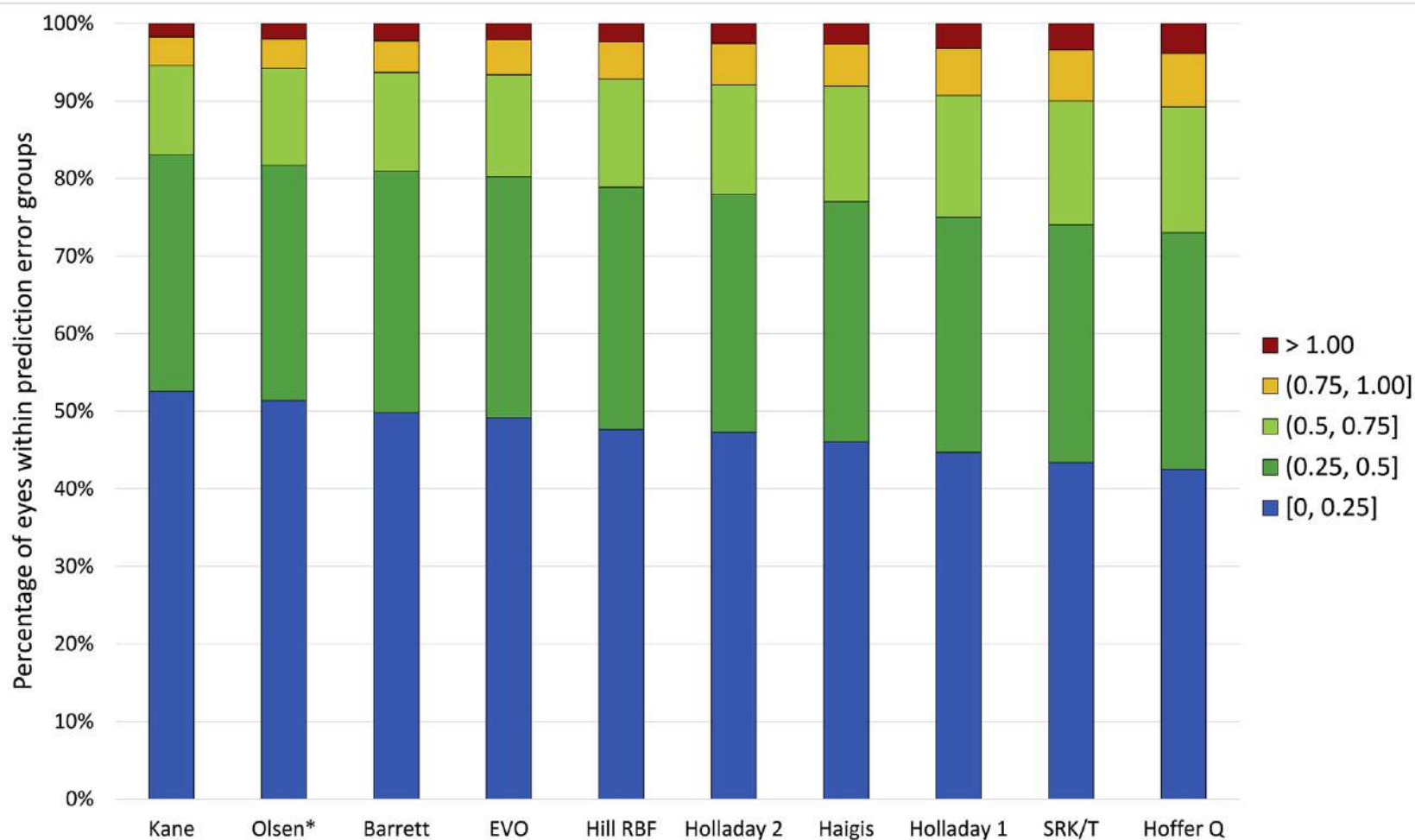
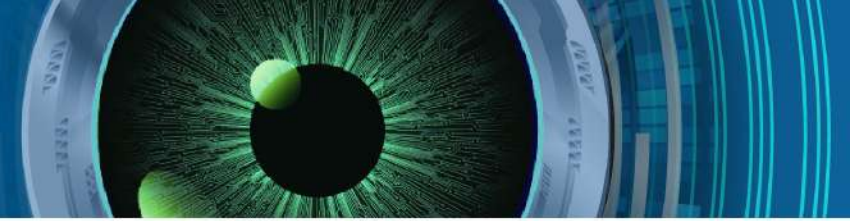
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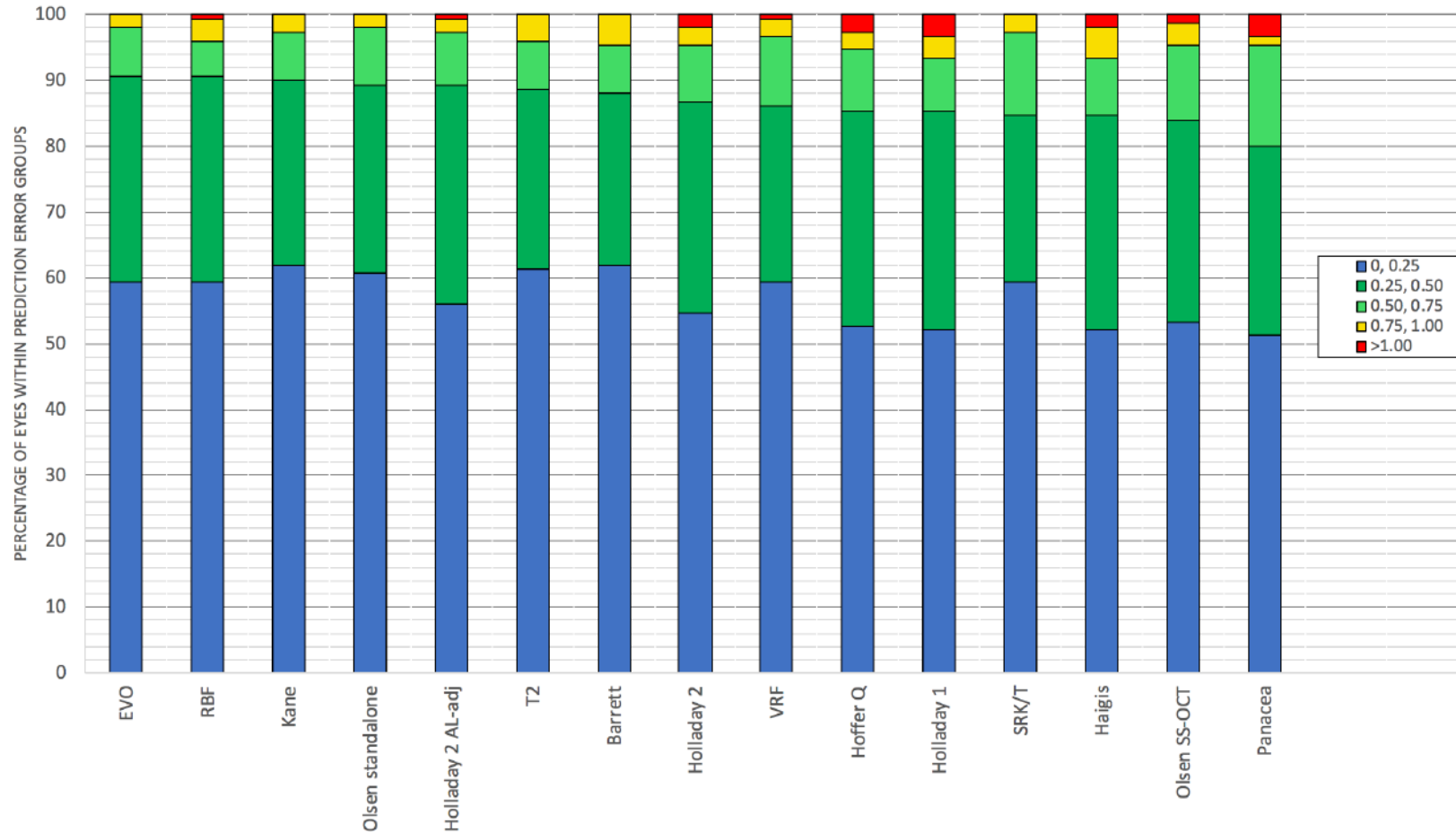
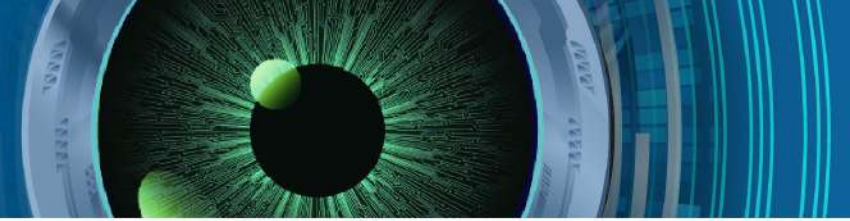
Why do we need new formulas?

- ✓ They are more accurate than older formulas
- ✓ They can be used in all eyes (short, medium and long)
- ✓ They are available online for free



- ✓ 13,301 eyes with SN60WF (Alcon)
- ✓ First demonstration that new formulas are more accurate than older formulas

Melles et al Ophthalmology 2019



✓ 150 eyes with
SN60WF (Alcon)

✓ Even higher
percentages of eyes
with a PE within
 ± 0.50 D

Savini et al JCRS 2020



ORIGINAL ARTICLE

Refractive Predictability Using the IOLMaster 700 and Artificial Intelligence–Based IOL Power Formulas Compared to Standard Formulas

Huanhuan Cheng, MD; Jack X. Kane, MBBS; Liangping Liu, MD, PhD; Jianbing Li, MD; Bing Cheng, MD; Mingxing Wu, MD, PhD

ABSTRACT

PURPOSE: To investigate the accuracy of intraocular lens (IOL) power calculation formulas using swept-source optical coherence tomography (SS-OCT).

METHODS: Eyes with biometry measurement by IOLMaster 700 (Carl Zeiss Meditec AG), uncomplicated phacemulsification, and IOL implantation were enrolled in this retrospective study. Newly released artificial intelligence–based formulas including Hill-Radial Basis Function (RBF) 2.0, Kane, and PEARL-DGS were compared with Gaussian optics–based standard formulas. The refraction predicted by each formula was compared with the actual refractive outcome in spherical equivalent.

RESULTS: A total of 410 eyes of 410 patients were included in this study. Using optimized constants for SS-OCT biometry led to a significant decrease in median absolute error (MedAE) for Barrett, Haigis, and Hoffer Q formulas compared with using User

Group for Laser Interference Biometry constants ($P < .05$). Overall, Olsen (0.283 diopters [D]), and Kane (0.286 D) formulas had significantly lower MedAEs than RBF 2.0 (0.314 D), Haigis (0.322 D), SRK/T (0.371 D), Holladay 1 (0.376 D), and Hoffer Q (0.379 D) formulas under constant optimization ($P < .05$). The first four formulas with the lowest standard deviations of prediction error were Kane (0.451 D), Olsen (0.456 D), EVO 2.0 (0.460 D), and Barrett (0.470 D). Olsen (47.1%), Barrett (45.9%), Kane (45.4%), and EVO 2.0 (45.1%) formulas had greater proportions of eyes within ± 0.25 D of the predicted refraction than Hoffer Q (35.7%), SRK/T (35.7%), and Holladay 1 (33.4%) formulas ($P < .05$).

CONCLUSIONS: Constant optimization for SS-OCT biometry further improves the performance of formulas. The most accurate prediction of postoperative refraction can be achieved with Barrett, EVO 2.0, Kane, and Olsen formulas.

[J Refract Surg. 2020;36(7):466–472.]

Original research article

Intraocular lens power calculation formula accuracy: Comparison of 12 formulas for a trifocal hydrophilic intraocular lens

Carlos Rocha-de-Losada^{1,2,3}, Elvira Colmenero-Reina⁴, David Filmer⁵, Francisco-Javier Castro-Afonso⁶, A Naro Rodriguez-Raton⁷, Jose-Luis Garcia-Madruga⁴, Jorge Peraza-Nieves¹ and José-Maria Sánchez-González^{4,5}

Abstract

Purpose: To evaluate the accuracy of 12 intraocular lens (IOL) power formulas: Barrett Universal II, Emmetropia Verifying Optical (EVO), Haigis, Hill-Radial Basis Function (RBF), Hoffer Q, Holladay 1, Kane, Ladas Super Formula, Olsen, Pausen, Pencil DGS, Sanders-Reitabell-Kruth-Theoretical (SRK/T). In addition, an analysis of the efficacy as a function of the axial length was performed.

Methods: About 171 from 93 patients (68 male eyes and 103 female eyes). Twelve IOL power formula calculations were studied with one IOL platform (trifocal hydrophilic IOL, FineVision Micro F), one biometer (IOLMaster LS 900), one topographer (CSO Stratus Topographer), one vergence, and one optometrist. Optimizations were determined to be zeroed mean refractive prediction error. Mean error (ME), mean absolute error (MAE), median absolute error (MedAE) and relative accuracy within ± 1.00 D was calculated. Axial length was split in short and medium eyes.

Results: One hundred and seventy eyes were included. Formulas were ranked by percentage within ± 0.50 diopters and MAE (D). Among all eyes, Olsen 86.55% (0.273 D) and Barrett Universal II 86.95% (0.285 D). For short eyes (< 22.5 mm), Olsen 90.70% (0.273 D) and Kane 90.70% (0.225 D). For medium eyes, Barrett 89.34% (0.23 D) and Pencil 86.89% (0.263 D). **Conclusion:** Olsen and Barrett formulas obtained excellent accuracy for over all eyes. Kane and Olsen formulas obtained the best results in short eyes. For medium and long length the RBF formula achieved the best accuracy results.



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SAGE

Comparative Analysis of Eighteen IOL Power Calculation Formulas Using a Modified Formula Performance Index Across Diverse Biometric Parameters

SHAN MA, CHENG LI, JING SUN, JUN YANG, KAI WEN, XITENG CHEN, FANGYU ZHAO, XUEQUAN SUN, AND FANG TIAN

PURPOSE: To evaluate the predictive accuracy of 18 intraocular lens (IOL) power calculation formulas across diverse biometric parameters using a modified formula performance index (FPI) and prediction error (PE) variability metrics.

DESIGN: Prospective, comparative, accuracy, and reliability analysis of IOL power calculations.

METHODS: This study included 213 cataract patients who underwent phacemulsification with SNG60WT IOL implantation. Preoperative biometry was obtained using the IOLMaster 700. Eighteen IOL power calculation formulas, including Barrett TK, Barrett Universal II, Castrop, Cooke K6, EVO 2.0, Haigis, Hoffer Q, Hoffer QST, Holladay 1, Holladay 2, Kane, Karmes, Ladas Super Formula, Nallakannu, PEARL-DGS, RBF 3.0, SRK/T, and T2, were evaluated. Predictive accuracy was assessed using FPI and standard deviation (SD) for overall performance, while root mean square error (RMSE) and subgroup-specific FPI (FPI_{sub}) were used for biometric subgroup analysis. Additional metrics included mean absolute error, median absolute error, and the percentage of eyes within ± 0.25 D, ± 0.50 D, ± 0.75 D, and ± 1.00 D.

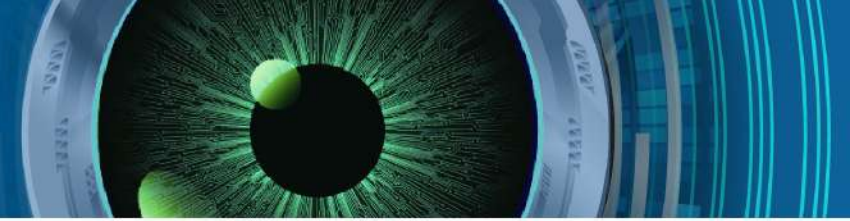
RESULTS: Cooke K6 achieved the highest FPI (0.740) and lowest SD (0.394), followed by PEARL-DGS (FPI = 0.714, SD = 0.399) and Barrett TK (FPI = 0.710, SD = 0.411). Barrett TK had the highest percentage of eyes within ± 0.25 D (54.5%). Subgroup analysis revealed that PEARL-DGS exhib-

ited the highest accuracy in short eyes (axial length ≤ 22 mm, FPI_{sub} = 0.838, RMSE = 0.271), while Haigis performed best in long eyes (axial length ≥ 26 mm, FPI_{sub} = 0.826, RMSE = 0.336) and steep corneas (K > 46 D, FPI_{sub} = 0.765, RMSE = 0.350). Barrett TK ranked highest in medium-long eyes (24.5–26 mm, FPI_{sub} = 0.700, RMSE = 0.400) and flatter corneas (K < 42 D, FPI_{sub} = 0.639, RMSE = 0.382). Cooke K6 was most accurate in shallow anterior chambers (anterior chamber depth ≤ 3.0 mm, FPI_{sub} = 0.737, RMSE = 0.381). In addition, SRK/T exhibited lower accuracy and higher PE variability.

CONCLUSIONS: Modern formulas, particularly Cooke K6, PEARL-DGS, and Barrett TK, demonstrated superior accuracy with lower PE variability than traditional formulas. Subgroup analysis highlighted the importance of biometric-driven formula selection to optimize refractive outcomes, providing a clinically reference for personalized IOL power selection. (Am J Ophthalmol. 2023;271: 221–230. © 2025 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>)).

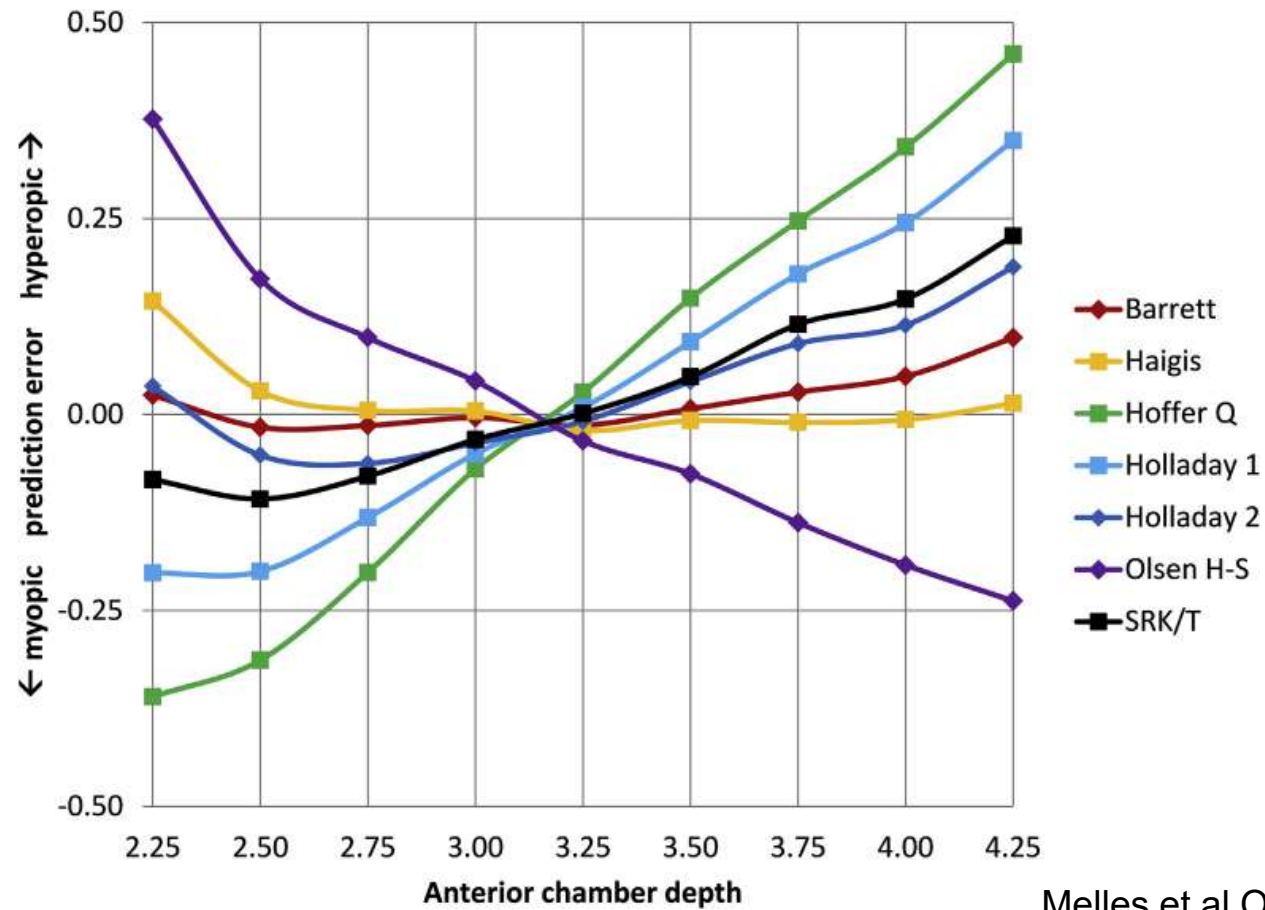
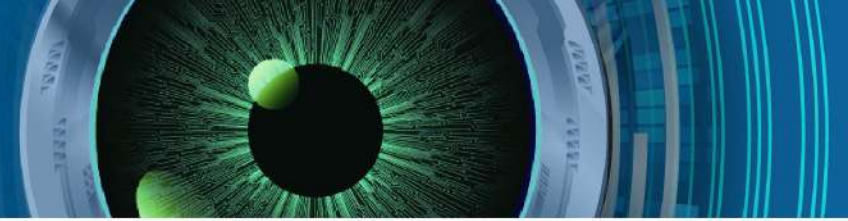
An increasing number of studies is showing the higher accuracy of new-generation formulas



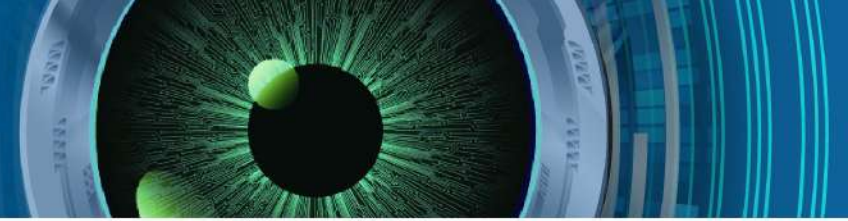


Why?

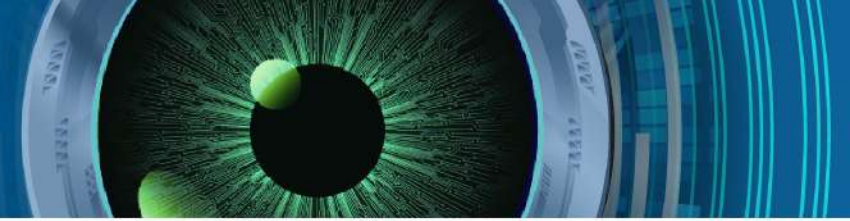
- ✓ Preop ACD included in the ELP prediction
- ✓ The Hoffer Q, Holladay 1 and SRK/T based the ELP prediction on K and AL only



Melles et al Ophthalmology 2018

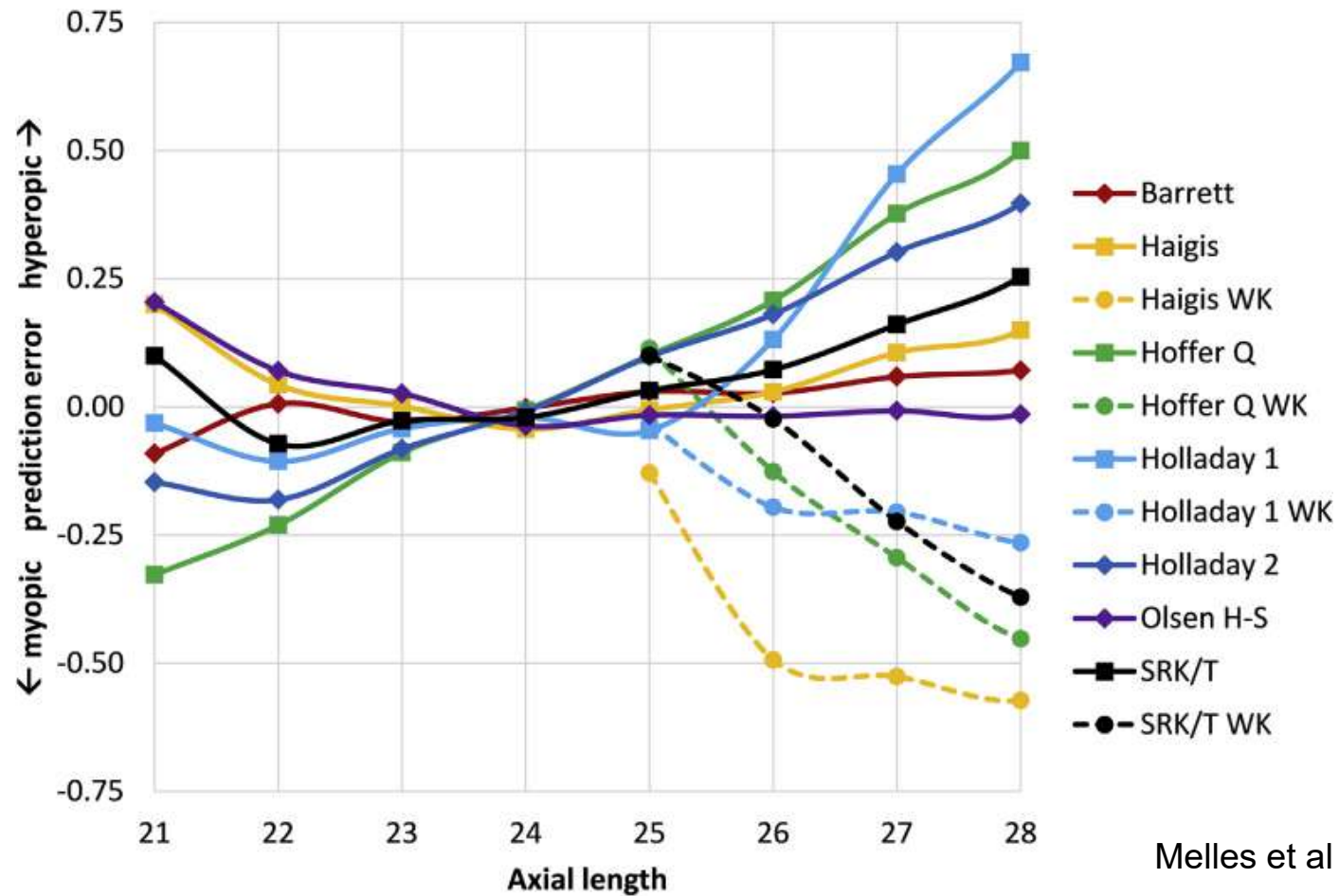
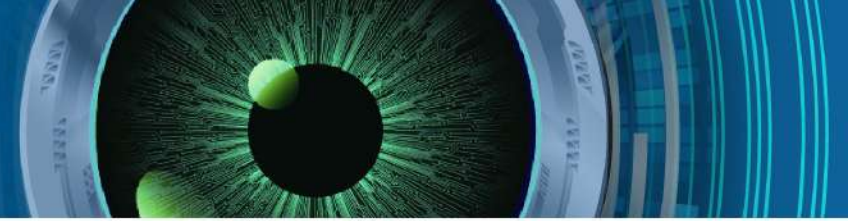


- ✓ Preop ACD is not entered into simple multiple linear regression (like for Haigis), but in more sophisticated non-linear approaches based on AI and including other variables (WTW, CCT, gender)

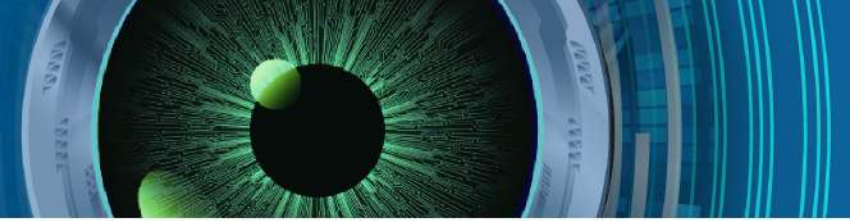


Why?

- ✓ Axial length is optimized in long eyes (>26 mm) in order to avoid the AL overestimation obtained with the traditional group refractive index method

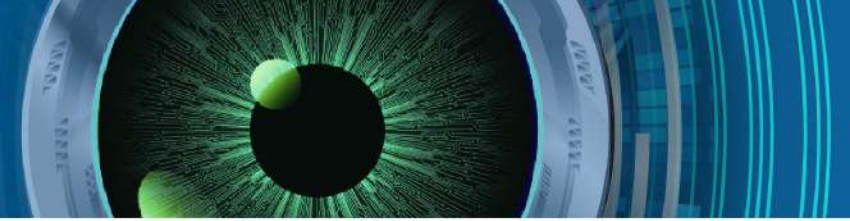


Melles et al Ophthalmology 2018



AL optimization can be performed with different approaches:

- ✓ AI (e.g., machine learning)
- ✓ Sum-of-segments and Cooke-modified AL



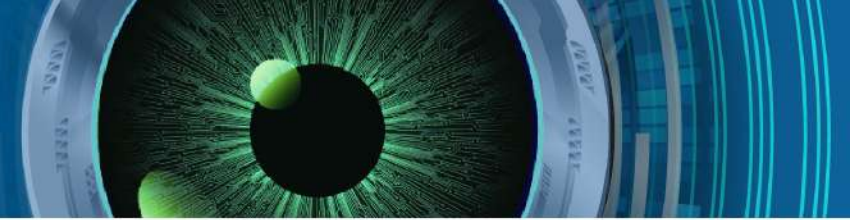
It is no longer wise to follow older recommendations based on AL

Hoffer guidelines

(confirmed by Aristodemou et al in 2011)

Axial length	
<22 mm	Hoffer Q
22-24.5 mm	Average of 3 formulas
24.5-26 mm	Holladay 1
>26 mm	SRK/T

- ✓ Haigis: valid in all groups
- ✓ Holladay II: valid but unnecessary
- ✓ SRK and SRKII: never!



REFRACTIVE OUTCOMES USING OLD FORMULAS, ESCRS IOL CALCULATOR AND WEBSCRAPING

Giacomo Savini, MD^{1,2}

Catarina Coutinho, MSc,^{1,3} Enrico Lupardi, MD^{1,4}

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4 - Ophthalmology Unit, I.R.C.C.S. Azienda Ospedaliera-Universitaria di Bologna, Bologna, Italy



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H JOHN SHAMMAS MD
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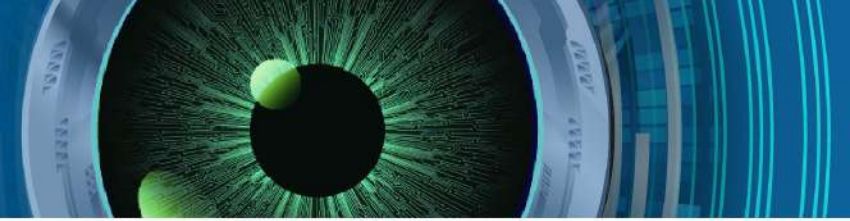




Results on 92 eyes with non-toric Vivity (DFT015)

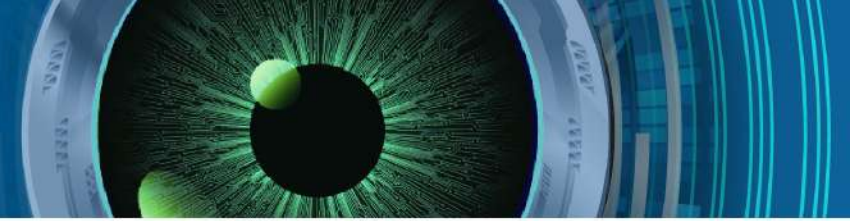
IOLMaster 700

MAE / ME (optimized constants in retrospect)							
Hoffer Q	<i>abs</i>	Holladay	<i>abs</i>	SRK/T	<i>abs</i>	Haigis	<i>abs</i>
PE	MAE	PE	MAE	PE	MAE	PE	MAE
0.01	0.23	0.00	0.24	0.01	0.25	-0.07	0.28
	MedAE		MedAE		MedAE		MedAE
	0.19		0.17		0.19		0.14
tot	93	tot	93	tot	93	tot	93
0.50	83	0.50	82	0.50	79	0.50	84
%	89.25	%	88.17	%	84.95	%	90.32



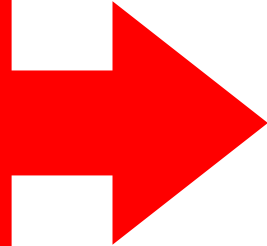
Purpose:

1. Are older formulas with optimized constants sufficient to satisfy my patients?
2. Should I spend time with new formulas on the ESCRS IOL calculator? Would this improve my results?
3. Is webscraping better than the ESCRS IOL calculator?



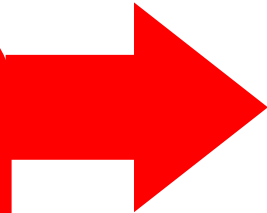
IOL power calculation by:

- ✓ Haigis
- ✓ Hoffer Q
- ✓ Holladay 1
- ✓ SRK/T

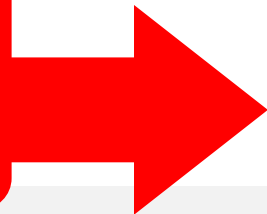


1) Constant optimization on Excel (Goal/ Seek tool) to zero out the mean PE

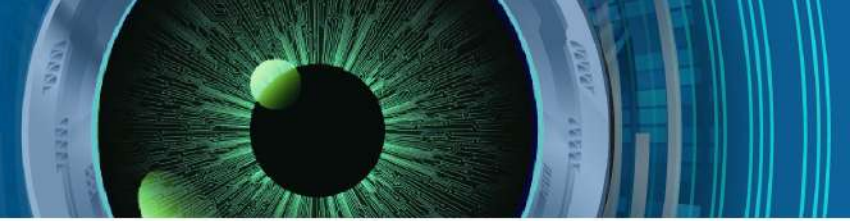
- ✓ Barrett UII
- ✓ EVO 2.0
- ✓ Kane
- ✓ Hoffer QST



2) Results by ESCRS IOL Calculator
3) Constant optimiz. by webscraping

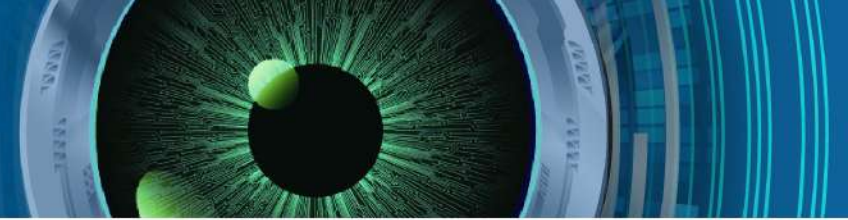


2) Results by ESCRS IOL Calculator
3) Constant optimiz. by hofferqst.com

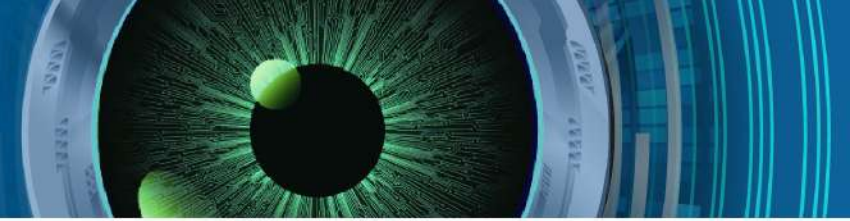


✓ Preoperative measurements

- ✓ K 43.13 ± 1.36 D (range: 39.50 - 46.28 D)
- ✓ ACD 3.22 ± 0.37 mm (range: 2.23 - 3.85 mm)
- ✓ LT 4.50 ± 0.37 mm (range: 3.44 - 5.22 mm)
- ✓ AL 23.95 ± 1.24 mm (range: 21.16 - 27.37 mm)
- ✓ IOL power 20.70 ± 3.40 D (range: 11.50 - 28.50 mm)



	Optimized constant	PE $\pm$ SD	MAE	MedAE	PE < $\pm$ 0.25	PE < $\pm$ 0.50	PE < $\pm$ 1.00
Haigis	-0.5059; 0.2428; 0.2038	0.00 $\pm$ 0.28	0.20	0.13	76.09%	90.32%	100.00%
Hoffer Q	5.67	0.00 $\pm$ 0.32	0.23	0.19	68.48%	89.25%	98.91%
Holladay 1	1.92	0.00 $\pm$ 0.32	0.24	0.17	67.39%	88.17%	100.00%
SRK/T	119.21	0.00 $\pm$ 0.33	0.25	0.19	64.13%	84.95%	100.00%
BUII (ESCRS)	119.08	-0.05 $\pm$ 0.27	0.21	0.18	68.48%	93.48%	100.00%
EVO (ESCRS)	119.08	0.00 $\pm$ 0.25	0.19	0.15	71.74%	93.48%	100.00%
H QST (ESCRS)	5.644	0.00 $\pm$ 0.27	0.20	0.14	72.83%	91.30%	100.00%
Kane (ESCRS)	119.08	0.01 $\pm$ 0.25	0.20	0.17	69.57%	95.65%	100.00%
BUII (webscraping)	119.17	0.00 $\pm$ 0.26	0.19	0.15	68.48%	96.74%	100.00%
EVO (webscraping)	119.08	0.00 $\pm$ 0.25	0.18	0.14	73.91%	94.57%	100.00%
HQST (hofferqst.com)	5.64	0.00 $\pm$ 0.27	0.19	0.13	77.17%	92.39%	100.00%
Kane (webscraping)	119.09	0.00 $\pm$ 0.25	0.19	0.13	73.91%	95.65%	100.00%



The percentage (60%) is lower for **short eyes**

Table 4. Prediction errors in the short axial length group for each formula.

Formula	Haigis	Hoffer Q	Holladay I	SRK/T	Barrett Universal II	T2	Holladay 2
MAE	0.473	0.499	0.453	0.458	0.469	0.459	0.466
MedAE	0.334	0.441	0.377	0.397	0.395	0.415	0.383
ME	-0.09	-0.22	-0.07	-0.04	-0.26	-0.10	-0.07
Eyes within PE (%)							
±0.25 D	36.5	28.2	29.5	32.7	30.8	33.3	31.4
±0.50 D	62.8	55.8	63.5	59.6	62.2	60.3	61.5
±1.00 D	91.0	91.0	92.3	92.3	92.3	92.9	91.7
±2.00 D	100.0	100.0	99.4	99.4	100.0	99.4	100.0

MAE = mean absolute prediction error; MedAE = median absolute prediction error; ME = mean prediction error; PE = prediction error

Kane et al. JCRS 2016

Short eyes

✓ Better outcomes with newer formulas

- K6 (70.5%)
- Kane (72.2%)
- Naeser 2 (71.4%)
- Olsen (70.9%)
- VRF-G (73.0%)

Table 2. Refractive outcomes and optimized constants obtained by each formula in eyes with AL ≤ 22.0 mm.

n	241								Percentage of Eyes within PE (%)				
	Optimized Constants								PE	PE	PE	PE	PE
Formula	SA60AT	SN60WF	PE	SD	PE Kurtosis	PE Skewness	MedAE	MAE	≤ 0.25 D	≤ 0.50 D	≤ 0.75 D	≤ 1.00 D	≤ 2.00 D
BUII	1.75	1.88	-0.034	0.559	0.406	-0.211	0.340	0.428	41.49	65.56	84.23	91.29	100.00
EVO 2.0	118.80	119.00	0.043	0.520	0.706	-0.074	0.325	0.411	39.00	70.12	83.82	95.02	100.00
Haigis	-0.111	-0.769	0.003	0.549	0.569	0.102	0.335	0.416	42.74	66.80	83.40	92.95	100.00
	0.249	0.234											
	0.179	0.217											
Hoffer Q	5.44	5.64	-0.125	0.521	0.653	-0.057	0.324	0.404	40.66	68.05	85.06	94.19	100.00
Holladay 1	1.67	1.84	-0.050	0.557	0.793	0.212	0.341	0.429	40.25	68.05	84.65	92.12	100.00
Holladay 2	5.40	5.52	-0.167	0.522	0.619	0.053	0.350	0.431	36.93	65.98	83.82	94.19	100.00
K6	118.80	119.00	0.024	0.506	0.461	-0.212	0.308	0.394	42.32	70.54	86.72	95.02	100.00
Kane	118.80	119.00	-0.002	0.509	0.982	-0.173	0.300	0.387	45.64	72.20	86.31	95.44	100.00
LSF AI	118.80	119.00	-0.175	0.589	0.510	-0.151	0.365	0.468	35.68	65.98	80.08	88.38	100.00
Naeser 2	1.879	1.093	-0.041	0.510	1.348	-0.324	0.277	0.386	48.13	71.37	87.55	94.19	99.59
	0.926	0.958											
Olsen	4.75	4.75	-0.087	0.504	0.842	-0.150	0.310	0.394	41.91	70.95	86.72	95.02	100.00
	0.41	0.41											
Panacea	118.80	119.00	0.141	0.622	0.689	0.252	0.390	0.492	33.61	62.24	75.93	89.21	99.17
Pearl-DGS	118.80	119.00	0.116	0.526	0.707	-0.030	0.335	0.421	37.76	68.46	85.48	93.78	100.00
RBF 2.0	118.80	119.00	-0.011	0.534	0.425	-0.059	0.325	0.413	40.24	67.65	86.33	92.95	100.00
SRK/T	118.80	119.00	0.101	0.635	0.784	0.313	0.359	0.483	39.83	62.24	77.59	89.21	99.59
T2	118.80	119.00	0.027	0.604	0.909	0.376	0.353	0.453	42.74	63.49	81.33	89.21	99.59
VRF	5.35	5.52	-0.012	0.533	0.940	0.050	0.321	0.409	41.49	69.71	86.31	94.19	100.00
VRF-G	118.80	119.00	0.021	0.501	1.129	-0.275	0.276	0.381	48.13	73.03	88.38	95.02	100.00

PE = mean prediction error. SD = standard deviation of the error. MedAE = median absolute error. MAE = mean absolute error. D = diopter. n = number of cases.

Voytsekhivskyy et al. Curr Eye Res 2021;12:1832

Short eyes

✓ Better outcomes with newer formulas

- Castrop (74.7%)
- Kane (78.7%)
- Okulix (79.3%)
- Pearl-DGS (80%)

Wendelstein et al. BJO 2022;106:795

Method	Subgroup	MAE	MedAE	ME	SD	MedE	% PE ≤0.25D	% PE ≤0.5D	% PE ≤0.75D	% PE ≤1.0D
Barrett	SA60AT	0.49	0.32	-0.16	0.65	-0.05	40.5	63.1	78.4	82.9
	ZCB00	0.50	0.34	-0.34	0.61	-0.20	41	61.5	71.8	89.7
	All	0.49	0.33	-0.20	0.64	-0.09	40.7	62.7	76.6	84.7
Castrop	SA60AT	0.33	0.28	-0.03	0.43	0.02	43.2	73.9	92.8	97.3
	ZCB00	0.32	0.27	-0.07	0.40	0.02	48.7	76.9	94.9	100
	All	0.33	0.27	-0.04	0.42	-0.01	44.7	74.7	93.3	99.3
EVO 2.0	SA60AT	0.38	0.34	0.21	0.45	0.20	39.6	71.2	90.1	95.5
	ZCB00	0.41	0.26	0.24	0.42	0.31	28.2	66.7	89.7	100.0
	All	0.39	0.30	0.22	0.44	0.22	36.7	70	90	96.7
Haigis	SA60AT	0.39	0.31	-0.07	0.49	-0.05	42.3	70.3	85.6	93.7
	ZCB00	0.41	0.41	-0.02	0.49	0.02	33.3	61.5	84.6	100
	All	0.39	0.32	-0.06	0.49	-0.01	40.0	68.0	85.3	95.3
Hill-RBF	SA60AT	0.39	0.32	-0.10	0.50	-0.08	42.3	73.0	83.8	94.6
	ZCB00	0.37	0.35	-0.11	0.46	-0.06	43.6	74.4	87.2	97.4
	All	0.38	0.32	-0.10	0.49	-0.06	42.7	73.3	84.7	95.3
HofferQ	SA60AT	0.46	0.38	-0.28	0.53	-0.24	40.5	62.2	82.9	90.1
	ZCB00	0.50	0.34	-0.45	0.48	-0.34	38.5	56.4	71.8	84.6
	All	0.47	0.38	-0.32	0.52	-0.26	40.0	60.7	80	88.7
Holladay	SA60AT	0.42	0.36	0.11	0.53	0.12	40.5	64.0	84.7	93.7
	ZCB00	0.37	0.25	-0.18	0.45	-0.17	51.3	74.4	87.2	94.9
	All	0.41	0.34	0.03	0.53	0.06	43.3	66.7	85.3	94.0
Holladay 2	SA60AT	0.43	0.38	-0.22	0.50	-0.23	39.6	64.9	82.0	92.8
	ZCB00	0.42	0.41	-0.35	0.46	-0.29	41.0	69.2	76.9	89.7
	All	0.43	0.38	-0.26	0.49	-0.24	40.0	66.0	80.7	92.0
Kane	SA60AT	0.34	0.30	0.06	0.43	0.05	40.5	79.3	92.8	95.5
	ZCB00	0.38	0.35	-0.21	0.44	-0.24	38.5	76.9	89.7	97.4
	All	0.35	0.30	-0.01	0.45	0.02	40.0	78.7	92.0	96.0
Okulix	SA60AT	0.34	0.30	-0.08	0.43	-0.07	44.1	80.2	90.1	98.2
	ZCB00	0.33	0.28	0.07	0.39	0.10	48.7	76.9	94.9	100
	All	0.34	0.30	-0.04	0.42	-0.05	45.3	79.3	91.3	98.7
Olsen	SA60AT	0.40	0.33	0.12	0.47	0.18	35.1	68.5	88.3	98.2
	ZCB00	0.41	0.32	-0.23	0.48	-0.21	46.2	74.4	87.2	92.3
	All	0.40	0.33	0.03	0.50	0.08	38.0	70.0	88.0	96.7
Pearl-DGS	SA60AT	0.34	0.27	0.10	0.43	0.10	48.6	77.5	93.7	96.4
	ZCB00	0.29	0.26	-0.10	0.36	-0.07	48.7	87.2	94.9	97.4
	All	0.33	0.26	0.03	0.42	0.03	48.7	80	94.0	96.7
SRK/T	SA60AT	0.54	0.45	0.35	0.61	0.35	31.5	53.2	73.9	88.3
	ZCB00	0.40	0.36	-0.05	0.48	0.08	30.7	59.3	77.3	90.0
	All	0.50	0.42	0.25	0.60	0.22	28.2	76.9	87.2	94.9

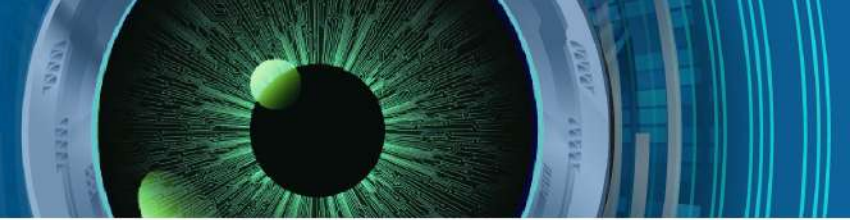
Short eyes

✓ Better outcomes with newer formulas

- EVO 2.0 (76.9%)
- Hoffer QST (74.4%)
- K6 (79.5%)
- Pearl-DGS (80.8%)

Formula	Optimized constant	MPE ± SD (D)	MedAE (D)	MAE (D)	MaxAE (D)	PE (%) <			
						0.25 D	0.50 D	0.75 D	1.00 D
New formulas									
B II	2.00	0.09 ± 0.418	0.31	0.35	1.01	38.5	70.5	93.6	98.7
BTAL	1.97	−0.07 ± 0.396	0.30	0.33	0.86	42.3	71.8	97.4	100.0
EVO	119.12	−0.11 ± 0.383	0.28	0.33	0.87	41.0	76.9	97.4	100.0
Hill-RBF ^a	119.22	0.18 ± 0.418	0.32	0.38	1.14	34.6	71.8	92.3	97.4
Hoffer QST	5.72	−0.00 ± 0.411	0.34	0.36	0.95	41.0	74.4	96.2	100.0
HOL2	5.65	−0.15 ± 0.437	0.36	0.38	1.09	34.6	68.0	92.3	97.4
HOL2-NLR	5.64	−0.11 ± 0.437	0.35	0.38	1.13	30.8	70.5	94.9	97.4
K6	119.22	0.09 ± 0.376	0.26	0.31	1.02	47.4	79.5	96.2	98.7
Kane	119.19	0.02 ± 0.422	0.35	0.36	1.03	37.2	69.2	96.2	98.7
Olsen	4.74	0.04 ± 0.383	0.28	0.32	0.88	42.3	79.5	94.9	100.0
P-DGS	118.60	−0.04 ± 0.377	0.27	0.32	0.86	47.4	80.8	97.4	100.0
T2	119.24	−0.02 ± 0.428	0.34	0.36	0.92	35.9	71.8	93.6	100.0
VRF	5.70	−0.06 ± 0.428	0.33	0.36	1.04	37.2	73.1	94.9	98.7
Traditional formulas									
Haigis	^b	0.05 ± 0.462	0.36	0.38	1.10	38.5	66.7	91.0	98.7
Hoffer Q	5.75	−0.08 ± 0.461	0.37	0.38	0.94	38.5	66.7	85.9	100.0
Holladay 1	1.98	0.02 ± 0.434	0.33	0.37	0.93	35.9	71.7	94.9	100.0
SRK/T	119.25	−0.02 ± 0.453	0.31	0.37	1.02	39.7	70.5	88.5	98.7

Shammas et al. JCRS 2022



In long myopic eyes, hyperopic surprises are frequent with traditional formulas

Accuracy of Intraocular Lens Calculations Using the IOLMaster in Eyes with Long Axial Length and a Comparison of Various Formulas

Stacy Bang, MD,¹ Erica Edell, MD,¹ Qilu Yu, PhD,² Kim Pratzner, AA, COT, ROUB,¹ Walter Stark, MD¹

Purpose: To evaluate the relationship between eyes with long axial length (AL) and postoperative refractive errors as predicted by various commonly used intraocular lens (IOL) formulas using the Zeiss IOLMaster (Carl Zeiss Meditec, Jena, Germany).

Design: Retrospective chart review.

Participants: A total of 53 eyes of 36 patients with an AL of more than 27 mm who underwent uncomplicated cataract extraction with IOL implantation.

Methods: Data were obtained from patient charts and the IOLMaster.

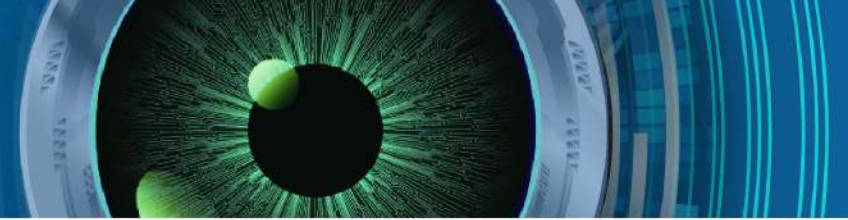
Main Outcome Measures: The main parameters assessed were AL, preoperative best-corrected visual acuity (BCVA), postoperative BCVA, and mean absolute error (actual postoperative spherical equivalent minus predicted postoperative spherical equivalent). Mean absolute error was calculated using predicted spherical equivalents obtained from the Holladay 1, Holladay 2, SRK/T, Hoffer Q, and Haigis formulas.

Results: The Haigis formula was found to be the most accurate in predicting postoperative refractive error in long eyes. The SRK/T formula was the second most accurate, followed by the Holladay 2, then the Holladay 1, then the Hoffer Q. All formulas predicted a more myopic outcome than was actually achieved.

Conclusions: These results suggest using the Haigis, SRK/T, or Holladay 2 formulas for very long eyes. It is also advisable to aim for a more myopic result than is intended.

Financial Disclosure(s): The author(s) have no proprietary or commercial interest in any materials discussed in this article. *Ophthalmology* 2011;118:503-506 © 2011 by the American Academy of Ophthalmology.

This study determined that all 5 formulas, using data obtained from the IOLMaster, resulted in postoperative hyperopic surprises. Furthermore, subgroup analyses re-



Low percentage of eyes with a prediction error within ± 0.50 D

Accuracy of Intraocular Lens Calculations Using the IOLMaster in Eyes with Long Axial Length and a Comparison of Various Formulas

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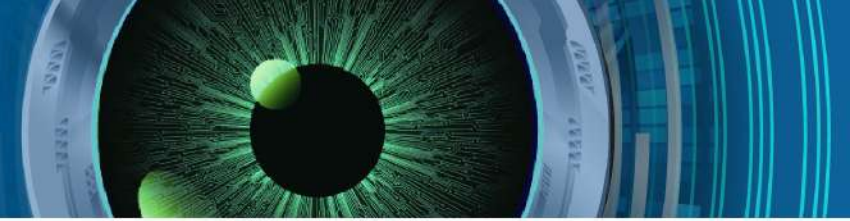
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Table 3. Percentages of Eyes with Mean Absolute Errors of <0.5 Diopter, <1 Diopter, <2 Diopters, and <3 Diopters

Formula	Percentage of Mean Absolute Error			
	<0.5 Diopter	<1 Diopter	<2 Diopters	<3 Diopters
Holladay 1	26.4%	62.3%	98.0%	100%
Holladay 2	41.5%	62.3%	94.3%	100%
SRK/T	50.9%	66.0%	96.2%	100%
Hoffer Q	34.0%	60.4%	79.3%	100%
Haigis	56.6%	73.6%	98.1%	100%

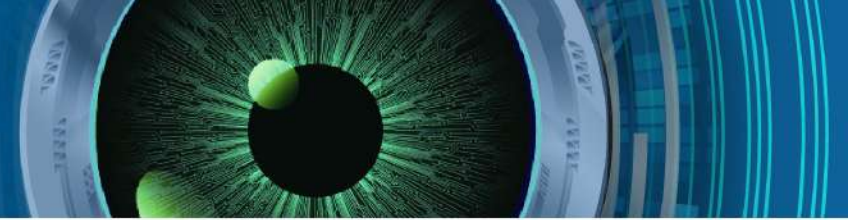


Long eyes

Barrett has been the first to introduce the optimized axial length, followed by the authors of the other formulas:

- ✓ EVO 2.0
- ✓ Hoffer QST
- ✓ Kane
- ✓ Naeser
- ✓ Olsen

Cooke K6 and Pearl-DGS use CMAL



Which are the results of modern formulas in eyes with axial length > 26 mm?

378

ARTICLE

Comparison of the new Hoffer QST with 4 modern accurate formulas

Leonardo Taroni, MD, Kenneth J. Hoffer, MD, FACS, Marco Pellegrini, MD, Enrico Lupardi, MD, Giacomo Savini, MD

Purpose: To investigate the new Hoffer QST (Savini/Taroni) formula (HQST) and compare it with the original Hoffer Q (HQ) and 4 latest generation formulas.

Setting: I.R.C.C.S. — G.B. Bietti Foundation, Rome, Italy.

Design: Retrospective case series.

Methods: Refractive outcomes of the HQST, Barrett Universal II (BUII), Emmetropia Verifying Optical (EVO) 2.0, HQ, Kane, and Radial Basis Function (RBF) 3.0 formulas were compared. Sub-group analysis was performed in short (<22 mm) and long (>25 mm) axial length eyes. The SD of the prediction error (PE) was investigated using the heteroscedastic method.

Results: 1259 eyes of 1259 patients divided in a White group (n=696), implanted with the AcriSof SN60AT (Alcon Labs), and an Asian group (n=563), implanted with the SN60WF (Alcon Labs), were investigated. In the Asian group, the heteroscedastic method did not disclose any significant difference among the SD of the 4 modern formulas (range from 0.333 to 0.346 D), whereas the SD of the HQ formula (0.384 D) was significantly higher. Compared with the original HQ formula, in both White and Asian groups, the HQST formula avoided the mean myopic PE in short eyes and the mean hyperopic PE in long eyes.

Conclusions: The new HQST formula was superior to the original HQ formula and reached statistical and clinical results comparable with those achieved by the BUII, EVO, Kane, and RBF formulas.

J Cataract Refract Surg 2023; 49:378–384 Copyright © 2023 Published by Wolters Kluwer on behalf of ASCRS and ESCRS

Table 2. Optimized constants and refractive outcomes of the White group

Formula	Optimized constant	PE ± SD (D)	RMS-PE	MAE (D)	MedAE (D)	% <0.25 D	% <0.50 D	% <0.75 D	% <1.00 D
All eyes (n = 696)									
BUII	118.58	0.00 ± 0.538	0.538	0.39	0.30	43.68	72.56	87.70	95.40
EVO	118.67	0.00 ± 0.464	0.464	0.35	0.30	44.68	76.87	89.37	96.84
HQ	5.39	0.00 ± 0.535	0.535	0.40	0.31	43.25	73.13	85.49	93.39
HQST	5.38	0.00 ± 0.470	0.470	0.36	0.29	45.26	76.29	89.66	96.70
Kane	118.64	0.00 ± 0.474	0.474	0.36	0.30	45.69	76.29	88.07	95.98
RBF 3.0	118.61	-0.02 ± 0.503	0.503	0.38	0.30	43.53	74.71	88.36	94.97
Short eyes (n = 75)									
BUII		-0.14 ± 0.795	0.997	0.58	0.38	34.72	61.81	75.00	84.03
EVO		-0.03 ± 0.590	0.677	0.44	0.35	37.50	70.83	83.33	90.28
HQ		-0.27 ± 0.669	0.905	0.52	0.38	35.42	64.58	75.00	85.42
HQST		0.03 ± 0.593	0.688	0.44	0.34	37.50	68.06	81.94	92.36
Kane		-0.05 ± 0.604	0.705	0.45	0.35	40.28	68.06	80.56	88.89
RBF 3.0		-0.16 ± 0.688	0.865	0.52	0.40	33.33	62.50	78.47	83.33
Medium eyes (n = 534)									
BUII		0.05 ± 0.44	0.448	0.35	0.28	46.47	75.65	90.33	97.96
EVO		0.01 ± 0.43	0.426	0.33	0.28	47.58	79.37	91.08	98.14
HQ		0.01 ± 0.45	0.446	0.34	0.29	47.03	77.88	90.33	97.21
HQST		0.02 ± 0.43	0.430	0.33	0.27	47.58	79.37	91.64	98.14
Kane		0.02 ± 0.43	0.432	0.33	0.27	47.58	78.81	90.33	97.77
RBF 3.0		0.01 ± 0.43	0.433	0.33	0.29	46.65	78.44	91.64	97.77
Long eyes (n = 87)									
BUII		0.05 ± 0.465	0.465	0.39	0.35	40.23	72.41	86.21	98.85
EVO		0.00 ± 0.458	0.455	0.37	0.34	39.08	72.41	88.51	98.85
HQ		0.32 ± 0.510	0.600	0.48	0.37	33.33	62.07	75.86	88.51
HQST		-0.03 ± 0.475	0.473	0.39	0.32	42.53	72.41	89.66	96.55
Kane		0.02 ± 0.468	0.466	0.38	0.34	42.53	74.71	86.21	96.55
RBF 3.0		0.10 ± 0.465	0.474	0.38	0.32	40.23	72.41	85.06	96.55



Which are the results of modern formulas in eyes with axial length > 26 mm?

1195

ARTICLE

Efficacy of corneal curvature on the accuracy of 8 intraocular lens power calculation formulas in 302 highly myopic eyes

Er Mo, MD, Ke Feng, MD, Qiyuan Li, MD, Jingyuan Xu, MD, Jiaying Cen, MD, Jin Li, MD, PhD, Yun-e Zhao, MD

Purpose: To investigate the effect of corneal curvature (K) on the accuracy of 8 intraocular lens formulas in highly myopic eyes.

Setting: Eye Hospital and School of Ophthalmology and Optometry, Wenzhou Medical University, Wenzhou, China.

Design: Retrospective consecutive case series.

Methods: 302 eyes (302 patients) were analyzed in subgroups based on the K value. The mean refractive error, mean absolute error (MAE), median absolute error (MedAE), root-mean-square absolute prediction error (RMSAE) and proportions of eyes within ± 0.25 D, ± 0.50 D, ± 0.75 D, ± 1.00 D were statistical analyzed.

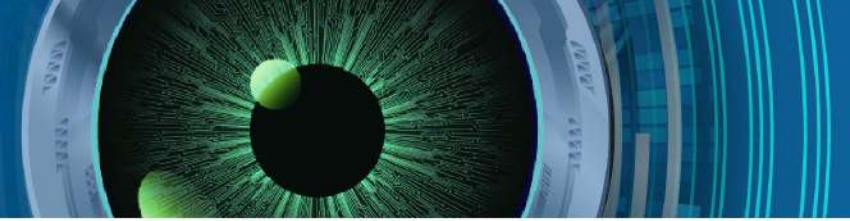
Results: Emmetropia-Verifying Optical (EVO) 2.0, Kane, and Radial Basis Function (RBF) 3.0 had the lower MAE (≤ 0.28) and RMSAE (≤ 0.348) and highest percentage of eyes within ± 0.50 D ($\geq 83.08\%$) in the flat (K ≤ 43 D) and steep K (K > 45 D) groups. Hoffer QST had the lowest MedAE (0.19), RMSAE (0.351) and the highest percentage of eyes within ± 0.50 D (82.98%) in the normal K group (K < 43 D). When axial length (AL) < 26 mm, all formulas showed close RMSAE values (0.322 to 0.373) in flat K group. When AL > 26 mm, RBF 3.0 achieved the lowest MAE (≤ 0.24), MedAE (≤ 0.17) and RMSAE (≤ 0.337) across all subgroups.

Conclusions: EVO 2.0, Kane, and RBF 3.0 were the most accurate in highly myopic eyes with a flat or steep K. Hoffer QST is recommended for long eyes with normal K values. RBF 3.0 showed the highest accuracy when AL > 26 mm, independent of corneal curvature.

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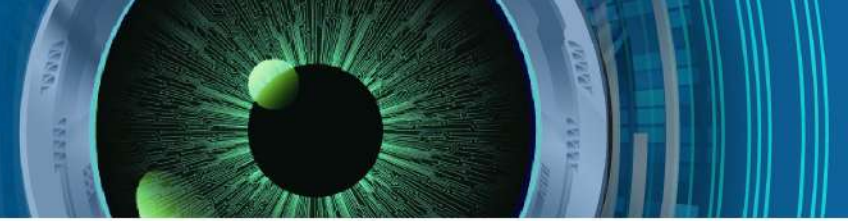
Table 2. Refractive prediction errors of 8 intraocular lens power calculation formulas overall in the highly myopic eyes (N = 302)

Formulas	ME $\pm$ SD	MAE $\pm$ SD	MedAE	RMSAE	Percentage of eyes within different PE (%)			
					± 0.25 D	± 0.50 D	± 0.75 D	± 1.00 D
BU II	0.15 $\pm$ 0.34	0.29 $\pm$ 0.23	0.23	0.369	52.98	80.79	96.36	99.67
EVO 2.0	0.09 $\pm$ 0.33	0.26 $\pm$ 0.21	0.21	0.338	57.28	84.44	97.02	99.67
Hoffer QST	-0.13 $\pm$ 0.36	0.29 $\pm$ 0.24	0.23	0.378	53.64	82.12	94.37	98.68
K6	0.20 $\pm$ 0.35	0.33 $\pm$ 0.25	0.29	0.409	44.70	76.49	94.04	99.34
Kane	0.03 $\pm$ 0.34	0.27 $\pm$ 0.21	0.23	0.340	55.30	86.09	97.02	99.67
Nallasamy	0.14 $\pm$ 0.35	0.31 $\pm$ 0.22	0.25	0.377	49.00	79.80	96.03	99.67
Pearl-DGS	0.26 $\pm$ 0.37	0.37 $\pm$ 0.26	0.32	0.454	37.09	73.51	89.74	98.34
RBF 3.0	0.11 $\pm$ 0.32	0.26 $\pm$ 0.22	0.21	0.342	56.95	86.75	97.02	99.34



Conclusions

- ✓ Use new-generation formulas on the ESCRS IOL calculator
- ✓ We can obtain up to 80% of eyes with a prediction error within 0.5 D both in short and long eyes (and >90% in the whole population)



Thanks

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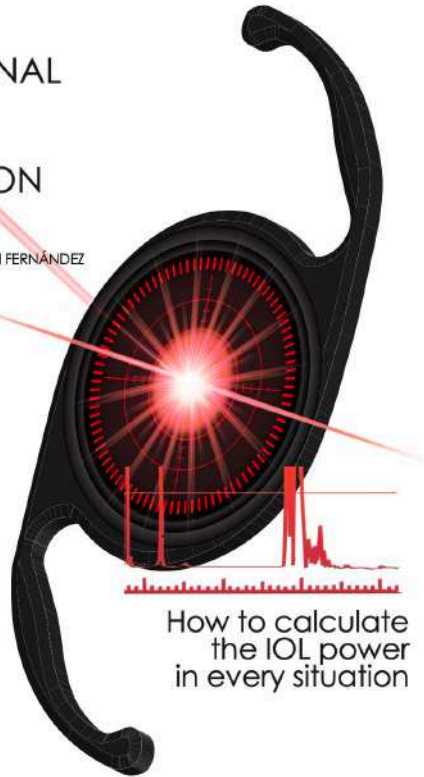
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