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The VRF and VRF-G Formulas

Oleksiy V. Voytsekhivskyy

The main method for the calculation of lens power, in most cases, still uses a technique that is based on paraxial optics, which is a simplified version of geometric ray tracing [1–4]. In this case, it is possible to significantly simplify the mathematical calculations and to reduce them to a relatively simple formula in relation to the optical system of the human eye, which can be represented by a system of two thin lenses (IOL and the cornea) as follows [3, 4]:

$$P = \frac{n \times 1000}{\mathrm{AL} - C} - \frac{n \times 1000}{V - C}; V = \frac{n \times 1000}{K}; K = \frac{1000 \times (\mathrm{nc} - 1)}{r};$$

where P is the optical power of the implanted IOL (D), n is the refraction index of the optical medium (1.336, aqueous humor; 1.000, air), C is the postoperative ELP (mm), AL is the axial length of the eye (mm), K is the refractive corneal power (D), nc is the refractive index of the cornea (1.3375), 1 is the refractive index of air (1.000), and r is the radius of the front surface of the cornea (mm).

The main advantage of this method is its relative simplicity and the need for only one parameter to calculate the IOL power; it is a specific constant determined by the manufacturer of this type of lens. The majority of modern formulas and methods use this formula to calculate the optical power of the intraocular lens with some correction factors; the difference lies only in the method of predicting the postoperative position of the intraocular lens in the eye [5, 6].

Investigation of Formula

Similar to all currently existing formulas for the calculation of intraocular lens power, this formula can in principle be divided into two main parts: the main formula and the method of predicting the postoperative position of the lens in the eye (ELP). This method uses the so-called classical stigmatic, paraxial optical formula [3, 4], which was proposed more than 150 years ago. Two reference values were used as correction factors: the factor correcting the axial length of the eye and the factor correcting the true refractive power of the cornea. Different authors used different values in their formulas. Binkhorst did a correction for the value of axial length of 0.25 mm and Holladay for 0.20 mm, and Hoffer used no correction factor [6, 7]. The value 0.20 mm for

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axial length correction was used because it yielded the best result for calculation according to this new method and was similar to that used by other researchers (Binkhorst; Holladay and associates) [3, 4, 6]. For highly myopic eyes was used correction factor obtained empirical way: if

$$\text{AL} \geq 26.5\,\text{mm}, \text{AL0} = \text{AL} + \left(-0.159 \times \text{AL} + 4.401\right).$$

The second factor is associated with the conversion of the refractive power of the cornea in true optical power. Recently, many authors [3, 4, 7, 8] have shown the irrationality of using the classic 1.3375 index refraction and the error in the refractive power of the cornea from 0.5 to 1 diopter [3, 4]. The standardized keratometric index of refraction was chosen many years ago, so that an anterior radius of curvature of the cornea of 7.5 mm would yield a power of 45.0 D. The cornea is a thick lens with two surfaces and thicknesses. Using the index of refraction of the corneal stroma of 1.376, a posterior corneal radius that is 1.2 mm steeper, and a corneal thickness of 0.55 mm results in a net corneal power of 44.4 D. This value is approximately 0.56 D less than the standardized keratometric power. As described in detail by Holladay, the value of 4/3 for the net corneal index of refraction is an appropriate value and would have the minimum impact and thus was recommended for use in modern formulas. Olsen recommends using an even lower value of 1.3315 that yielded an appropriate corneal power of 44.20 diopters [3]. Holladay's value of the refraction index was chosen (1.3333) because a more appropriate result was achieved with it than using Olsen value (1.3315) that overestimated the resulting IOL power [3, 5, 9]. Therefore, we used the following correction factor:

$$\text{Ktrue} = \frac{\left(4/3 - 1\right)}{\left(1.3375 - 1\right)} = 0.98765431 \times K.$$

Thus, we used a classical stigmatic, paraxial optical formula with an adjusted axial length and a correction of the true optical power of the cornea:

$$P = \frac{1336}{\text{AL}_0 - C} - \frac{1336}{\dfrac{1336}{\dfrac{1000}{\dfrac{1000}{\text{tgRef}} - \text{Vd}} + \text{Ktrue}} - C};$$

$$\text{AL}_0 = \text{AL} + 0.20, \text{if AL} \geq 26.5\,\text{mm}, \text{AL}_0 = \text{AL} + \left(-0.159 \times \text{AL} + 4.401\right).$$

P is the optical power of the implanted IOL for emmetropia (D), *n* is the refraction index of aqueous humor and vitreous liquid (1.336) and air (1.000), AL is the axial length of the eye (mm), *C* is the postoperative estimated lens position (ELP) (mm), tgRef is the target postoperative refraction (D), Vd is the spectacle back vertex distance (mm), *K* is the refractive corneal power (D), AL0 is the true axial length (mm), Ktrue is the true refractive corneal power (D), and 0.20 and (−0.159 × AL + 4.401) are the correction factors of the axial length (mm).

The second and the main part of our formula is a method of predicting the postoperative position of IOL in the eye. Hoffer was one of the first authors who suggested considering this value; for the first time, he applied a factor in changing the ELP values using the axial lengthof the eye. In 1988, Holladay suggested using two variables; namely, he added the value of the refractive power of the cornea to the axial length of the eye and suggested the term "effective lens position." [3, 4] Furthermore, the number of variables used to predict the postoperative position of the lens increased, and some authors suggested considering additional parameters, which are associated with anatomic changes in the anterior segment of the eye [1, 5, 8].

Thus, there are two unknown values in any formula: the optical power of the lens and the postoperative position of the lens in the eye. As we cannot change the first unknown value, the second value is the key in any IOL calculation formula. The main difference between all the formulas used in this study lies in the difference of the algorithms for predicting the postoperative position of lens, which actually determines the optical power IOL.

Investigation of Estimated Lens Position

To obtain the regression algorithm of ELP prediction, we used the data group of patients with two different types of lenses, Alcon ReSTOR SN6AD1 (169 eyes) and AMO Tecnis MF ZMB00 (160 eyes). In total, there were 329 eyes.

Based on the data of the preoperative parameters of the eye (AL, K, ACDpre, and CD), the values of the optical power of the two different types of implanted IOLs and the received postoperative manifest refraction empirically based on the multiple regression analysis (SPSS 22.0, IBM) obtained the equation describing the postoperative position of the IOL in the eye, namely the postoperative ELP. To develop the regression formula, multiple linear regression was performed using the ELP as the dependent variable and the axial length (AL), corneal power (K), preoperative anterior chamber depth (epithelium to lens) (ACDpre), and horizontal corneal diameter (CD) as independent variables. For each value of the predicted postoperative ACD, the corresponding regression equation was obtained. More than 700 iterations were performed to obtain the averaged regression equation model. Accordingly, for two different types of lenses (Alcon ReSTOR SN6AD1 and AMO Tecnis MF ZMB00), two regression models were derived as follows:

$$\begin{aligned}&\mathrm{AL}\times(\mathrm{CACD}\times 0.051-0.006)+K\times(\mathrm{CACD}\times 0.019-0.008)+\mathrm{ACDpre}\\&\quad\times(\mathrm{CACD}\times 0.053+0.005)-\mathrm{CD}\times(\mathrm{CACD}\times 0.013-0.003)-(\mathrm{CACD}\times 0.959-0.013);\end{aligned}\tag{55.1}$$

$$\begin{aligned}&\mathrm{AL}\times(\mathrm{CACD}\times 0.050-0.007)+K\times(\mathrm{CACD}\times 0.018-0.001)+\mathrm{ACDpre}\\&\quad\times(\mathrm{CACD}\times 0.056+0.004)-\mathrm{CD}\times(\mathrm{CACD}\times 0.012-0.003)-(\mathrm{CACD}\times 0.974-0.005);\end{aligned}\tag{55.2}$$

where CACD is an ACD constant from the manufacturer, AL is the axial length of the eye (optical method) (mm), K is the refractive power of the cornea (D), $K = (\mathrm{nc} - 1)/r$ (D), r is the radius of curvature of the anterior corneal surface (mm), nc is the refractive index of 1.3375, ACDpre is the preoperative anterior chamber depth (epithelium to lens) (mm), and CD is the horizontal corneal diameter (mm).

Equation (55.1) had a higher correlation coefficient ($R^2 = 0.922$ vs. $R^2 = 0.895$) and a lower standard error (0.316 vs. 0.334) than Eq. (55.2) and was therefore selected for further evaluation. A new formula was programmed using Eq. (55.1). The proposed method was called Voytsekhivskyy regression function (VRF). Thus, in the new formula, the ELP is a function of five variables as follows:

$$\mathrm{ELP} = f(\mathrm{CACD};\mathrm{AL};K;\mathrm{ACDpre};\mathrm{CD});$$

$$\begin{aligned}\mathrm{ELP} = {}&\mathrm{AL}\times(\mathrm{CACD}\times \mathrm{D1}-\mathrm{E1})+K\times(\mathrm{CACD}\times \mathrm{D2}-\mathrm{E2})+\mathrm{ACDpre}\\&\times(\mathrm{CACD}\times \mathrm{D3}+\mathrm{E3})-\mathrm{CD}\times(\mathrm{CACD}\times \mathrm{D4}-\mathrm{E4})-\mathrm{offset};\end{aligned}$$

where AL is the axial length of the eye (optical method) (mm), K is the refractive power of the cornea (D) and $K = (nc - 1)/r$ (D), r is the radius of curvature of the anterior corneal surface (mm), nc is the refractive index of 1.3375, ACDpre is the preoperative anterior chamber depth (epithelium to lens) (mm), CD is the horizontal corneal diameter (mm), CACD is an ACD constant from the manufacturer, D constants 1–4 and E constants 1–4 are the regression constants obtained empirically by the study, and the offset is the regression equation obtained empirically.

The regression constants are as follows:

$$D1 = 0.051; D2 = 0.019; D3 = 0.053; D4 = 0.013;$$

$$E1 = 0.006; E2 = 0.008; E3 = 0.005; E4 = 0.003.$$

The offset is given by

$$\text{Offset} = \text{CACD} \times 0.959 - 0.013.$$

CACD Constant of VRF Formula

The main feature of this algorithm is the use of a single IOL constant that is repeated several times and not the use of a number of different constants [8, 10]. Each of the four preoperative parameters of the eye affects a constant and gives a final value corresponding to the postoperative position of the IOL in the eye. The so-called optical constant of the anterior chamber depth (optical CACD) was used as a constant. The CACD constant was used exclusively as the optical constant due primarily to the fact that the sample was taken from patients whose AL was measured using an optical method (PCI, IOLMaster 500, software version 7.3, Carl Zeiss Meditec AG, Jena, Germany).

There is a method to determine the appropriate optical CACD. The option is to use the regression equation proposed by Haigis [10, 11] for optimized constants to obtain the values of the optical CACD constant from the optical A-constants given by the manufacturer.

$$\text{Optical CACD constant} = \left(\text{Optical A} - \text{constant} \times 0.62467\right) - 68.82.$$

where the optical CACD is a constant depth of the anterior chamber for optical measurement techniques, and the optical A-constant is a constant for optical measurement techniques by the manufacturer of the intraocular lens.

Evaluation of VRF Formula

The aim of this study was to develop and compare a new method for predicting the postoperative IOL position and further calculating the optical power of the implanted lens using four parameters: the axial length of the eye (AL), the optical refractive power of the cornea (K), the preoperative anterior chamber depth (epithelium to lens) (ACDpre), and the horizontal corneal diameter (CD). The clinical performance of the VRF formula was compared to that of the other formulas by calculating the spectacle prediction error of each formula in the evaluation subset of eyes using separate IOL-specific constants optimized for each formula. AcrySof IQ SN60WF IOL was used for the evaluation of the second subgroup of patients (494 eyes, Alcon Laboratories, Inc., Fort Worth, TX, USA). Overall, there was a good correlation between the prediction errors of the seven formulas (best, $r^2 = 0.905$ Haigis; worst, $r^2 = 0.844$ Holladay 2). In general, the VRF formula produced a prediction error similar to that of the Hoffer Q on short eyes, Holladay 1 on medium eyes, T2 on medium-long eyes, and SRK/T on long eyes but of smaller magnitude, as indicated in Fig. 55.1.

The main indicators of formula accuracy were the indices MedAE and MAE [12, 13]. Moreover, the value MedAE was less sensitive to outliers compared to MAE and allowed for a more precise estimate of the refractive error data.

The obtained results were very encouraging. In the first group with short AL (53 eyes), the best result was from the VRF method (MedAE 0.345 D) and the Hoffer Q formula (MedAE 0.350 D) and the worst result was produced by the SRK/T formula (MedAE 0.426 D), which was predictable in short eyes. For the medium AL group (320 eyes), the VRF formula demonstrated the highest accuracy (MedAE 0.302 D) and the least accuracy was demonstrated by the Holladay 2 formula (MedAE 0.338 D). The third group with medium-long AL (70 eyes) showed the best accuracy using the VRF formula (MedAE 0.301 D)

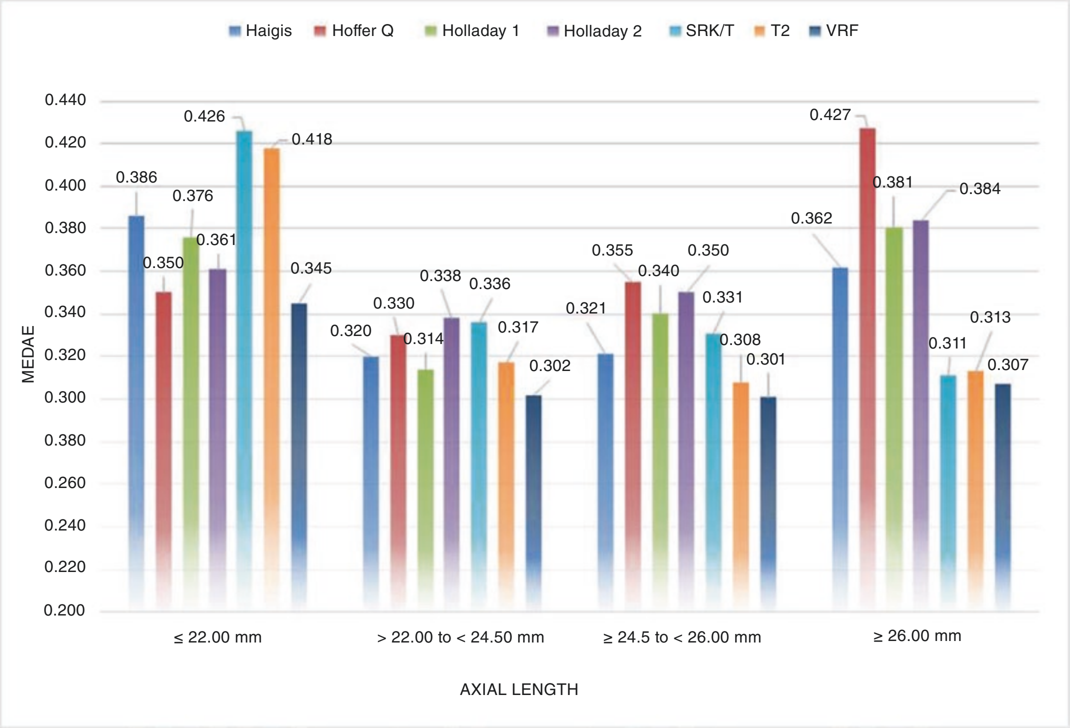


Fig. 55.1 Median absolute error plotted against axial length groups for the Haigis, Hoffer Q, Holladay 1, Holladay 2, SRK/T, T2, and VRF formulas

and the worst using the Hoffer Q formula (MedAE 0.355 D). In the long AL group (51 eyes), the best result was from the VRF (MedAE 0.307 D) and the worst result was from the Hoffer Q formula (MedAE 0.427 D). For the entire AL group, VRF showed better predictability than the other formulas (MedAE 0.305 D). However, there was a very small difference between the corresponding values; most of the formulas were stacked in the value of 0.01 diopters, which indicated the high accuracy of all the presented methods. Overall, 41.3% of the eyes were within ±0.25 D of prediction using the VRF formula and 39.0% using the Haigis formula. The other formulas had lower results of 35.0% for SRK/T and 38.0% for T2 and Hoffer Q. All formulas had prediction errors within ±2 D except T2 at 99.8%. There were no statistically significant differences between the formulas for short eyes, medium eyes (except Holladay 2 and SRK/T, $P < 0.005$, W-test), medium-long eyes, or long eyes (except Holladay 2, $P < 0.005$, W-test). For all axial length ranges, statistically significant differences were found for Holladay 2 ($P < 0.005$, W-test) and SRK/T ($P < 0.005$, W-test) formulas [14].

Recently, Savini et al. [15] studied the 13 formulas in a sample of 150 average eyes. The lowest MedAE values were achieved with the following formulas: Kane (0.200 D), T2 (0.200 D), Barrett (0.202 D), EVO (0.205 D), RBF (0.205 D), Olsen (standalone) (0.209 D), and VRF (0.215 D). Dunn's posttest analysis showed that only the following paired comparison had statistically significant differences ($P < 0.005$): EVO vs Haigis, EVO vs Hoffer Q, and RBF vs Haigis. The proportion of absolute errors less than ±0.50 D was more than 85% for almost all formulas. The calculation with the EVO and VRF formulas showed the best results on eyes with axial length > 26.00 mm (MedAE 0.168 D and 0.198 D respectively). The results from the current study confirm that the VRF (MedAE 0.210 D) was most accurate than the traditional formulas for average eyes with T2 (MedAE 0.200 D) as an exception (Haigis (MedAE 0.254 D), Hoffer Q (MedAE 0.248 D), Holladay 1 (MedAE 0.249 D), Holladay 2 (MedAE 0.228 D), and SRK/T (MedAE 0.221 D), respectively).

The VRF-G Formula

The first formula for calculating the optical power of the anterior chamber IOL was suggested by Fyodorov and associates in 1967 [16].

$$\mathrm{Dp} = \frac{n - a\mathrm{Dc}}{(a-k) \times \frac{(1-\mathrm{kDc})}{n}}; k = r - \sqrt{r^2} - \frac{d2}{4}; \mathrm{Dc} = \frac{1000 \times (\mathrm{nc}-1)}{r};$$

where "*a*" represents the axial length (in meters), "*k*" anterior chamber depth with the pupillary implant in place (in meters), "Dc" the refracting power of cornea (in diopters), "Dp" the refracting power of the intraocular lens (in diopters and assuming a thin lens), and "*n*" the refractive index of aqueous and vitreous (1.336).

For many years, formulas such as Hoffer Q, Holladay 1, and SRK/T were the gold standard for calculating IOL power, and they remain the standard for many ophthalmologists [3, 7, 17]. The third generation of formulas used two predictors to estimate postoperative lens position, including axial length and cornea power, whereas newer formulas use up to seven predictors (Holladay 2), and some of them even include race and sex (Hoffer H-5) and some just sex (Kane and VRF-G). Recently, more than 30 new methods and formulas for calculating IOL power have appeared (Fig. 55.2) [1, 2, 14, 18–26]. A new generation of IOL power formulas such as Barrett Universal II, Castrop, EVO 2.0, Hoffer QST, Cooke K6, Kane, Karmona, LSF AI, Naeser 2, Olsen, Panacea, Pearl-DGS, and RBF 3.0 have brought a new level of accuracy and allowed cataract surgery to become a refractive procedure. With the existence of many new methods and unsatisfied accuracy of traditional formulas on long eyes, the update of existing classical formulas appeared. The Wang-Koch modification was implemented for Holladay 1, Hoffer Q, and SRK/T formulas [27, 28].

Currently, there are many methods and principles for calculating the optical power of an intraocular lens (IOL). All existing methods can be divided into four groups: methods using the principles of paraxial approximation, or Gaussian optics; methods using the real, exact path of rays in the optical system of the eye, the so-called geometric optics, or ray tracing, models that are based on different algorithms of artificial intelligence (AI) and mixed mathematical algorithms

- Barrett Universal II
- Barrett True Axial Length (BTAL)
- Bayesian Additive Regression Trees (BART)
- Castrop
- Emmetropia Verifying Optical 2.0 (EVO)
- FullMonte IOL (2018)
- Haigis
- Hoffer H-5
- Hoffer Q
- Hoffer QST (Savini, Taroni)
- Hoffer Q (Wang-Koch)
- Holladay 1
- Holladay 1 (NLR)*
- Holladay 1 (MWK)□
- Holladay 1 (Wang-Koch)
- Holladay 2
- Holladay 2 (NLR)*
- Holladay 2 (Wang-Koch)
- Cooke K6
- Kane
- Karmona
- Ladas Super Formula AI (LSF AI)
- Naeser 2
- Nallasamy
- OKULIX
- Olsen (OLCR)
- Olsen (PhacoOptics)
- Panacea
- Pearl-DGS
- Radial Basis Function 3.0 (RBF)
- SRK/T
- SRK/T (MWK)□
- SRK/T (Wang-Koch)
- T2
- VRF
- VRF-G

* Nonlinear Regression □ Modified Wang-Koch

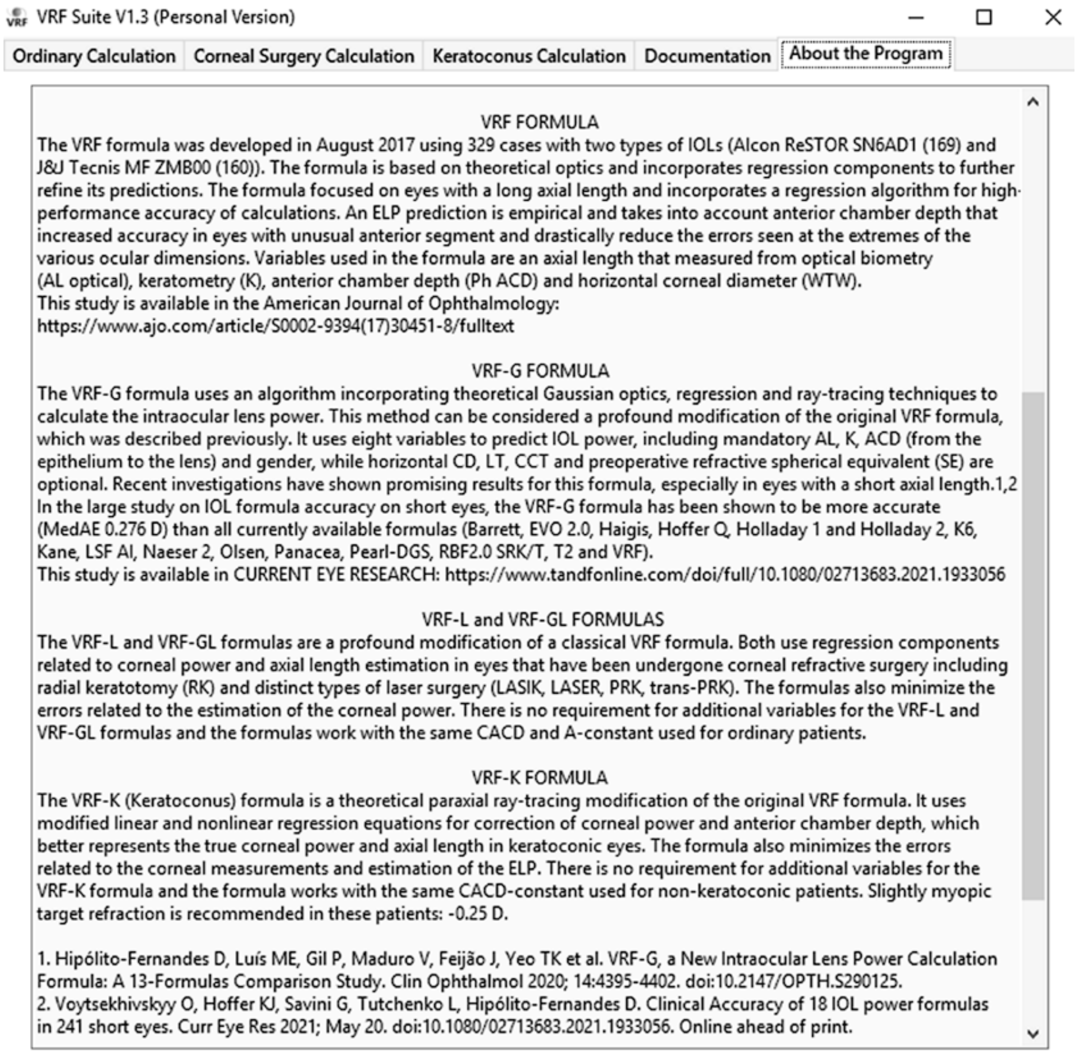
Fig. 55.2 IOL power formulas and methods that featured aforementioned models with a prevalence one of them [1, 2, 14, 18–24]. Interestingly, all recently presented formulas as a rule are mixed models that use artificial intelligence (AI) or ray tracing and are based on traditional vergence formulas.

Today, there is no consensus on the best formula among the available ones. Many researchers have attempted to evaluate the accuracy of these formulas in their investigations. For example, Savini and associates studied the 13 formulas (Barrett Universal II with and without anterior chamber depth (ACD) as a predictor, Emmetropia Verifying Optical 2.0 (EVO), Haigis, Hoffer Q, Holladay 1, Holladay 2, Holladay 2 AL, Kane, Naeser 2, Pearl-DGS, RBF 2.0, SRK/T, T2, and VRF) in 200 eyes with the same IOL model (Si 255; Hoya). The lowest values were achieved with the Kane (0.214 D), RBF 2.0 (0.215 D), BUII with and without ACD (0.218 D), and SRK/T (0.223 D). A percentage ranging from 80% to 88.5% of eyes showed a PE within ±0.50 D, and all formulas achieved more than 50% of eyes with a PE within ±0.25 D. The median absolute error (MedAE) ranged between 0.214 D and 0.256 D, with a statistically significant difference among formulas ($P < 0.0001$) [29]. Cooke and Cooke tested the nine IOL power formulas and found that the formulas yielded different results depending on which machine measurements were used [30]. Taroni and associates compared the 13 IOL power formulas and found that in average eyes with a mean AL 24.01 ± 1.56 mm (range 20.45–28.80 mm), the Pearl-DGS formula was a more accurate predictor of actual postoperative refraction than the other formulas [31].

Investigation of Formulas

The VRF formula is a vergence-based thin-lens formula using four variables: axial length, keratometry, anterior chamber depth, and horizontal corneal diameter. However, it does not consider parameters such as lens thickness and gender, and the published results did not position it as one of the most accurate formulas [29, 31]. This method is a part of the VRF Suite software version 1.3. (V/C/Systems, Kyiv, Ukraine), created and designed specifically for calculating IOL power. This program enables the determination of the optical power of the IOL and planned postoperative refraction for ordinary (VRF and VRF-G formulas) cataract surgery, conditions after corneal refractive surgery (VRF-L and VRF-GL formulas), and cataract surgery in keratoconus (VRF-K) (Fig. 55.3).

The VRF-G (gender) is an unpublished new formula that is based on theoretical optics with regression and ray-tracing components. It uses the optical A-constant for the SRK/T formula and operates eight variables including AL, K, ACDpre (epithelium to lens), LT, horizontal CD (corneal diameter), CCT, preoperative refractive spherical equivalent (SE), and gender. Parameters such as AL, K, ACDpre (epithelium to lens), and gender are mandatory for calculation. It was programmed into IBM PC software and was called VRF Suite V1.3 (Fig. 55.4) [21, 32]. This formula was introduced as a profound modification of the original VRF formula, does not rely on any artificial intelligence (AI) assumption, and showed promising outcome across all axial length range with a special focus on the short eyes [21].



VRF FORMULA

The VRF formula was developed in August 2017 using 329 cases with two types of IOLs (Alcon ReSTOR SN6AD1 (169) and J&J Tecnis MF ZMB00 (160)). The formula is based on theoretical optics and incorporates regression components to further refine its predictions. The formula focused on eyes with a long axial length and incorporates a regression algorithm for high-performance accuracy of calculations. An ELP prediction is empirical and takes into account anterior chamber depth that increased accuracy in eyes with unusual anterior segment and drastically reduce the errors seen at the extremes of the various ocular dimensions. Variables used in the formula are an axial length that measured from optical biometry (AL optical), keratometry (K), anterior chamber depth (Ph ACD) and horizontal corneal diameter (WTW).
This study is available in the American Journal of Ophthalmology:
https://www.ajo.com/article/S0002-9394(17)30451-8/fulltext

VRF-G FORMULA

The VRF-G formula uses an algorithm incorporating theoretical Gaussian optics, regression and ray-tracing techniques to calculate the intraocular lens power. This method can be considered a profound modification of the original VRF formula, which was described previously. It uses eight variables to predict IOL power, including mandatory AL, K, ACD (from the epithelium to the lens) and gender, while horizontal CD, LT, CCT and preoperative refractive spherical equivalent (SE) are optional. Recent investigations have shown promising results for this formula, especially in eyes with a short axial length.1,2
In the large study on IOL formula accuracy on short eyes, the VRF-G formula has been shown to be more accurate (MedAE 0.276 D) than all currently available formulas (Barrett, EVO 2.0, Haigis, Hoffer Q, Holladay 1 and Holladay 2, K6, Kane, LSF AI, Naeser 2, Olsen, Panacea, Pearl-DGS, RBF2.0 SRK/T, T2 and VRF).
This study is available in CURRENT EYE RESEARCH: https://www.tandfonline.com/doi/full/10.1080/02713683.2021.1933056

VRF-L and VRF-GL FORMULAS

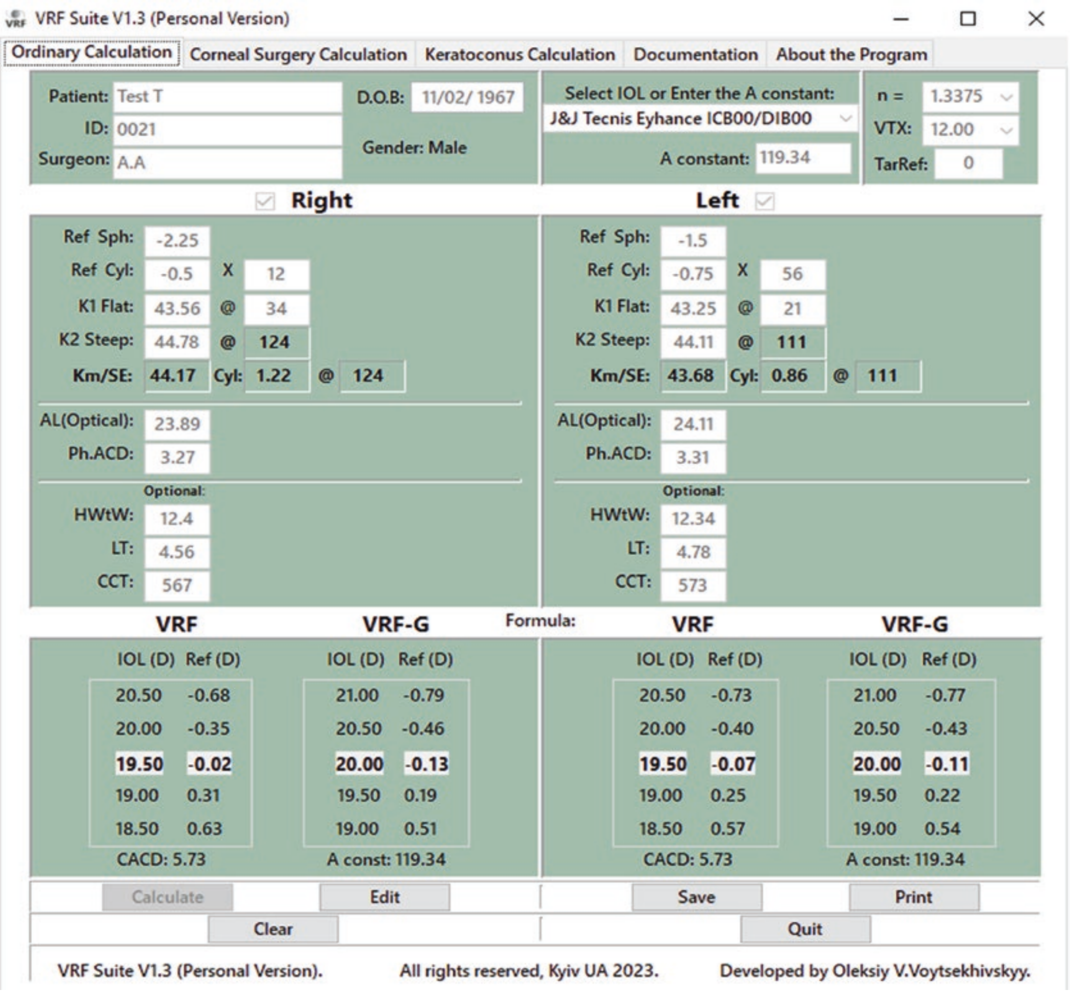
The VRF-L and VRF-GL formulas are a profound modification of a classical VRF formula. Both use regression components related to corneal power and axial length estimation in eyes that have been undergone corneal refractive surgery including radial keratotomy (RK) and distinct types of laser surgery (LASIK, LASER, PRK, trans-PRK). The formulas also minimize the errors related to the estimation of the corneal power. There is no requirement for additional variables for the VRF-L and VRF-GL formulas and the formulas work with the same CACD and A-constant used for ordinary patients.

VRF-K FORMULA

The VRF-K (Keratoconus) formula is a theoretical paraxial ray-tracing modification of the original VRF formula. It uses modified linear and nonlinear regression equations for correction of corneal power and anterior chamber depth, which better represents the true corneal power and axial length in keratoconic eyes. The formula also minimizes the errors related to the corneal measurements and estimation of the ELP. There is no requirement for additional variables for the VRF-K formula and the formula works with the same CACD-constant used for non-keratoconic patients. Slightly myopic target refraction is recommended in these patients: -0.25 D.

1. Hipólito-Fernandes D, Luís ME, Gil P, Maduro V, Feijão J, Yeo TK et al. VRF-G, a New Intraocular Lens Power Calculation Formula: A 13-Formulas Comparison Study. Clin Ophthalmol 2020; 14:4395-4402. doi:10.2147/OPTH.S290125.
2. Voytsekhivskyy O, Hoffer KJ, Savini G, Tutchenko L, Hipólito-Fernandes D. Clinical Accuracy of 18 IOL power formulas in 241 short eyes. Curr Eye Res 2021; May 20. doi:10.1080/02713683.2021.1933056. Online ahead of print.

Fig. 55.3 VRF Suite V1.3 with VRF, VRF-G, VRF-L, VRF-GL, and VRF-K formulas



Patient: Test T
ID: 0021
Surgeon: A.A
D.O.B: 11/02/ 1967
Gender: Male
Select IOL or Enter the A constant: J&J Tecnis Eyhance ICB00/DIB00
A constant: 119.34
n = 1.3375
VTX: 12.00
TarRef: 0

	☑ Right						Left ☑					
Ref Sph:	-2.25						-1.5					
Ref Cyl:	-0.5	X	12				-0.75	X	56			
K1 Flat:	43.56	@	34				43.25	@	21			
K2 Steep:	44.78	@	124				44.11	@	111			
Km/SE:	44.17	Cyl:	1.22	@	124		43.68	Cyl:	0.86	@	111	
AL(Optical):	23.89						24.11					
Ph.ACD:	3.27						3.31					
Optional:												
HWtW:	12.4						12.34					
LT:	4.56						4.78					
CCT:	567						573					

Formula:

VRF		VRF-G		VRF		VRF-G	
IOL (D)	Ref (D)	IOL (D)	Ref (D)	IOL (D)	Ref (D)	IOL (D)	Ref (D)
20.50	-0.68	21.00	-0.79	20.50	-0.73	21.00	-0.77
20.00	-0.35	20.50	-0.46	20.00	-0.40	20.50	-0.43
19.50	**-0.02**	**20.00**	**-0.13**	**19.50**	**-0.07**	**20.00**	**-0.11**
19.00	0.31	19.50	0.19	19.00	0.25	19.50	0.22
18.50	0.63	19.00	0.51	18.50	0.57	19.00	0.54
CACD: 5.73		A const: 119.34		CACD: 5.73		A const: 119.34	

VRF Suite V1.3 (Personal Version). All rights reserved, Kyiv UA 2023. Developed by Oleksiy V.Voytsekhivskyy.

Fig. 55.4 VRF Suite V1.3 with VRF and VRF-G formulas

Evaluation of the Formula

Recently, we investigated the results of 13 formulas for a large database of 828 eyes, with one type of lens (AcrySof SN60WF; Alcon Laboratories, Inc.) [32] Overall, VRF-G showed promising outcomes with the best median absolute error (MedAE 0.273 D) among all methods and was third with the absolute error value (MAE 0.332 D), after Kane (MAE 0.324) and EVO 2.0 (MAE 0.329 D). Additionally, VRF-G produced the highest percentage of eyes within ±0.50 D (79.5%) (Fig. 55.5).

In our other study, we compared 18 IOL power formulas in 241 short eyes [21]. A recently developed new formulas such as K6, Kane, Naeser 2, Olsen, and VRF-G obtained the lowest MedAE compared to other formulas (0.308, 0.300, 0.277, 0.310, and 0.276 D, respectively). Comparison of the absolute prediction errors revealed a statistically significant difference ($P < 0.05$) between some of the newer formulas (K6, Kane, Naeser 2, Olsen, and VRF-G) and the remaining ones. These formulas also yielded the highest percentage of eyes with a PE within ±0.50 D (70.54%,

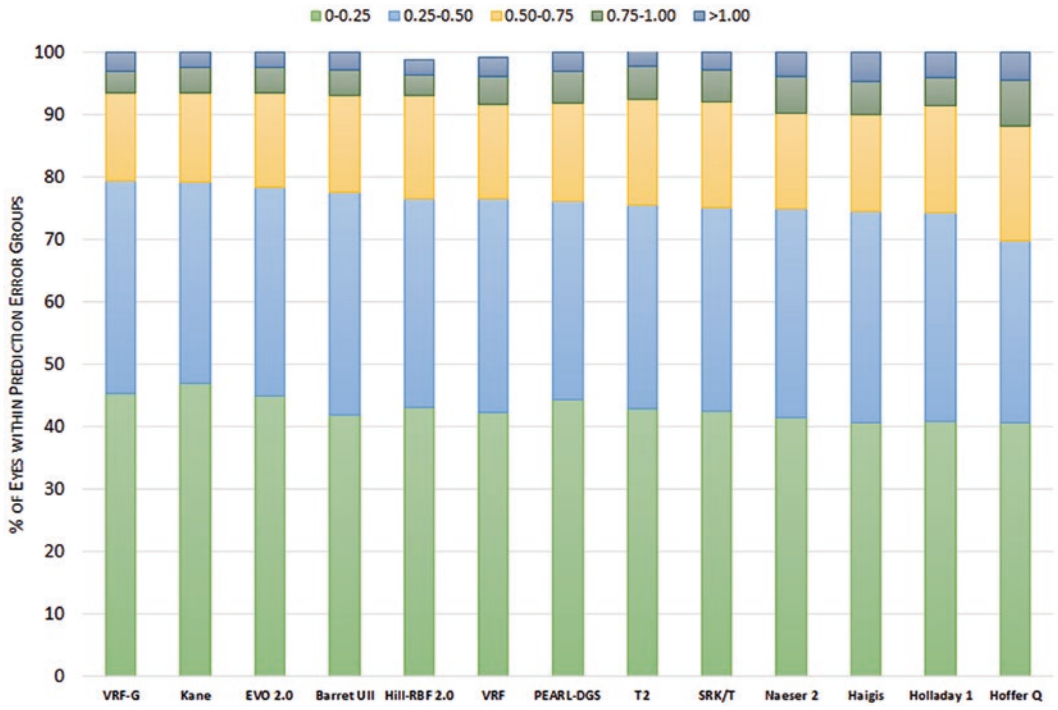


Fig. 55.5 Stacked histogram comparing the percentages of eyes within ±0.25 D, ±0.50 D, ±0.75 D, and ±1.00 D of prediction error. Formulas are ranked according to the higher percentage of eyes within ±0.50 D. In short eyes (*n* = 82), VRF-G (MAE 0.345 D) produced a smaller absolute error when compared to other formulas. For all AL subgroups, VRF-G had one of the most accurate performances, being slightly worse than Kane and EVO 2.0 formulas (SD and MAE values) [32]

72.20%, 71.37%, 70.95%, and 73.03%, respectively). The VRF-G formula showed the highest percentage of eyes within ±0.50 D (73.03%) and the lowest median absolute error value (MedAE = 0.276 D), with slight superiority over other methods. Overall, it was not worse and equal to existing methods.

Recently, in our investigation, the VRF-G formula (MedAE 0.242 D) had the lowest median absolute error value and outperformed all other formulas [33]. The Haigis (MedAE 0.247 D) and Kane (MedAE 0.263 D) methods demonstrated slightly worse results. The calculation with other formulas was less predictable.

In conclusion, the findings of the present investigations support the idea that the VRF-G formula, as a rule, outperforms the original formulas for short eyes showing promising outcomes on medium and long eyes.

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