A three-part system for refining intraocular lens power calculations

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ABSTRACT

A three-part system that determines the correct power for an intraocular lens (IOL) to achieve a desired postoperative refraction is presented. The three components are (1) data screening criteria to identify improbable axial length and keratometry measurements, (2) a new IOL calculation formula that exceeds the current accuracy of other formulas for short, medium, and long eyes, and (3) a personalized "surgeon factor" that adjusts for any consistent bias in the surgeon's results, from any source, based on a reverse solution of the new formula; the reverse solution uses the postoperative stabilized refraction, the dioptric power of the implanted IOL, and the preoperative corneal and axial length measurements to calculate the personalized surgeon factor. The improved accuracy of the new formula was proven by performing IOL power calculations on 2,000 eyes from 12 surgeons and comparing the results to seven other currently used formulas.

Key Words: A-constant, anterior chamber depth, data screening, intraocular lens power calculation, regression formula, reverse solution, surgeon factor, theoretical formula

Evaluating the accuracy of intraocular lens (IOL) power calculation formulas is difficult for most surgeons. The formulas are often quite complex and studies comparing their performance require careful scrutiny to determine if the results are unbiased and applicable to one's practice.

The definitive evaluation would be a prospective study using all the formulas with actual patient measurements (corneal power and axial length) and comparing the predicted values with the actual stabilized refractions. Unfortunately, this requires a large computer and extensive programming—a difficult task for even the most avid computer enthusiast.

Although most studies evaluate formula accuracy, we have previously shown that 43% to 67% of large refractive surprises (>2 diopters) were not due to formula errors but were the result of inaccurate preoperative measurements.[1] Measurement errors hinder any attempt to determine the most accurate formula.

We will show that a new formula (Holladay), which is a modification of the theoretical formula, is superior to other formulas because it more accurately predicts the effective position of the implanted IOL based on the axial length and the average corneal curvature. Furthermore, we provide data screening criteria which

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preoperatively identify measurements that are highly unusual and are at greatest risk for error.

Finally, we will show that each surgeon should develop a personalized "surgeon factor" to achieve the greatest accuracy. This factor is dependent upon not only the IOL style and manufacturer, but also the ultrasound unit, keratometer, lens placement, wound closure, technician, and use of postoperative steroids.

This three-part system—data screening, a new formula for normal and abnormal eyes, and a personalized surgeon factor to eliminate constant bias as a source of error—is described and evaluated.

MATERIALS AND METHODS

Twelve surgeons were asked to provide 100 cases during a period in which their surgical technique, lens style and manufacturer, keratometer, A-scan unit, and method of postoperative care did not change. The patient selection criteria were a stabilized refraction (at least three months postsurgery) and a visual acuity better than 20/40 to assure accuracy of the refraction. Patients only contributed one eye to the data set of 100. There were no restrictions on axial length or corneal power measurements.

For each of the 100 patients, the surgeons were asked to provide the axial length, keratometry, actual IOL power implanted, and the stabilized refraction. There was no attempt to match the number of right or left eyes or the sex distribution. To eliminate selection bias, we specifically requested that no patients be excluded because of "refractive surprises" or any reason other than those listed.

Each of the initial 12 data sets were then evaluated using eight different formulas. The formulas were used exactly as published, including any special instructions described by the authors.[2-15] Each formula had its own constant (e.g., A-constant for SRK and anterior chamber depth [ACD] for Binkhorst) which was adjusted so that for each initial data set of 100 eyes the average predicted refraction by each formula exactly equaled the average actual refraction.

For example, surgeon 1 had an average actual refraction of −0.51225 diopters (D) for his initial 100 patient data set. Each of the constants for the eight formulas was adjusted so that the average predicted refraction for these 100 patients was also −0.51225 D. Adjusting each of the eight formulas in this manner assured that all formulas were performing optimally and a "best fit" on every one of the initial 12 data sets had been attained.

As a result of optimizing all eight formulas on each of the 12 data sets, a correspondence among all formula constants was derived. The correspondence between the two most commonly used constants (A-constant with SRK and ACD with Binkhorst) and our new constant, the surgeon factor, is shown in Table 1.

Table 1. Corresponding values for commonly used formula constants and the "surgeon factor."

SRK A-Constant	Binkhorst Anterior Chamber Depth	Surgeon Factor*
110	.30	−3.31
110.5	.59	−3.02
111	.88	−2.74
111.5	1.17	−2.46
112	1.46	−2.17
112.5	1.76	−1.89
113	2.05	−1.61
113.5	2.34	−1.32
114	2.63	−1.04
114.5	2.92	−.76
115	3.21	−.48
115.5	3.51	−.19
116	3.80	.09
116.5	4.09	.37
117	4.38	.66
117.5	4.67	.94
118	4.96	1.22
118.5	5.26	1.51
119	5.55	1.79
119.5	5.84	2.07
120	6.13	2.36

*Surgeon factor = (A-constant × .5663) − 65.60
Surgeon factor = (ACD × .9704) − 3.595

Once the optimal constant for each formula on each data set had been determined, the absolute value of the error between the actual and predicted refraction was determined for each of the 1,200 eyes. The mean absolute error and standard error of the mean (SEM) for each of the 12 data sets were calculated for each of the eight optimized formulas.

Four surgeons were requested to provide two additional data sets of 100 short (<22.5 mm) and 100 long (>24.5 mm) eyes (N = 800) that were not in the initial data sets. These eyes were selected using the same criteria specified for the original data set except for the restricted axial length requirement.

The mean absolute error and SEM were calculated for these eight additional data sets (four data sets of long eyes and four data sets of short eyes) using the same eight formulas. The optimal constants determined on the initial 12 data sets for each surgeon were used with these additional data sets of short and long eyes.

RESULTS

The mean absolute error and SEM for all 12 data sets and each of the eight formulas is shown in Table 2. The

Table 2. Mean absolute error* for 12 surgeons and eight formulas using the initial data sets of 100 eyes.

	Surgeons														
Formulas	1	2	3	4	5	6	7	8	9	10	11	12	Mean	SEM†	95% CI‡
Holladay	.48	.46	.50	.60	.59	.60	.58	.64	.61	.72	.78	.81	.61	.02	.57–.65
Thompson-M	.48	.50	.52	.55	.57	.63	.67	.65	.69	.74	.75	.80	.63	.02	.59–.67
Shammas	.51	.51	.55	.59	.65	.64	.60	.69	.65	.75	.80	.85	.65	.02	.61–.69
Hoffer	.52	.51	.56	.57	.65	.65	.61	.68	.66	.75	.80	.84	.65	.02	.61–.69
Binkhorst II	.51	.53	.57	.61	.65	.65	.61	.70	.66	.77	.80	.85	.66	.02	.62–.70
SRK	.52	.55	.56	.56	.56	.65	.75	.65	.75	.78	.79	.80	.66	.02	.62–.70
Donzis	.51	.58	.58	.58	.56	.63	.75	.66	.86	.81	.84	.81	.68	.02	.64–.72
Fyodorov	.55	.61	.64	.72	.69	.69	.64	.76	.71	.78	.86	.91	.71	.02	.67–.75
Mean	.51	.53	.56	.60	.61	.64	.65	.68	.70	.76	.80	.83	.66	.02	
SEM	.06	.07	.06	.07	.07	.08	.07	.09	.09	.10	.10	.11	.08		

*in diopters
†SEM = standard error of the mean
‡CI = confidence interval

mean absolute error ranged from a low of 0.61 D ± 0.02 (SEM) for the Holladay formula to a high of 0.71 D ± 0.02 for the Fyodorov formula. The data indicate that there is a difference in the performance of the formulas, but the difference does not appear clinically significant.

The mean absolute error and SEM for the four data sets of short eyes for each of the eight formulas are shown in Table 3. The mean absolute error ranged from a low of 0.82 D ± 0.06 for the Holladay formula to a high of 1.24 D ± 0.08 for the Fyodorov formula. The data indicate that a significant statistical and clinical difference among these formulas exists in short eyes.

The mean absolute error and SEM for the four data sets of long eyes for each of the eight formulas are shown in Table 4. The mean absolute error ranged from a low of 0.73 D ± 0.05 for the Holladay formula to a high of 1.32 D ± 0.09 for the Donzis formula. The data indicate that a significant statistical and clinical difference among formulas exists in long eyes.

The Holladay formula yielded the lowest mean absolute error in short, average, and long eyes. Clinically, these differences were most significant in the short and long eyes. Our data indicate that the choice of formulas becomes more important the more unusual the eye.

DISCUSSION

Although our study was designed to compare the performance of existing IOL power calculation formulas, accurate predictions of the stabilized postoperative refraction require three elements: (1) data screen-

Table 3. Mean absolute error* for four surgeons and eight formulas using the data sets of 100 short eyes.

	Surgeons						
Formulas	1	2	3	4	Mean	SEM†	95% CI‡
Holladay	.69	.77	.76	1.06	.82	.06	.70– .94
Hoffer	.73	.80	.81	1.15	.87	.06	.75– .99
Binkhorst II	.81	.87	.80	1.20	.92	.06	.80–1.04
Thompson-M	.74	.81	1.03	1.15	.93	.06	.81–1.05
Shammas	.77	.89	.82	1.27	.94	.06	.82–1.06
Donzis	.72	.86	1.12	1.17	.97	.07	.83–1.11
SRK	.78	.88	1.05	1.28	1.00	.07	.86–1.14
Fyodorov	1.09	1.13	1.03	1.69	1.24	.08	1.08–1.40
Mean	.79	.88	.93	1.25	.96	.06	
SEM	.11	.12	.13	.17	.13		

*in diopters
†SEM = standard error of the mean
‡CI = confidence interval

Table 4. Mean absolute error* for four surgeons and eight formulas using the data sets of 100 long eyes.

	Surgeons					
Formulas	1	2	3	4	Mean	SEM†
Holladay	.58	.79	.68	.89	.73	.05
Shammas	.56	.83	.76	.82	.74	.05
Binkhorst II	.58	.80	.80	.82	.75	.05
Hoffer	.59	.85	.75	.84	.76	.05
Fyodorov	.68	.77	1.10	.83	.84	.06
Thompson-M	.77	.93	1.14	1.22	1.02	.07
SRK	.89	.94	1.01	1.47	1.08	.07
Donzis	1.15	1.06	1.42	1.66	1.32	.09
Mean	.73	.87	.96	1.07	.91	.06
SEM	.10	.12	.13	.14	.12	

*in diopters
†SEM = standard error of the mean
‡CI = confidence interval

ing to reduce the possibility of mismeasurements, (2) an accurate formula for normal as well as unusual eyes, and (3) a method for individualizing the formula to account for each surgeon's unique characteristics and instrumentation.

Data Screening Criteria

Routine data screening is an essential ingredient for accurate IOL calculation that identifies the majority of large refractive surprises preoperatively. In most studies, these large surprises occur in 5% to 10% of IOL implantations.[16-19] Obviously, no formula can accurately predict the stabilized postoperative refraction in the presence of axial length and/or corneal power mismeasurements.

In a previous study,[1] we demonstrated that the most significant factor leading to large refractive surprises (>2 D) was mismeasurement, not formula error. In addition, we found that 92% of these surprises could have been identified preoperatively if a difference greater than one diopter existed between the Binkhorst and SRK formulas.

This one diopter difference occurs when the axial length and corneal power measurements are statistically unlikely. Further analysis reveals that these differences can be characterized by three monocular and three binocular data checks as shown in Table 5. If the measurements fail any one of the data screening checks, the measurements should be repeated by a second observer who is unaware of the results of the first measurements. If the measurements are independently repeatable, the chances of a mismeasurement have been significantly reduced. If there is a great deal of variability, repeated mesurements must be taken until the source of error can be identified or an average can be obtained.

Table 5. Data screening criteria to identify
are unusual and require remeasurer

Repeat measurements if:
1. Axial length < 22.0 mm or > 25.0 mm
2. Average corneal power < 40 D* or > 47 I
3. Calculated emmetropic IOL power is more
average for specific lens style†
4. Between eyes, the difference in
a. average corneal power > 1 D
b. axial length > 0.3 mm
c. emmetropic IOL power > 1 D

*D = diopters
†The average emmetropic IOL power for a s
calculated using the corresponding "surge
power of 43.81 D, and axial length of 23.5 n

Unusually long (>25.0 mm) or sh
eyes are at higher risk of measuren
normal eyes.[1] Long eyes are at highe
the frequent presence of a staphylo
predictable location of the fovea wit
staphyloma. In contrast, short eye
dimensions that require a greater acc
the same error tolerance in the final
the need for special caution and re
ments in these unusual eyes exists.

Formulas

Intraocular lens power calculation
two major categories: (1) theoretical v
and (2) empirically determined reg
Each of the authors of the eight formu
formula was theoretical or empirical,
to the accuracy of IOL power calculati
of the evolution of these formulas an

tions is germane to the development of the Holladay formula.

Fyodorov first estimated the optical power of an IOL using vergence formulas in 1967.[20] Between 1972 and 1975, when accurate ultrasonic A-scan units became commercially available, several investigators derived and published the theoretical vergence formula.[2-5,21,22] All these formulas were identical[23] except for the form in which they were written and the choice of various constants such as retinal thickness, optical plane of the cornea, and optical plane of the IOL. These slightly different constants accounted for less than 0.50 D in the predicted refraction.[16] The variation in these constants was a result of differences in lens styles, A-scan units, keratometers, and surgical techniques among the investigators.

A good example of this difference is seen in the choice of a retinal thickness factor for Binkhorst and Hoffer. Binkhorst suggested adding 0.250 mm to the measured axial length to account for retinal thickness and Hoffer found more accurate predictions using the same formula without adding a retinal thickness factor.[16] The explanation of this difference was simply that Hoffer's Kretz 7200 MA immersion A-scan measured approximately 0.200 mm longer on the average than Binkhorst's applanation Sonometric DBR unit. This difference is supported by the published mean axial length of 23.65 mm measured by Hoffer and 23.45 mm measured by Binkhorst.[6,7,24,25] These different findings do not indicate that one unit is necessarily more accurate than the other, only that their characteristics are different and a different retinal thickness factor must be added to the axial length to obtain the most accurate prediction of the desired postoperative refraction.

First Generation Formulas. In the original theoretical formula, the anterior chamber depth (ACD) was a constant value that was dependent on lens style and placement within the eye. During this early period, IOLs were iris supported and the optical plane of the lens was near the anterior plane of the iris, making the ACD and the effective position of the lens nearly the same for most lens styles. Although these investigators were aware of variations in ACD when using the same lens style, no accurate method for estimating the postoperative ACD was apparent and the resultant error seemed small (approximately 1.0 D per mm in normal eyes). As the use of posterior chamber lenses increased, significant variations in optical configuration and effective position of the optical plane of the IOL began to occur. The value for ACD began to represent the distance from the corneal vertex to the IOL, rather than the anatomic ACD.

Around 1980, several investigators[8,9,10,26,27] published linear regression techniques to improve upon the accuracy of the theoretical formula. Each of these investigators determined a linear equation with an empirically derived constant for a specific lens style and coefficients for the axial length and corneal power that yielded the emmetropic IOL power. The ametropic lens power (e.g., desired refraction of −1.0 D) was also calculated using either a constant or another linear equation. The constants were usually 1.5 or 1.7 and were multiplied by the ametropia to determine the value to be added (for myopia) to the emmetropic lens power to achieve the desired ametropia.

During the early 1980s, independent studies comparing the results of the theoretical formulas with constant ACD and the linear regression formulas were almost equally divided in their results.[16-19,28] Those investigators who had derived their own linear regression constant and coefficients,[16] however, consistently found better results than with the theoretical formula using a constant ACD.

Second Generation Formulas. Shortly after these initial studies, a second generation of both theoretical and regression formulas emerged. The empiricists began to find better results with polynomial regression formulas[14,15] than with either the linear regression or the original theoretical formulas. Simultaneously, investigators using the theoretical formula[7,12,13] found better results by relating the expected postoperative ACD to the axial length (i.e., larger ACDs for longer eyes, and vice versa).

The relationship between the first and second generation formulas can be seen in Figure 1. The second generation formulas, whether empirical or theoretical, have converged into the same general region. This convergence among independent investigators using different approaches graphically illustrates that the optimal relationship for predicting the necessary IOL power for a given refraction is somewhere between the original theoretical (constant ACD) and the linear regression formulas. The fact that these second generation formulas are improvements over the first generation formulas is also supported by our results as shown in Tables 1, 2, and 3.

Holladay Formula. The Holladay formula is a further modification of the second generation theoretical formula (Appendix, Eqs. 1-5). The improved performance is primarily a result of more accurately locating the optical plane of the IOL with respect to the vertex of the cornea and fovea. The postoperative position of the IOL is predicted in the following way.

The effective lens position of any IOL is the sum of the anatomic ACD and the distance from the anterior plane of the iris to the optical plane of the IOL as seen in Figure 2. The anatomical ACD in the pseudophakic eye is defined as the distance from the corneal vertex to the anterior iris plane. This distance can be predicted more accurately by using a combination of the corneal curvature and the axial length than by using the axial length alone as in previous modifications.

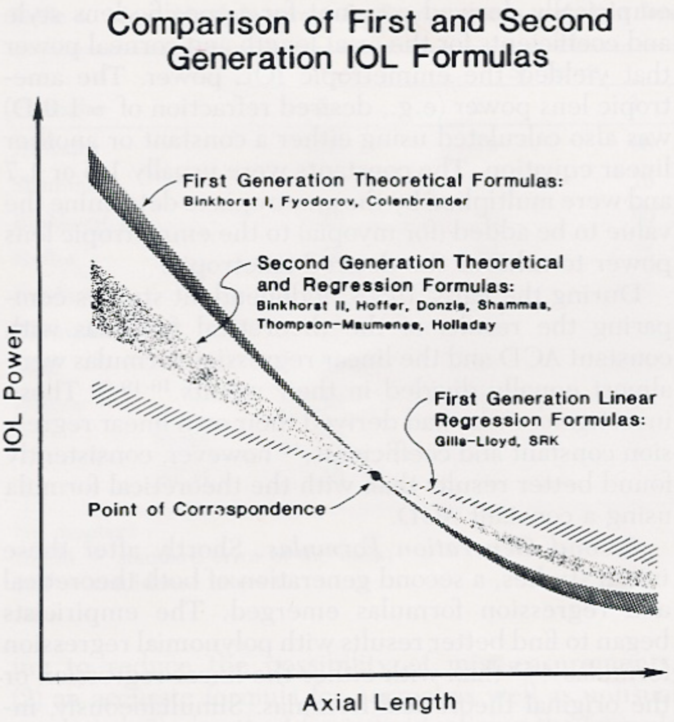

Fig. 1. (Holladay) Relationship among first generation theoretical formulas, first generation linear regression formulas, and second generation formulas. Notice that the second generation formulas, whether theoretical or regression, converge into the same general area.

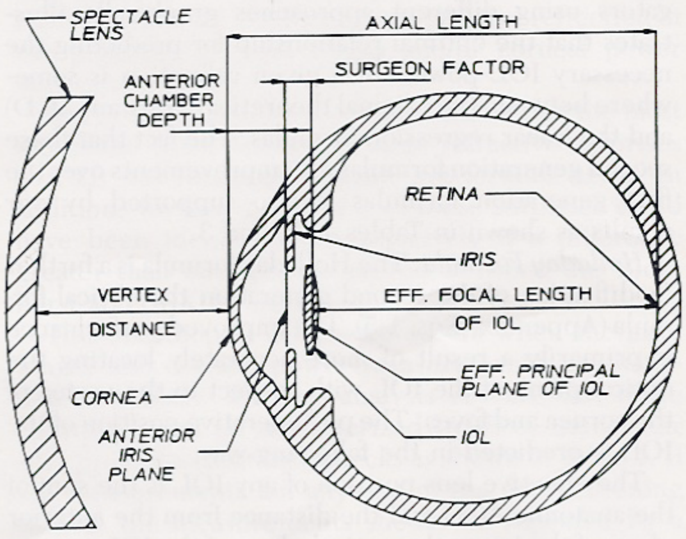

Fig. 2. (Holladay) Cross-sectional diagram of the human eye showing the location of various variables in the Holladay equations. The "surgeon factor" is represented as the distance in millimeters from the aphakic (pseudophakic) anterior iris plane to the effective optical plane of the implanted intraocular lens (EFF. = effective).

Previous attempts to calculate the value of the postoperative aphakic (or pseudophakic) ACD did not include the asphericity of the cornea and steeper radius on the posterior corneal surface compared to the anterior corneal surface. When these factors are taken into account, the relationship can still be simplified as shown in the Appendix, Eqs. 1-3. This ACD can be calculated more accurately in the aphakic eye than in the phakic eye because the plane of the iris is entirely a function of the location of the iris root. In the phakic eye, the iris plane is frequently bowed forward from contact with the crystalline lens introducing other factors, such as the thickness and position of the crystalline lens. This also explains the poor correlation between preoperative and postoperative ACDs, particularly in cataract patients in whom the lens thickness is usually greater and more variable.[29,30,31]

The distance from the aphakic anterior iris plane to the optical plane of the IOL is the constant in our formula and is termed the surgeon factor. This distance has been chosen as the constant because for a specific lens style, from a given manufacturer, with a single surgeon, this dimension remains very consistent. This is not surprising since the supporting structures for IOLs (ciliary sulcus, insertion of the zonules into the ciliary processes, and anterior chamber angle) are a consistent distance from the iris root. This structure is a predictive reference point for the axial position of the implanted IOL. The accuracy of our results using the Holladay formula further supports the use of this structure as a reference.

Personalized Surgeon Factor

Although the surgeon factor represents a measurable distance (anterior iris plane to the effective optical plane of the IOL), the optimal way to arrive at this factor for a given surgeon is not by direct measurement. As shown in Table 6, many factors make each surgeon unique. Each source of variation can result in significant differences, which require a different factor even when using the same lens (e.g., the previously

Table 6. Possible errors corrected by the use of the "surgeon factor."

Factor	Error Range
1. Lens style	0 - 3.00 D*
2. Lens position	0.50 - 1.00 D
3. A-scan unit	0.50 - 1.25 D
4. Wound closure and suture	0.25 - 1.00 D
5. Keratometer	0 - 0.25 D
6. Miscellaneous Technician, IOL power accuracy, refraction, postoperative steroids	0 - 0.50 D

*D = diopters

described difference in A-scan units resulting in a different retinal thickness for Binkhorst and Hoffer).

The proper method for arriving at the optimal constant is to solve the formula in reverse for the constant (Appendix, Eqs. 6-12), using as input variables the preoperative corneal and axial length measurements, the IOL power implanted, and the stabilized postoperative refraction. If this is done on a significant number of patients, the factor will be personalized and will reflect any consistent biases from any source, including error biases from other constants in the equation such as an incorrect retinal thickness factor or index of refraction for the cornea. This surgeon factor is therefore not actually a measurement, but a number representing a particular surgeon's previous experience.

What is a significant number of patients? In our study the standard deviation in the error with the Holladay formula ranged from 0.65 D to 1.11 D for the 12 surgeons. The precision in optimizing the surgeon factor can be approximated using the standard error, which is the standard deviation divided by the square root of the number of samples. For 10 samples the standard errors would have ranged from 0.20 D to 0.35 D and for 25 samples the standard errors would have ranged from 0.13 D to 0.20 D. These considerations indicate that using between 10 and 25 patients to calculate the personalized surgeon factor would have reduced any constant bias to less than 0.25 D for all 12 surgeons in our study.

Future Developments

Although we have shown that our modification of the theoretical formula had the smallest mean absolute error for eyes of any length, it represents only one of the three essential ingredients for accurate lens calculations. It was apparent from analyzing our data that most large errors (>2 D) would have been identified preoperatively by our data screening criteria (Table 5). Repeating measurements on those eyes that failed the data screening criteria would certainly have reduced the number of measurement errors.

The need for a data screening program and using the formula in reverse to determine a personalized surgeon factor from one's own data are just as important as our new formula. We hope that our emphasis on these three elements will stimulate other investigators to develop better data screening criteria and personalization routines as well as improve upon our formula.

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APPENDIX

Holladay Formulas and Constants

Recommended constants:

n_c = refractive index of cornea = 4/3
n_a = refractive index of aqueous = 1.336
RT = retinal thickness factor = 0.200 mm

Measured values:

K = average K-reading (diopters)
R = average corneal radius (mm) = 337.5/K
AL = measured ultrasonic axial length (mm)

Chosen values

V = vertex distance of pseudophakic spectacles (mm), default = 12 mm
Ref = desired postoperative spheroequivalent refraction (diopters)
SF = "surgeon factor" = distance from aphakic anterior iris plane to optical plane of IOL (mm)

Definitions of Other Variables

AG = anterior chamber diameter from angle to angle (mm)
ACD = anatomic anterior chamber depth (mm), distance from corneal vertex to anterior iris plane
Alm = modified axial length (mm) = ultrasonic axial length (AL) + retinal thickness factor (RT)
I = power of IOL (diopters)
ARef = actual postoperative spheroequivalent refraction (diopters)

Equations

Eq 1. Rag = R, if R $<$ 7 mm, then Rag = 7 mm
Eq 2. AG = 12.5 AL/23.45, if AG $>$ 13.5 mm, then AG = 13.5 mm
Eq 3. ACD = 0.56 + Rag - (SQRT (Rag Rag-(AG AG/4)))

IOL power (I) from desired postoperative refraction (Ref)

Eq 4. $$I = \frac{1000\ n_a\ (n_a R - (n_c - 1)\ \text{Alm} - 0.001\ \text{Ref}\ (V(n_a R - (n_c - 1)\ \text{Alm}) + \text{Alm}\ R))}{(\text{Alm} - \text{ACD} - \text{SF})\ (n_a R - (n_c - 1)\ (\text{ACD} + \text{SF}) - 0.001\ \text{Ref}\ (V\ (n_a R - (n_c - 1)\ (\text{ACD} + \text{SF})) + (\text{ACD} + \text{SF}) R))}$$

Resultant refraction (Ref) from IOL power (I)

Eq 5. $$\text{Ref} = \frac{1000\ n_a\ (n_a R - (n_c - 1)\ \text{Alm}) - I\ (\text{Alm} - \text{ACD} - \text{SF})\ (n_a R - (n_c - 1)\ (\text{ACD} + \text{SF}))}{n_a\ (V\ (n_a R - (n_c - 1)\ \text{Alm}) + \text{Alm}\ R) - 0.001\ I\ (\text{Alm} - \text{ACD} - \text{SF})\ (V\ (n_a R - (n_c - 1)\ (\text{ACD} + \text{SF})) + (\text{ACD} + \text{SF})\ R)}$$

Reverse Solution: "Surgeon Factor" (SF) from IOL power (I) and actual stabilized post-operative refraction (ARef)

Eq 6. AQ = (n_c - 1) - (0.001 ARef ((V (n_c - 1)) - R))
Eq 7. BQ = ARef 0.001 ((Alm V (n_c - 1)) - (R (Alm - (V n_a)))) - (((n_c - 1) Alm) + (n_a R))
Eq 8. CQ_1 = 0.001 ARef ((V ((n_a R) - ((n_c - 1) Alm))) + (Alm R))
Eq 9. CQ_2 = (1000 n_a ((n_a R) - ((n_c - 1) Alm) - CQ_1))/I
Eq 10. CQ_3 = (Alm n_a R) - (.001 ARef Alm V R n_a)
Eq 11. CQ = CQ_3 - CQ_2
Eq 12. SF = (((-BQ) - SQRT ((BQ BQ) - (4 AQ CQ)))/ (2 AQ)) - ACD

Numeric Example

K = 46 D
AL = 22 mm
Alm = 22.2 mm

V = 12 mm
I = 21.45970 D

Ref = - 0.50000 D
ARef = - 0.50000 D
SF = + 0.50000 mm

Forward solution for "I" and "Ref"

Rag = R = 7.33696 mm
AG = 11.72708 mm
ACD = 3.48676 mm
I = 21.45970 D
Ref = - 0.50000 D

Reverse Solution for "SF"

AQ = .331665
BQ = - 17.22395
CQ_1 = - 0.095853
CQ_2 = 155.51774

CQ_3 = 218.91391
CQ = 63.39617
SF = + 0.50000 mm