Theme Section

Demystifying Intraocular Lens Power Calculation

Nirupama Kasturi[1], Arup Chakrabarti[2]
[1]Department of Ophthalmology, Jawaharlal Institute of Postgraduate Medical Education & Research (JIPMER) Pondicherry, Tamil Nadu, India.
[2]Cataract and Glaucoma services, Chakrabarti Eye Care Centre, Trivandrum, Kerala, India.

Abstract *Cataract surgery has advanced from a mere replacement of the cloudy lens to a refractive-cataract surgery due to the advancements in diagnostic and surgical instrumentation and techniques. The availability of premium intraocular lenses provides patients the opportunity to regain excellent vision and be less dependent on spectacles. In order to attain the desired postoperative refraction or target emmetropia following cataract surgery, accurate biometry and appropriate intraocular lens power formula selection are required, along with safe and precise surgery. This article reviews the salient features and recent advances in biometry and intraocular lens power calculations.*

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Introduction

The quest for accurate intraocular lens (IOL) power calculation has existed ever since Sir Harold Ridley implanted the first IOL in 1949.[1] The postoperative refraction was highly myopic due to the higher refractive index of the IOL as compared to the crystalline lens. In the present day, with high patient expectations, even a prediction error of 0.5 D can make the patient unhappy, especially with multifocal and toric implants. Intraocular lens power calculation has met with several developments over the years in the form of better instrumentation and the use of more precise mathematical formulae that have significantly improved surgical outcomes. The major components of IOL power calculation are precise biometry, appropriate use of formulae, and understanding patient expectations. If the calculations are not performed accurately, then patients may be left with a significant refractive error post-operatively.

(I). Ocular Biometry

The refractive power of the human eye depends on the power of the cornea (Keratometry-K), the refractive index of the lens, the position of the lens (Effective lens position -ELP), and the length of the eye (Axial length-AL) [Figure 1]. Accurate assessment of these variables is essential in achieving optimal postoperative refractive results. The modern-day IOL power prediction errors are due to keratometry (22%), axial length measurement (36%), and post-op anterior chamber depth (ACD) estimation (42%).[2]

Keratometry (K)

The central corneal power is an important factor, and an error of one dioptre can translate to a 0.9 D error in IOL power. The average adult keratometry (K) reading is 43.0 - 44.0 D, with barely a dioptre difference between the two eyes. It can be determined using various instruments like the manual or auto-keratometers or keratometers incorporated in optical biometers and corneal topography/ tomography-based keratometry. The standard keratometry relies purely on measurements of the anterior corneal surface and extrapolates it by assuming a constant ratio between the anterior and posterior corneal radii (Gullstrand ratio) to obtain the total corneal power and astigmatism.[3,4] However, the posterior curvature and corneal thickness also contribute to the total refractive power of the cornea. Neglecting their effects can lead to a significant postoperative overcorrection or undercorrection, especially in eyes with corneal abnormalities. Before performing keratometry, it is important to treat any dry eye or meibomian gland disease. Also, discontinue contact lens wear 1 week for soft and 4 weeks prior for rigid gas permeable lenses to prevent keratometry errors due to corneal warpage.[5]

In Manual keratometry, the central cornea is assumed to be a perfect sphere and acts as a spherical convex mirror. From the size of the reflected image formed by the anterior surface of the cornea (3-3.2mm zone), the radius of curvature is determined, which is then converted to power in diopter or mm. Eg. Bausch & Lomb Keratometer.[6] It requires a highly skilled technician and is operator-dependent, affecting measurement accuracy. It is preferred in patients with poor fixation, distorted mires, highly toric cornea, and a dry ocular surface where automated keratometry is not possible. Automated Keratometers provide the K readings at the central 3mm of the cornea in the steepest and flattest meridians. The optical biometers have included auto-keratometers enabling measurements of K readings and axial length from a single instrument. The IOL Master (Carl Zeiss Meditec) and Lenstar LS900 (Haag Streit) have incorporated automated keratometers that calculate K readings by analyzing reference

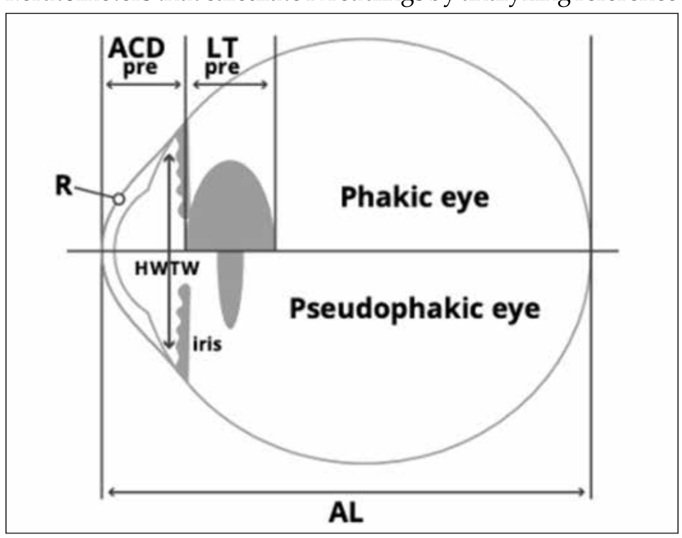

Figure 1: *Diagramatic representation of variables used for IOL power calculation*

points on the anterior cornea. The IOL Master makes six measurements at 3mm of the central cornea, and the Lenstar performs 16 central corneal readings—eight at 1.7mm and eight at 2.3 mm radius.[7] There is no interoperator difference in its measurement accuracy. The T-cone topography add on to Lenstar LS 900 provides placido topography with 11 placido rings on the central 6 mm of anterior corneal surface which evaluates keratometry measurements of the cornea through the position of 32 projected light reflections in 2.3 mm (outer) and 1.65 mm (inner) rings. For each measuring point, the equivalent of an ideal sphere is calculated. Bench tests in addition to evaluation of real eye data showed that K-readings calculated from the topography image and the Lenstar's standard dual zone keratometry are equivalent. The newer version of IOL Master 700 uses telecentric keratometry at 18 points, with constant spot distance irrespective of device-to-eye distance, which makes it easier to use and more precise. It also measures the anterior and posterior corneal power separately to generate the total keratometry (T K value), which translates accurately into the true corneal power.[8]

Corneal Topography is highly recommended in post-refractive surgery eyes, toric IOL, and patients with keratometry readings < 40 D or > 46D. The cornea is mapped in detail, giving the simulated keratometry (SimK) within the central 3 mm optical zone. The topographic axis is more valuable than the topographic cylinder and becomes extremely useful when planning a toric intraocular lens.[9]

Corneal Tomography includes the Oculus Pentacam, which images the anterior segment of the eye using a rotating Scheimpflug camera and provides a tomographic analysis of the corneal front and back surfaces as well as the central corneal thickness. It can generate a "True Net Power" map of the cornea and measure the power of the post-refractive-surgery cornea within ±0.55D at the central 4.5 mm. The ''Holladay EKR Detail Report'' which generates the equivalent keratometry reading (EKR) was developed to calculate the total corneal power specifically for patients who have undergone corneal refractive surgery. It takes measurements at 1-mm intervals in the central cornea from 1 mm up to 7 mm. The 4.5-mm corneal zone, as the actual zone, is also measured. The Anterior segment OCT can also be used to measure both the anterior and posterior corneal power separately and generates the corneal power without using the Gullstrand ratio.[10]

Axial Length (Al)

The AL is the most important factor in IOL calculation. A 1-mm error in AL measurement results in a refractive error of approximately 2.5 D in an average eye. It can be measured by Ultrasound methods or Optical biometry. It should be noted that optical and acoustic ALs are not equivalent because the retinal pigment epithelium (RPE) is the endpoint of the optical measurements, and the internal limiting membrane (ILM) is the endpoint of the ultrasonic measurements.

Ultrasound methods: A parallel sound beam is emitted from the probe tip at approximately 10 MHz, which echoes back into the probe tip as the sound beam strikes each interface. The echoes received back into the probe from each of these interfaces are converted by the biometer to spikes arising from the baseline. The axial length is measured as the product of the time taken by the sound to travel from one interface to another at a given velocity. Other measurements obtained are the anterior chamber depth (ACD), Lens thickness (LT), and vitreous chamber depth (VCD). Two types of A-scan ultrasound biometry currently in use are the Contact applanation Ultrasound and Immersion Ultrasound.

Contact Applanation Biometry

This technique requires placing an ultrasound probe on the central cornea. Errors in measurement almost invariably result from the probe indenting the cornea and shallowing the anterior chamber. Since the compression error is variable, it cannot be compensated for by a constant. IOL power calculations using these measurements will lead to an overestimation of the IOL power, which is amplified in shorter eyes. (Error due to 1mm corneal compression-Average eye: 2.5D, Long eye: 1.75D, Short eye: 3.75D). The patient must lie flat on a couch and fixate on their thumb held directly above the eyeball. The eyelids are held apart gently with a wire speculum. The probe should gently be brought in contact with the moist cornea.

Immersion A-scan biometry requires placing a saline-filled scleral shell (Ossoinig or Prager) between the probe and the eye. Since the probe does not exert direct pressure on the cornea, compression of the anterior chamber is avoided. A mean shortening of 0.25–0.33mm has been reported between applanation and immersion AL measurements, which can translate into an error of IOL power by approximately 1 D. In general, immersion biometry is more accurate than contact applanation biometry in several studies.[11]

Limitations of ultrasound methods include poor image resolution due to the use of a relatively long, low-resolution of 0.03 mm for a 10 MHz probe. The fovea is not located accurately, and variations in retinal thickness surrounding the fovea contribute to inconsistency in the final measurement. Incorrect assumptions regarding sound velocity can lead to errors.

Tips for accurate measurement of axial length (using applanation):

The ultrasound machine must be calibrated and set for the correct velocity setting (e.g., cataract, aphakia, pseudophakia). The probe must be perpendicular, and the echoes from the cornea, anterior lens, posterior lens, and retina should produce good amplitude spikes. The retinal spike should be a sharp straight line with no humps or steps on its ascending edge. If the alignment of the A-scan is along the optic nerve instead of the fovea (recognized by an absent scleral spike), the axial length will be underestimated. Excessive indentation – corneal compression (indicated by reduced ACD and AL but normal VCD) commonly causes errors. Average the 5–10 most consistent results giving the lowest standard deviation (ideally < 0.06 mm).

Optical biometry is a highly accurate non-invasive automated method for measuring the anatomical details of the eye. In 1999, the first automated optical biometry device became available for clinical use – IOL Master 500 (Carl Zeiss Meditec, Jena, Germany). Because of its ease of use, non-contact technique, accuracy, and reproducibility, optical biometry is now considered the current gold standard of IOL power calculation in clinical practice and is an indispensable tool for preoperative evaluation of cataract patients. However, ultrasound biometry may be helpful in media opacities like corneal leucoma, dense cataracts, or vitreous hemorrhage. The newer optical biometry devices provide several biometric measurements, namely AL, keratometry (K), anterior chamber depth (ACD), lens thickness (LT), central corneal thickness (CCT), and pupil size (PS), and white-to-white distance (WTW). The currently available optical biometers are based on one of the following technologies: [12,13,14]

(1) *Partial coherence interferometry (PCI):*
Zeiss IOL master 500, Galilei G6, and Nidek AL scan
(2) *Optical low-coherence reflectometry (OLCR):*
Haag Streit Lenstar LS900, Topcon Aladdin
(3) *Swept-source optical coherence tomography (SS-OCT):*
Zeiss IOL master 700, Argos-Movu, OA-2000 by Tomey, Anterion by Heidelberg engineering

Anterior Chamber Depth And Effective Lens Position And Lens Constants

When the human lens is replaced with an IOL, the optical situation becomes a two-lens system (cornea and IOL) projecting an image at the fovea. The distance between the two lenses (Effective Lens Position, or ELP) affects the refraction, as does the distance between the two-lens system and the macula. ELP is defined as the distance from the anterior surface (vertex) of the cornea to the effective principal plane of the lens in the visual axis.[15]

The ELP needs to be estimated mathematically before the implantation of IOL, and a 0.25 mm change in ELP can alter the IOL power by 0.5D. It is the only variable that cannot be measured directly and has to be estimated using other eye dimensions measured. This factor was historically referred to as the anterior chamber depth (ACD) because the optic of all IOLs in the early era was positioned in front of the iris, in the anterior chamber. This value is required for all formulae, and it is incorporated into the lens constant along with lens geometry, placement, and refractive index, which is different for different IOLs [Figure 2]. The A constant is specific to each IOL style is used for regression formulas, Surgeon factor (SF) in Holladay 1, personalized ACD in Hoffer Q, a0,a1,a2 constants in Haigis, lens factor in Barett Universal 2, and C constant in Olsen formula. The manufacturer supplies the nominal lens constant based on its design and material, which the surgeon can refine for more accurate results.[16,17]

The concept of personalization was first introduced by Retzlaff using A constant to refine the formula with data from a single user in ultrasound biometry. It is recommended that each surgeon conducts at least 20-30 uneventful cases with the specific IOL model of interest. The eyes should all contain the same lens style by the same manufacturer implanted by the same surgeon. Eyes with postoperative surprises or visual acuity worse than 6/12 should be excluded. Specific IOL formula is selected and determine the starting point of the associated lens constant. Post-op manifest refraction 6 weeks after surgery is noted. IOL formula can be personalized by adding the mean error to the lens constant.

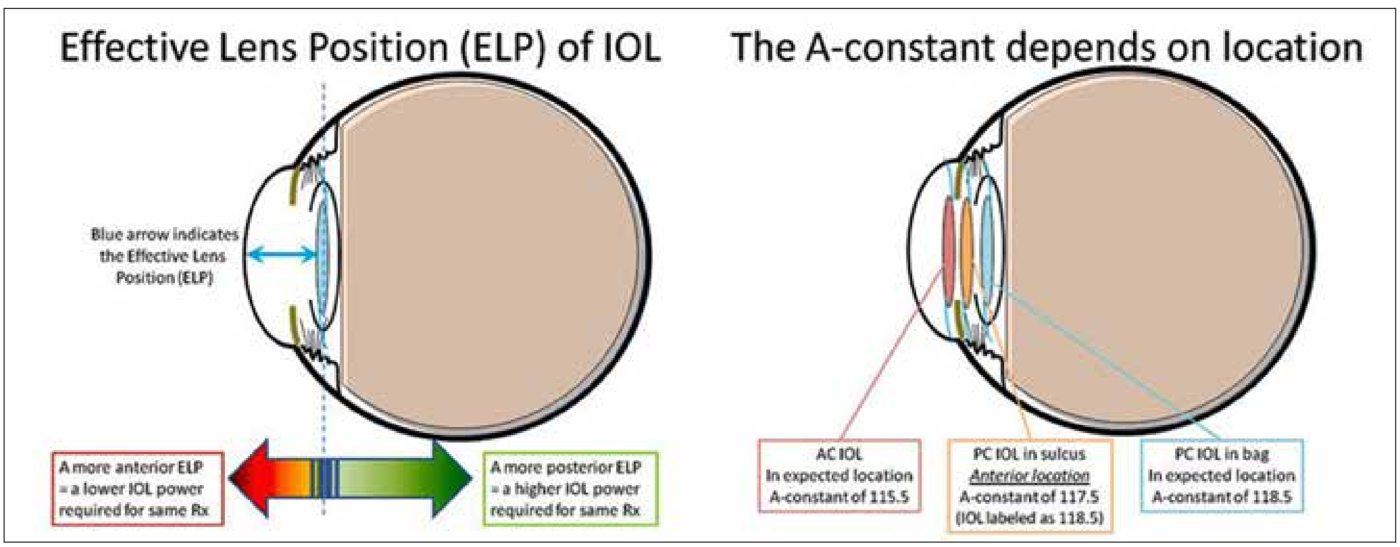

Figure 2: *Role of ELP and lens constant in IOL power calculation and how it varies with lens design [Adapted from Fig.2&3, Devgan U. Ocular surgery news 2012].*

Table 1: Holladay concept of nine-types of eyes

Anterior segment size vs. Axial length			
Large AS	Megalocornea + axial hyperopia (0%)	Megalocornea (2%)	Large eye, Buphthalmos, Megalocornea + axial myopia (10%)
Normal AS	Axial hyperopia (80%)	Normal (96%)	Axial myopia (90%)
Small AS	Small eye nanophthalmos (20%)	Microcornea (2%)	Microcornea +axial myopia (0%)
	Short AL	**Normal AL**	**Long AL**

Table 2: List of formulae used in the present day along with the principle, variables, and lens constant used

IOL Formula	Principle	Preoperative Measurable Variables	Variable used for ELP estimation	Lens Constant
Holladay I	Vergence	AL, K	AL, K	Surgeon factor (SF)
SRK/T	Vergence	AL, K	AL, K	A-constant
Hoffer Q	Vergence	AL, K	AL, K	pACD
Haigis	Vergence	AL,K,ACD	Pre-op ACD, AL	a0, a1, a2
Holladay II	Vergence	AL, K, HWTW, Refraction (previous), ACD, LT, Age	K, Pre-op ACD, LT, age, refraction	ACD
Barett Universal II	Vergence	AL, K, ACD, WTW*, LT		Lens factor (LF)
EVO	Vergence	AL, K, ACD, LT, WTW		SRK/T ULIB A constant
Olsen Okulix PhacoOptics	Ray Tracing	AL, K, ACD, LT	AL,K,Pre-op ACD,LT, age, refraction	C-constant
Hill RBF, Super Ladas, Clarke neural network Kane	Artificial Intelligence (AI)	AL, K, ACD, WTW*, LT* AL, K, ACD, LT, CCT		A-constant
Intra-op aberrometry ORA SYSTEM	Modified refractive vergence/AI	ASE, AL, K, WTW		Specific surgeon factor

The personalized lens constant can then be generated by the back-calculation method using the stable postoperative manifest refraction and the preoperative measurements (e.g., AL, K, ACD, HWTW, LT, etc.) with the selected formula. The personalization process can be repeated when more cases, including more anatomically non-average eyes, are available, targeting a standard error of the mean of less than ±0.25 D. Optimisation of IOL constants is made with pooled data from many users in Zeiss IOL master, available in the User group for Laser Interference Biometry (ULIB) database.[18] Manufacturer-recommended lens constants, either calculated theoretically or optimized clinically with the data from a group of surgeons, are a starting point for individual surgeons. Lens Constant personalization is a critically important step for each surgeon to further improve their patients' refractive outcomes [Figure 3].

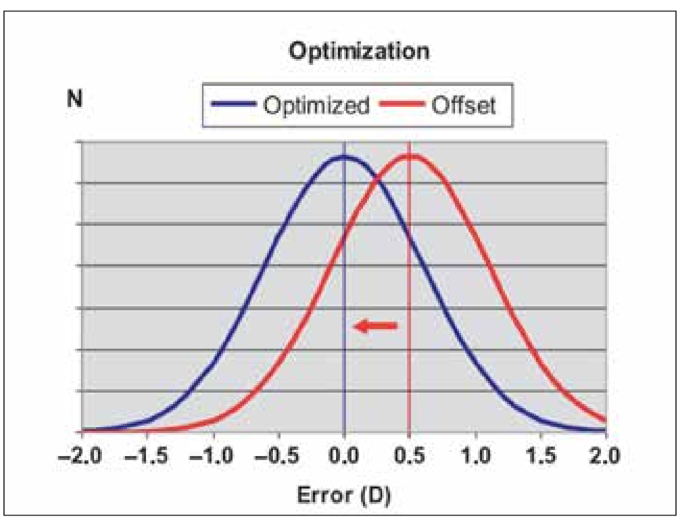

Figure 3: *Graph showing improvement in post-operative refractive outcomes with optimisation of the lens constant. [Adapted from Fig.9, Olsen T. Acta Ophthalmol Scand. 2007;85:472-85].*

(II). Iol Formulae

Various IOL calculation formulae have evolved through several generations and are reclassified based on the method or principle used[19]

1. Theoretical
2. Regression
3. Vergence
4. Ray tracing and artificial intelligence

Theoretical formulae were based on mathematical and geometric principles revolving around the optics of the eye using theoretical constants. They used a fixed power based on the patient's refraction and optics of the eye. Fyodorov published the first IOL power formula in 1967.[20]

Regression formulae were of the 2nd generation and arrived at by looking at the postoperative outcomes and working backward using regression analysis to arrive at the desired IOL power. Retzlaff, Sanders, and Kraff each developed a regression formula based on an analysis of their previous surgical cases. This work was amalgamated in 1980 to yield the SRK I and II formula.[21]

Vergence formulae include third, and fourth-generation formulae that incorporate both theoretical (geometric optics) and regression formulae. They are used to accurately estimate the effective lens position (ELP) and are further subclassified by the number of biometry variables used to predict this ELP. The two-variable formulas, such as the Holladay 1, Hoffer Q, and SRK/T employ axial length and

•Formula	•Modification
•Holladay 1	•0.829XAL+4.27
•Haigis	•0.928XAL+1.56
•SRK-T	•0.854XAL+3.72
•Hoffer Q	•0.853XAL+3.58

corneal curvature; the three-variable Haigis formula also uses anterior chamber depth, and the latest five variable version Barrett universal 2 includes lens thickness and corneal diameter. [22,23,24] The Holladay 2 utilizes 7 variables which include age and refraction.[25] (Table 1) Holladay et al. studied the variables correlation between AL and the size of the anterior segment and determined the predictors of ELP. Horizontal WTW measurements emerged as the next most important variable after AL and K. It was also proved that there is almost no correlation in 80–90% of the eyes and developed the concept of nine types of eyes–not just three (short, medium, or long).[26]

These results led to the formulation of the Holladay 2 formula, an easy-to-use program in which 7 variables (AL, K, ACD, LT, WTW, age of the patient, and previous refraction) are inserted for calculation of ELP and appropriate IOL power. The Barrett Suite is a combination of five formulas: i) Barrett Universal II for non-toric IOL calculation with Keratometry (K) values. ii) Barrett Toric for toric IOL calculation with Keratometry (K) values. iii) Barrett True K for non-toric IOL calculation for post Laser Vision Correction cases (LASIK, LASEK, PRK) and RK with Keratometry (K) values. iv) Barrett TK Universal II for non-toric calculation with Total Keratometry (TK) values. v) Barrett TK Toric for toric calculation with Total Keratometry (TK) values which is available online at apacrs.com and also incorporated in the IOL master 700. Barrett RX formula is available online to calculate the IOL power for piggyback lenses and IOL exchange.

The Kane formula is a combination formula that uses theoretical optics with both regression and artificial intelligence components to refine the predictions further. It uses the AL, K, ACD, LT, central corneal thickness (CCT), and biological sex to make its predictions.[27]

The emmetropia verifying optical (EVO) formula is also a newer, thick-lens, vergence-based formula that considers the eye's optical dimensions and different IOL geometries. It estimates ELP based on the fact that there is a specific axial length and ELP to achieve emmetropia for specific corneal power.28 In a retrospective study, the formula showed a lower prediction error compared to Holladay 1, Haigis, Hoffer Q, SRK/T, and the Hill-RBF 2.0 but was less accurate than the Kane, Olsen, and Barrett formulas.[27] The performance of the EVO suffered in the short and long axial length eyes, indicating the emmetropization concept may break down at the extremes of the axial lengths.

Ray tracing. Similar to the theoret¬ical versions above in their dependence on ELP, methods like the Olsen formula use individual rays that refract light on all surfaces of the lens and cornea. It calculates the postoperative lens position as a fraction of the crystalline lens thickness and the ACD. This approach allows accurate calculation of the lens position independent of the corneal status of the eye. It also takes the corneal and IOL higher-order aberrations into account, thus improving accuracy.[29] The concept of the C-constant was developed by Dr.Olson as a method to predict ELP from the preoperative dimension and position of the natural crystalline lens. It is defined as a ratio of the distance between the center of IOL (post-op) and the preoperative anterior lens capsule to the preoperative crystalline lens thickness. C= (ACDpost + TIOL/2- ACDpre)/LTpre. The prediction of IOL position with the C-constant is used in Olsen's ray tracing-assisted IOL power calculation.[3]

Artificial Intelligence-Based Formula

The Hill RBF, Clarke neural network, Super Ladas, Kane formula use regression based on a huge database and AI-based complex statistical models whose accuracy may be limited by the type of data.

Hill-RBF (radial basis activation function) is an advanced, self-validating method for IOL power selection. It was launched in 2016. It is purely "data-driven," independent of ELP, and has no data bias. RBF method uses artificial intelligence-driven pattern recognition and sophisticated data interpolation. RBF algorithms are used globally in a variety of technologies such as facial recognition software and thumbprint security scanners.[31] A special feature is that it is the only IOL power calculation formula that provides the user the reliability of the result; that is, the software can tell whether the result is correct or whether it is incorrect and outside the ability of the calculator. Hill-RBF has been optimized for biometry data from LenstarLS900 optical biometer and a particular IOL (Alcon SN60WF biconvex IOL). The latest version 3 has an expanded database for calculations in the range of +6 to +30D for biconvex IOLs and from -5 to +5D for meniscus IOLs.

Most of the newer generation formulae give accurate results in average-sized eyes, but the results are varied in short and long axial length eyes[32] (Figure 4).

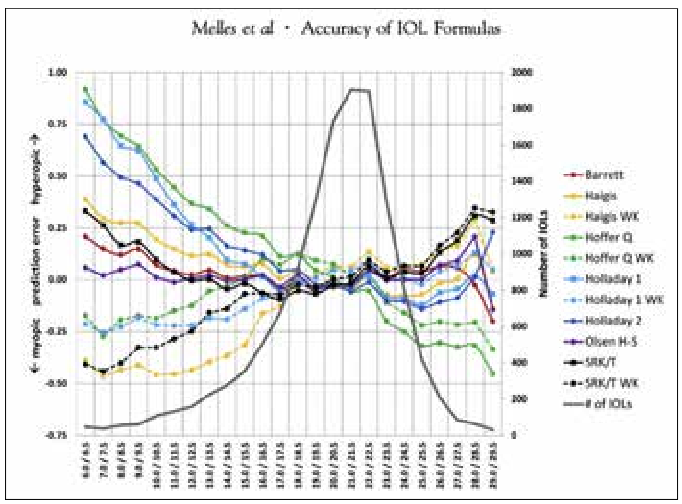

Figure 4: *Graph showing Prediction errors using various IOL calculation formulas across different IOL powers [Adapted from Fig. 5, Melles RB et al. Ophthalmology. 2018;125(2):169-178]*

(III).Special Circumstances

1. **Long eyes**

The presence of a posterior staphyloma can lead to difficulty in the identification of fovea, and a paraxial erroneously longer axial length may be obtained with ultrasound biometry. The addition of the A-scan measurement of anterior chamber depth and lens thickness to the B-scan measurement of vitreous depth may give a more accurate measurement of the axial length. This is overcome by the use of a fixation target in optical biometers if the patient's vision is fairly good and more accurate with IOL master 700, which directly visualizes the fovea on OCT image during measurement. Optimizing the A-constant shifts the power prediction curve and optimizes the formula to operate well over a wide range of axial lengths. The third-generation formulas overestimated the axial length leading to hyperopic refractive surprise. Wang Koch suggested modification of the AXL to offset this error as follows.[33]

Newer formulae like Kane, Olsen, Barrett Universal 2, and Hill RBF can be used without any modification giving more accurate values in longer eyes. The percentage of eyes within a prediction error of ±0.5D using the top-performing formula ranged from 57 to 86.5%.27 The surgeon can aim for residual myopic refraction to avoid a hyperopic refractive surprise. Also, myopic patients are accustomed to using near vision, and if they are corrected to Plano, their ability to see near objects will be lost.

2. Short eyes

Short eyes requiring higher dioptric IOLs tend to have higher prediction errors compared to long eyes ranging from 43-83.2% for ±0.5D.27 Optical biometry with advanced formulae like Kane, Olsen, Haigis, Holladay, 2 Barett universal II, or Hill RBF is preferred over ultrasound biometry as the estimation of ELP is more accurate in these. Many surgeons prefer Hoffer Q for IOL power estimation in short axial length eyes. It is preferable to use multiple formulas to obtain concordance in the readings and also explain the risk of a refractive myopic surprise post-operatively. Piggyback IOLs may be better than large powered single IOL in reducing the spherical aberration.[34]

3. Post-refractive surgery eyes

A pre-operative topography to assess the extent, depth, regularity, and centration of the ablation, along with a careful fundus exam with a +90D lens, indirect ophthalmoscopy, and OCT of the macula to assess its structure and possible function is needed. Eyes that have undergone refractive surgery will have to be evaluated for dry eyes, epithelial basement membrane dystrophy (EBMD) changes, irregular and decentered ablation, and irregular and thickened corneal epithelium.[35]

Post Radial keratotomy

The Gullstrand ratio is not altered as both the anterior and posterior corneal radii are flattened. Eyes with fewer cuts and a larger optical zone can be treated like a regular eyes with predictable results. With multiple cuts, the cornea's structural integrity is lost, leading to a progressive anterior corneal flattening and hyperopic drift. It is better to aim for postoperative -0.75 to -1.00 D myopia to compensate for this.[24]

Post-PRK, LASIK, and SMILE

The major cause of the error is the fact that most keratometers measure at the paracentral 3 mm zone of the cornea, which often misses the central flatter ablated zone of effective corneal power. A small or decentered optical zone of treatment is more likely to induce this type of error when compared to a large 6 mm treatment zone. The normal relationship between the anterior and posterior cornea is lost as the anterior corneal radius alone is flattened. This alters the Gullstrand ratio and leads to errors in corneal power estimation when the anterior corneal power alone is measured. The standard methods of measuring corneal power cause the power to be underestimated in myopia and overestimated in hyperopia. Tomographic devices that measure central K anterior and posterior surface powers are more accurate, like the Pentacam, Lenstar, or IOL master 700 and Galilei G6.[36] SRK/T uses K reading to alter ELP. Due to myopic Lasik, the formula will erroneously assume a shorter ACD and an anterior ELP in eyes with a flat cornea. The resultant IOL will be underpowered for that eye and result in a hyperopic postoperative error. To avoid the ELP-related IOL prediction error, Aramberri proposed the double K method, where the pre-refractive surgery corneal power is used to estimate the ELP and the post-refractive surgery corneal power is used to calculate the IOL power. Formulas that do not use K to alter ELP like Haigis-L or Shammas do a better calculation. Haigis L uses measured ACD for post Lasik eyes and can give 70% of eyes within 0.5D. When only the anterior corneal measurement is known, the Barrett's True K formula gives good results as it utilizes a predicted corneal power using a theoretical model known as the predicted posterior corneal astigmatism (PCA) method.[37]

Online calculators

The Iolcalc.ascrs.org has the post-refractive surgery IOL calculator. This was the gold standard until recently. The calculator accepts pre-refractive surgery data and post-refractive surgery data from various sources. Multiple formulas, including Shammas PL or Barrett True K formula, give a suggested set of IOL powers. If the calculations do not agree, extreme values are disregarded, and the median value is selected. In post-refractive surgery eyes requiring a toric IOL, intra-operative aberrometry helps the surgeon confirm IOL powers by neutralizing refractive astigmatism with high accuracy.[38,39] Other clinical pearls include aiming for residual myopia, operating on the non-dominant eye first, and refining the dominant eye's calculation based on the outcome. Avoid using multifocal IOL as it can exaggerate the optical aberrations in post-refractive surgery eyes.

4. Post silicone oil-filled globe

Gain must be increased to visualize the echospikes. The average sound velocity used for routine axial length measurement is 1550 m/sec, while the sound velocities in silicone oil-filled eyes are 980 m/sec (low viscosity-1300 cSt) and 1040 m/sec (high viscosity-5000 cSt).

If one uses the typical default velocity setting in the A-scan machine, the axial length obtained will be erroneously long, and IOL power is underestimated by 2-3 D. In the velocity conversion method, the true AL may be calculated by determining the ACD, LT, and corrected VCD separately. Corrected VCD = velocity of silicone oil/ velocity in vitreous X calculated vitreous length. A conversion factor of 0.71

corrects the apparent increase in AL induced by silicone oil of 1300 cSt. Optical biometry is the ideal method that allows for the accurate calculation of IOL power in silicone-filled eyes.40 Preferably, the patient must be sent to a center that can perform this measurement for the patient. Plano-convex configuration of IOL is preferred with Plano surface facing posteriorly, as the silicone in the eye acts as a negative lens altering the IOL power by 3-5 dioptres.

5. Aphakic and pseudophakic eyes

In Aphakic eyes, the two lens spikes are replaced by a single spike of the anterior vitreous face. The aphakic mode is selected in the biometers, in which the calculation compensates for the change in velocity of sound waves. For the anterior chamber, iris fixated or scleral fixated IOL, the appropriate A constant is used. In pseudophakic eyes, biometry is done in pseudophakia for comparison with other eye or in the setting of IOL exchange. The gain must be reduced to avoid the reverberation spikes from the IOL. The pseudophakic mode is selected in the biometers, in which the calculation compensates for the change in velocity of sound waves. True axial length = AL at aphakic velocity (1532m/sec) + (conversion factor center X lens thickness)

(IV).Recent Advances And Future Trends

The intraoperative wavefront aberrometry can be used to measure and analyze the refractive power of the eye. The ORA (optiwave refractive analysis) SYSTEM by Alcon captures a total ocular refraction measurement that accounts for total ocular astigmatism, including surgically-induced astigmatism and posterior corneal astigmatism, as well as post-myopic PRK/LASIK and long and short eye measurements to provide guidance for adjustments of lens selection and placement for all eye types and refine the toric IOL axis.[41] The ORA Analyz OR database can identify outliers mid-procedure to help surgeons hit refractive targets with more precision and consistency. Post-operatively, it verifies IOL power constants against manufacturer recommendations with global outcomes data to calculate optimized global and surgeon-specific lens constants.

Frontiers to be conquered include achieving greater accuracy in measuring total corneal power and ELP prediction, adopting a true optical path length, and availability of IOLs in smaller dioptric increments (e.g., 0.25 D) to facilitate more precise targeting.

Conclusion

The accuracy of IOL biometry can be improved by implementing a single calibrated biometer, repeating and verifying measurements by a second instrument or formula when necessary, using the IOL Master or immersion biometry rather than a contact applanation technique, using one of the newer IOL power calculation formulas, and personalizing the lens constants for each formula, tracking the refractive outcomes, and optimizing the surgical technique by making the capsulorhexis round, centered and overlapping the lens optic edge can all help to optimize the postoperative outcomes. Understanding the advantages and limitations of the current technology and following these guidelines makes it possible to consistently achieve highly accurate results.

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Address for correspondence

Nirupama Kasturi, MS
Additional Professor & Head - Ophthalmology
Department of Ophthalmology,
Jawaharlal Institute of Postgraduate
Medical Education & Research
(JIPMER) Pondicherry,
Tamil Nadu, India.
Email : kasturiniru@gmail.com

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