Biometry

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ABSTRACT: The present review focus on biometry discussing different parameters used to estimate the optical power of the intraocular lens after cataract surgery. Considerations for obtaining accurate measurements, different techniques, axial length measuring instruments, corneal power measurement and current formulas are discussed. This study also analyzes the specific considerations such as astigmatism, keratoconic, post-keratoplasty and post-corneal refractive surgery eyes.

J Emmetropia 2011; 2: 210-216

INTRODUCTION

Reason for biometry

Since Sir Harold Ridley experienced a 21 diopter «surprise» in lens power calculation on his first two cases in 1949 and 1950, we have been seeking ways to calculate intraocular lens (IOL) power with greater accuracy (fig. 1). Without a reasonable calculation of IOL power, intraocular lenses would never have proceeded to the standard of care they are today.

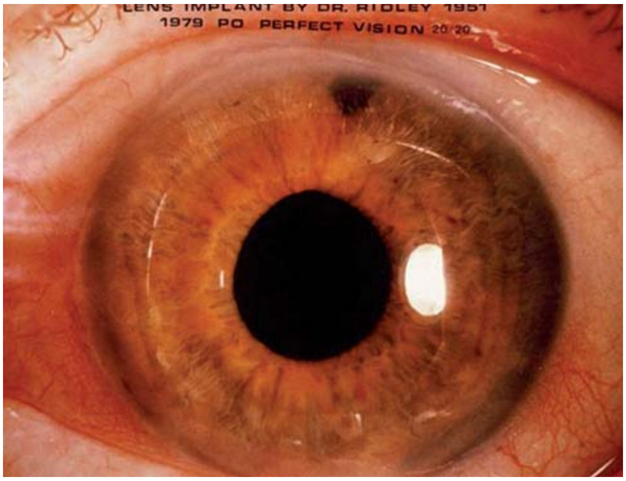

Figure 1. Uncorrected 20/20 vision in an eye with a Ridley posterior chamber IOL implanted after ECCE by Harold Ridley in 1951. [Photo by author in 1979].

This entire subject is based on the formula to calculate the power of the IOL which requires input of specific biometric data that must be collected for each individual patient. Let's first discuss the foundation of the formula and then the collection of the biometry.

When the human lens is replaced with an IOL, the optical status becomes a two-lens system (cornea and IOL) projecting an image onto the fovea. The distance (X) between the two lenses affects the refraction as does the distance (Y) between the two-lens system and the fovea. X is defined as the distance from the anterior surface (vertex) of the cornea to the effective principle plane of the IOL in the visual axis. Y is defined as the distance from the principle plane of the IOL to the photoreceptors of the fovea in the visual axis. It is easy to see that X + Y is equal to the visual axis axial length of the eye (A). Therefore knowing X and A will allow the calculation of Y ($Y = A - X$).

Also to calculate the IOL power (P), we must know the vergence of the light rays entering the cornea (refractive error (R)). For emmetropia, R is zero. The relationship of these factors (X, Y (A-X), P, K, R) are such that a formula can be written to describe it. Knowing the values of any four of these variables will allow for the calculation of the fifth.

BIOMETRY

Axial length

If the crystalline lens (cataract) is to be removed, obtaining an accurate axial length (AL) is mandatory. If the lens has already been removed (aphakia/ pseudophakia) or will not be removed (phakic IOL), an AL is not always necessary because the correct implant lens power can be calculated using a refraction formula (see below). Because this formula

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ISSN: 2171-4703

Table 1. Considerations for obtaining accurate measurements (in order of importance)

A. Optical or Ultrasound Axial Length:

1. A-scan Ultrasound Instrument
2. Real-Time Oscilloscope Screen
3. Immersion Technique
4. Experienced Technician
5. Appropriate Ultrasound Velocities
6. B-scan backup

B. Corneal Power:

1. Instrumentation
2. Contact Lens Wear
3. Astigmatism
4. Previous Refractive Surgery
5. Corneal Transplant Eyes

Figure 2. Optical Measuring devices. A: Zeiss IOLMaster. B: Haag-Streit Lenstar LS-900.

requires an accurate vertex distance, it is not dependable in cases of aphakia where errors in the vertex distance of a high-powered refraction can have a significant effect.

The important considerations for obtaining accurate ultrasound AL are listed in table 1.

Axial Length Measuring Instruments

Up to 1999, all axial length measuring instruments have been A-scan ultrasound units. In 1999 Carl Zeiss Meditec introduced a new instrument (fig. 2A) which uses laser coherent interferometry to measure AL. The IOLMaster® performs five functions; it measures 1) the AL, 2) the corneal power (K or r), 3) the anterior chamber depth (ACD), 4) the corneal white-to-white diameter (the latter three by optical means) and 5) performs the formula IOL power calculations using four modern 3rd generation theoretic formulas (the Hoffer Q, the Haigis, the Holladay I and the SRK/T.) A multitude of reports in the literature conclude that the IOLMaster is extremely accurate and reproducible but cannot obtain results in from 10-17% of eyes because of either posterior subcapsular cataracts (PSC) cataract, the density of a cataract, or the patient's inability to fixate. We have so far noticed increased success with PSC cataracts with the latest version 5 of the instrument software. In 2009, Haag-Streit introduced a similar unit called the Lenstar LS-900 (fig. 2B). Several studies since then have shown the instrument to be as accurate as the IOLMaster, but the Lenstar measures AL, K, Cyl, CD, ACD, LT, RT PD all in one shot. It also has all the modern formulas and performs the calculations.

Immersion Ultrasound Technique

Since neither of these optical instruments can obtain results in 5-8% of eyes due to dense cataracts and patient fixation, ultrasound will still be needed. The immersion technique of Ossoinig[1] has been shown to be more accurate than the standard applanation contact technique in several studies[2,3] over the past 15 years. They report a mean average shortening of the AL of 0.25-0.33 mm using applanation compared to immersion.

Arguments against using the immersion technique are that it is time-consuming, more expensive, messy and requires the patient to be totally supine. On the contrary, the examination can be performed in a standard ophthalmic examination chair reclined backward at a 45° angle with the headrest set back so that the patient's AL is perpendicular to the floor (fig. 3). To maintain a non-leaking fluid bath in the Ossoinig scleral shell [Hansen Ophthalmic Development Labs, 745 Avalon Place, Coralville, IA 52241, 319-338-

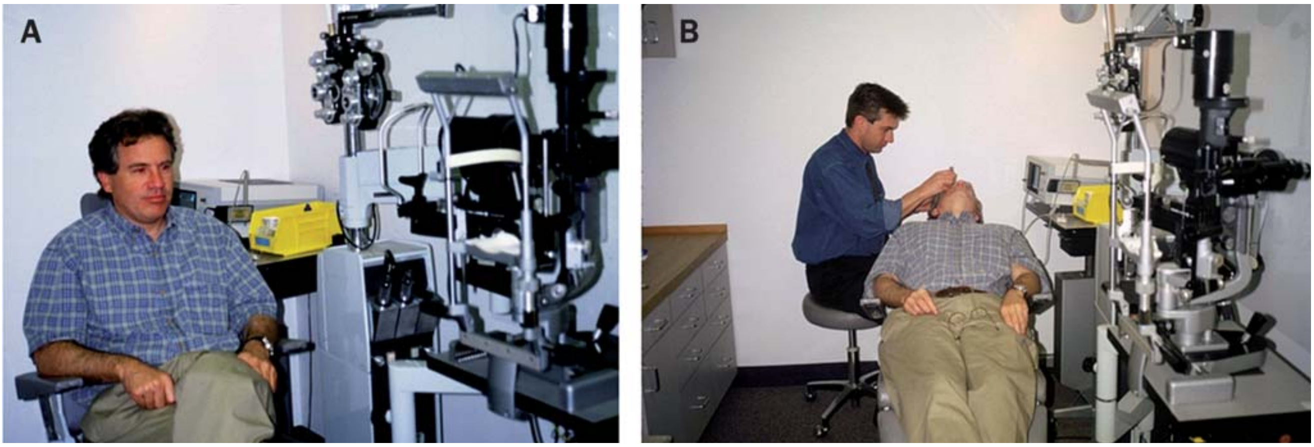


Figure 3. A: Patient sitting up in normal ophthalmic examining chair. B: Chair reclined 45° for Immersion A-scan procedure.

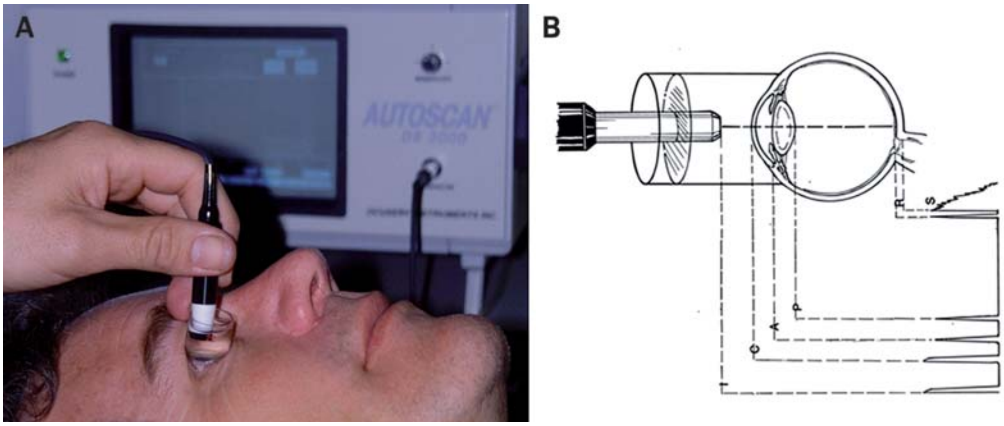


Figure 4. A: Immersion ultrasound probe in cup in exam chair with A-scan facing examiner. B: close up of immersion shell.

1285 www.HansenLab.com], we use a 50/50 dilution of 2.5% hydroxypropyl methylcellulose (Goniosol®) in Dacriose® solution. Once the eye is anesthetized topically, the scleral shell is gently placed between the lids and filled $^3/_4$ full with the solution. Any air bubbles should be vacuumed with a short silicone tube attached to a syringe. The latter can also be used to remove the solution at the completion of the procedure. The ultrasound probe is placed into the solution and positioned parallel to the axis of the eye (fig. 4). Axiality is judged by watching for the correct spike patterns on the oscilloscope screen as the probe position is adjusted. First the corneal and retinal spikes must be identified and «equally» maximized. An undilated pupil aids the examiner by the fact that eliminating the iris spikes improves the chances of being more axial; a dilated pupil eliminates this advantage.

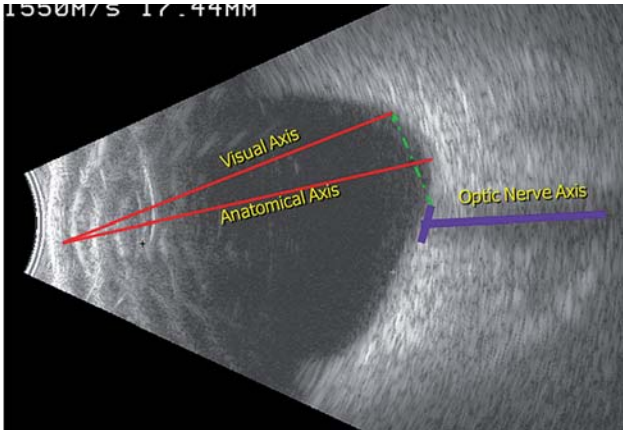


Figure 5. B-scan of an eye with a staphyloma showing the anatomical axis (blue) and the visual axis (red).

<u>WARNING</u>: Measuring the AL of <u>BOTH</u> eyes is prudent and customary.

<u>WARNING</u>: If the AL is very difficult to obtain and the eye appears to have a length greater than 25 mm, suspect a <u>STAPHYLOMA</u>. Use the IOLMaster or the Shammas method: By direct ophthalmoscopy (with patient fixating on the cross-hair target), measure the distance from the target (macula) to the edge of the optic nerve (in disc diameters). A B-scan exam is then performed to measure the AL at that distance from the edge of the optic nerve shadow (fig. 5).

WARNING: If planning silicone oil injection into the vitreous space, perform an accurate AL measurement before doing so and make this information available to the patient. It is practically impossible to measure a silicone oil eye (try using a velocity of 1000 m/sec.) The Zeiss IOLMaster is the only way to get an accurate measurement in silicone oil-filled eyes. Alternatively, consider performing a secondary IOL after the aphakic refraction is obtained.

Always measure AL to the nearest hundredth of a millimeter and record it carefully. Errors in AL are the most significant and amount to ~2.5 D/mm in IOL power but it is important to be aware that this error drops to ~1.75 D/mm in very long eyes (30 mm) but jumps to ~3.75 D/mm in very short eyes (20 mm). Greater care must be taken in measuring short eyes.

Ultrasound Velocities

The ultrasound velocity[4,5] for the various parts of the eye, intraocular lens materials and average pseudophakic velocities that I have calculated are shown in Table 2.

WARNING: Measuring an eye containing a silicone IOL with standard phakic velocity (1555 m/sec) can amount to an error of 3-4 D.

The nominal average velocity for the normal range AL eye is 1555 m/sec. Because of the inversely proportional change in the axial ratio of solid to liquid as the eye increases in length, the average phakic velocity of a short 20 mm eye is 1560 m/sec and that of a long 30 mm eye is 1550 m/sec (fig. 6) This factor amounts to only a small (0.25 D) error in the extremes of AL, but it can be corrected for. The inversely proportional relationship is greater in pseudophakic eyes but is not a factor at all in aphakic eyes (1534 m/sec.)

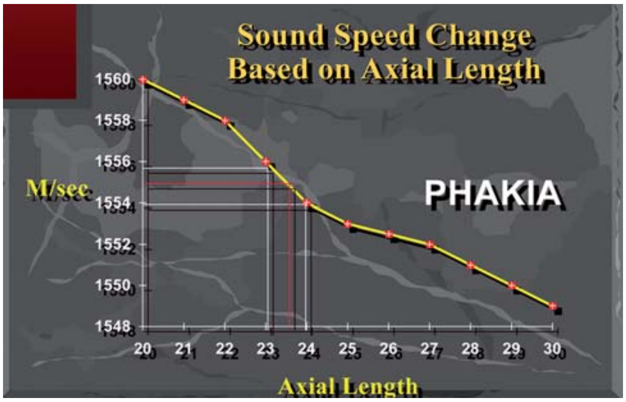


Figure 6. Phakic Velocity. Graph of decline in average sound velocity of a phakic eye as the axial length increases.

Table 2. Ultrasound Velocities (4,5) (at body temperature)

A. From the following sound velocity values (4,5):

• Cornea & Lens	1641 m/sec
• Aqueous & Vitreous	1532 m/sec
• PMMA IOL	2660 m/sec
• Silicone IOL	980 m/sec
• Acrylic IOL	2026 m/sec
• Glass IOL	6040 m/sec
• Silicone Oil	987 m/sec

B. I calculated average sound speeds4 for various conditions of a 23.5 mm eye:

• Phakic Eye	1555 m/sec
• Aphakic Eye	1534 m/sec
• PMMA Pseudophakic	1556 m/sec
• Silicone Pseudophakic	1476 m/sec
• Acrylic Pseudophakic	1549 m/sec
• Glass Pseudophakic	1549 m/sec
• Phakic Silicone Oil	1139 m/sec
• Aphakic Silicone Oil	1052 m/sec

If an eye has been measured using the wrong velocity, it can be easily corrected without remeasuring the eye by using the following formula:

$$AL_{CORRECTED} = (AL_{MEASURED}) \times (V_{CORRECT}) \div V_{MEASURED}$$

where V = ultrasound velocity.

This is because the instrument does not measure length or distance (d) directly. Instead it measures the time (t) it takes the sound to traverse the eye and converts it to a linear value using the velocity (V) formula where d = V × t.

Biphakic Eyes (Phakic eye with a Phakic IOL)

The problem here is eliminating the effect of the sound velocity through the phakic lens when measuring the AL using ultrasound. I published a method (6) to correct for this potential error by using the following formula:

$$AL_{CORRECTED} = AL_{1555} + (C \times T)$$

where AL_{1555} = the measured AL of the eye at sound velocity of 1555 m/sec, T = the central thickness of the phakic IOL and C = the material specific correction factor of +0.42 for PMMA, **–0.59** for silicone, +0.11 for collamer, +0.23 for acrylic, and +0.247 for Alcon acrylic anterior chamber phakic IOL.

The publication[6] contains tables showing the phakic IOL central thickness for each dioptric power for each phakic IOL on the market today.

Retinal Thickness Factor

Some formula writers add a value to the ultrasonic AL measurement to take into account the additional distance from the surface of the retina to the level of the receptive end of the retinal cones. This value has been estimated to be 0.20-0.25 mm and is automatically added to the AL in some formulas (Binkhorst, Holladay) and not used at all in others (Colenbrander, Hoffer Q).

CORNEAL POWER

The first lens in the eye's optical system is the cornea. We usually think of corneal power in terms of diopters of optical power but really we are measuring the radius of curvature of the anterior surface and making assumptions regarding the curvature of the back surface based on the Gullstrand eye. It has been proposed by many that we should convert to using the radius of curvature (r) rather than diopters (D) but that may take a long time, especially in America. The important factors to consider in obtaining accurate corneal power are listed in table 1B.

Instrumentation

A manual keratometer measures only the front surface of the cornea and converts the radius (r) of curvature obtained to diopters (K) using an index of refraction (IR) of 1.3375 (some units use a different IR.) The formula to change from D to r is [r = 337.5/D] and from r to D is [D = 337.5/r]. Many postulate that this index is too high and that lower ones should be used.

Corneal topography units also supply simulated corneal power values as do the newer Scheimpflug camera instruments such as the Pentacam and Galilei units.

> *WARNING: Hard contact lenses (including gas permeable) should be removed permanently for at least two weeks prior to measuring corneal power for IOL power calculation. Do this one eye at a time.*

Astigmatism

Regular astigmatism is not a factor in IOL power calculation because the goal is to predict the postoperative spherical equivalent refractive error. Therefore, the average of the two K readings is the only value used.

Keratoconus Eyes

Because a cornea with keratoconus can become very steep, it is important to consider the fact that formulas that use the K reading to estimate the ultimate IOL position (ELP) may overestimate this actual PO position. One should be aware that the K reading has less of this effect in the Hoffer Q formula than the other modern theoretic formulas. It is not a factor at all with the Haigis formula since it does not use the K reading at all in estimating the ELP.

Previous Corneal Refractive Surgery

Previous corneal refractive surgery causes three errors in IOL power calculation: 1) error in obtaining K reading, 2) error due to the change in the cornea's index of refraction (IR) [not a factor in an RK eye], and 3) modern theoretic formulas use the flat K reading to estimate the IOL position.

The first error is the fact that most keratometers measure at the 3.2 mm zone of the central cornea, which often misses the central flatter zone of effective corneal power; the flatter the cornea, the larger the zone of measurement. There are now many methods proposed to more accurately estimate the corneal power in these refractive surgery eyes. There are also methods proposed which adjust the calculated IOL power using standard data. To make it easier for the surgeon to analyze these many methods, we created the Hoffer/Savini LASIK IOL Calculation Tool (fig. 7) which automatically calculates the results using all the methods available. This Tool is available for free by downloading the MS Excel Template from www.EyeLab.com.

Corneal Transplant Eyes

A problem also arises when attempting to predict what the corneal power will be after corneal transplantation. Some have suggested using the corneal power of the other eye (if it is available) or using an average of one's post-transplant corneal powers, but published reports show a very large range of prediction and refractive errors using these methods. Performing the IOL implantation after the corneal transplant has settled down was suggested by this author (35) in 1986 and in 1990, Geggel[7] reported excellent refractive results (fig. 8) using this two-stage approach (66% 20/40 or better acuity without correction). A secondary piggy back toric IOL or toric phakic IOL is another alternative to correct residual ametropia in these cases.

Corneal Scar Eyes

The problem of getting an accurate corneal power measurement in eyes with corneal scarring and irregular astigmatism has not received much attention. Cua, et al[8] studied this in 2 eyes needing IOL exchange due to large «IOL surprises» of +5 and –7.5 D. They compared 6 methods to ascertain the corneal power and found the hard contact lens over refraction method to be the most accurate; decreasing the error they would have obtained with the manual keratometer of plus 4-

A

Calculating IOL Power in Eyes with Previous Corneal Refractive Surgery Ver 1.0 SURGEON John Augen, MD

WARNING!!⇒ THIS SPREADSHEET WILL PRODUCE ERRONEOUS INFORMATION UNLESS THE LETTERS NA ARE TYPED INTO EACH CELL WHERE YOU DO NOT HAVE THE REQUESTED DATA

WHITE cells are for Data Entry GRAY cells are for IOL Power Entry

Patient Name	Date	Eye For Surgery	
Patient Name	7/4/2007	OD	DATA
Enter DATA [or NA] Needed For Calculations			
Pre-LASIK SE Rx =	NA	Axial Length	27.00
PO LASIK SE Rx =	NA	IOL A-con	NA
Rx Δ (RCc) 0mm =	No Hx	Target PO Rx =	0.00
Rx Δ (RCs) 12mm =	No Hx	TARGET IOL "Single-K"	
Pre-LASIK K =	NA	Using PO K	NA
PO MK/TK =	NA	c "Low/High" K	NA
PO Topog EffRP	NA	Contact Lens Method	
Flattest Man PO K	NA	CL Base Curve	NA
PO Topog Central-K	NA	Hard CL Power	NA
IOLMaster PO K	NA	Refrx (SE) c CL	NA
IOLMaster IR	1.3375	Refrx (SE) Bare	NA
Pentacam =	NA	Must Use Hard PMMA	
Ant Radius r =	NA	Aphakic Refrx Methods	
Post Radius r =	NA	IANCHULEV IN OR	NA
C Thickness =	NA	MACKOOL PO	NA
IOL and POWER USED		NA	NA
POSTO P DATA	UCVA	NA	PO ACD
	BCVA	NA	NA
PO SE Refrx	NA	IOL Pred Err	NA

Must Enter NA in Cell if Data is Not Available

Calculation Results in Diopters

For K Reading — MYP: Lowest K HYP: Highest K

Method	
Clinical History Method	NA
Contact Lens Method	No CL
Maloney* Method	No Top
Koch/Maloney Method	No Top
Hamed-Wang-Koch	NA
Haigis Method	NA
BESSt© Formula	NA
Savini-Barboni-Zanini	No Top
Ronje Method	NA
Shammas No History	No K
Speicher (Seitz) Method	NA
IR METHODS: Savini IR Method	NA
IR METHODS: Camellin IR Method	NA
IR METHODS: Jarade IR Method	NA
IR METHODS: Ferrara IR Method	NA
Rosa Method	NA
Jarade Formula	NA
Pentacam =	NA

For IOL Power — *IOLs Calculated By SRK/T© (>24.5 mm)

The IOLs must be calculated using other software and added in the 3 Cells

Method		
Enter Powers using Single K	Emmetropic IOL c Pre-K	NA
	Target IOL c PO-K	NA
	TARGET IOL c PO Flat-K	NA
Feiz-Mannis Formula		NA
Feiz-Mannis Method		NA
Latkany Method Flat K		NA
**Latkany Method [K]		NA
Masket Method		NA
Aramberri DOUBLE-K (Target)		
Lowest or Highest K	NA	NA
PO K	NA	NA
AVG K	NA	NA
Your Choice of K	NA	NA
Wake Forest Method		NA
APHAKIC REFRX		
Ianchulev Method		Not Done
Mackool Method		Not Done

recommended to use the lowest in Myopes; highest in Hyperopes. Perhaps the Average?

LOW.../HIGH... K NA CHOSEN IOL EXACT NA

B

HOFFER®–SAVINI LASIK IOL POWER TOOL ©2007

Calculating IOL Power in Eyes with Previous Corneal Refractive Surgery Ver 1.0 SURGEON Jay Patel, MD

WARNING!!⇒ THIS SPREADSHEET WILL PRODUCE ERRONEOUS INFORMATION UNLESS THE LETTERS NA ARE TYPED INTO EACH CELL WHERE YOU DO NOT HAVE THE REQUESTED DATA.

WHITE cells are for Data Entry GRAY cells are for IOL Power Entry

Patient Name	Date	Eye For Surgery	
James A**k*ki	7/12/2006	OD	DATA
Enter DATA [or NA] Needed For Calculations			
Pre-LASIK SE Rx =	-6.00	Axial Length	27.55
PO LASIK SE Rx =	-0.37	IOL A-con	118.50
Rx Δ (RCc) 0mm =	-5.23	Target PO Rx =	-0.50
Rx Δ (RCs) 12mm =	-5.63	TARGET IOL "Single-K"	
Pre-LASIK K =	41.83	Using PO K	14.92
PO MK/TK =	39.00	c "Low/High" K	17.58
PO Topog EffRP	38.75	Contact Lens Method	
Flattest Man PO K	38.50	CL Base Curve	38.00
PO Topog Central-K	38.00	Hard CL Power	0.00
IOLMaster PO K	38.37	Refrx (SE) c CL	-0.25
IOLMaster IR	1.3375	Refrx (SE) Bare	-3.00
Pentacam =	37.30	Must Use Hard PMMA	
Ant Radius r =	8.68	Aphakic Refrx Methods	
Post Radius r =	6.75	IANCHULEV IN OR	8.75
C Thickness =	489	MACKOOL PO	9.25
IOL and POWER USED		18.0	SA60AT
POSTO P DATA	UCVA	20/25+2	PO ACD
	BCVA	20/20-1	5.00
PO SE Refrx	-0.25	IOL Pred Err	-0.25

Must Enter NA in Cell if Data is Not Available

Calculation Results in Diopters

For K Reading — MYP: Lowest K HYP: Highest K

Method	
Clinical History Method	36.60
Contact Lens Method	40.65
Maloney* Method	36.84
Koch/Maloney Method	37.07
Hamed-Wang-Koch	37.92
Haigis Method	36.50
BESSt© Formula	38.67
Savini-Barboni-Zanini	38.47
Ronje Method	37.09
Shammas No History	37.66
Speicher (Seitz) Method	38.67
IR METHODS: Savini IR Method	38.42
IR METHODS: Camellin IR Method	37.62
IR METHODS: Jarade IR Method	38.09
IR METHODS: Ferrara IR Method	33.35
Rosa Method	34.82
Jarade Formula	38.62
Pentacam =	37.30

For IOL Power — *IOLs Calculated By SRK/T© (>24.5 mm)

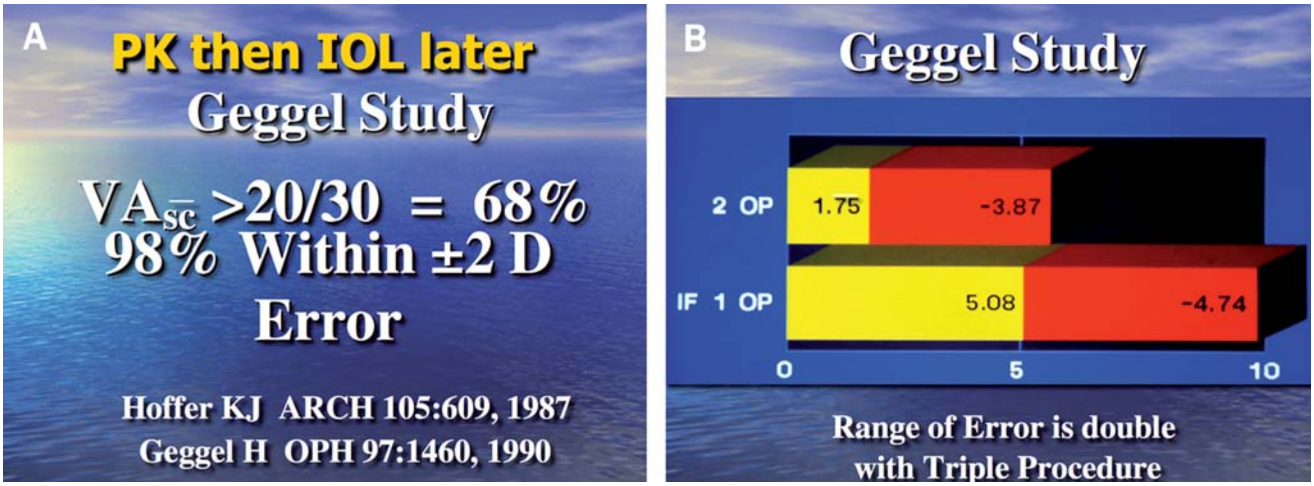
The IOLs must be calculated using other software and added in the 3 Cells BELOW ⇓.

Method		
Enter Powers using Single K	Emmetropic IOL c Pre-K	10.88
	Target IOL c PO-K	14.92
	TARGET IOL c PO Flat-K	15.49
Feiz-Mannis Formula		18.92
Feiz-Mannis Method		18.04
Latkany Method Flat K		17.46
**Latkany Method [K]		17.47
Masket Method		16.73
Aramberri DOUBLE-K (Target)		
Lowest or Highest K	36.50	19.18
PO K	39.00	15.68
AVG K	37.46	17.85
Your Choice of K	NA	NA
Wake Forest Method		18.96
APHAKIC REFRX		
Ianchulev Method		17.73
Mackool Method		16.29

It has yet to be proven which K is best to use. In the past it has been recommended to use the lowest in Myopes; highest in Hyperopes. Perhaps the Average?

LOW.../HIGH... K 36.50 CHOSEN IOL EXACT 17.85

Figure 7. Hoffer/Savini LASIK IOL Power Calculation Spreadsheet organizer. (A) without any data entered, (B) with all data entered for one patient.



A

PK then IOL later

Geggel Study

VA_{sc} >20/30 = 68%

98% Within ±2 D Error

Hoffer KJ ARCH 105:609, 1987

Geggel H OPH 97:1460, 1990

B

Geggel Study

Range of Error is double with Triple Procedure

Figure 8. Geggel keratoplasty study results. Dramatic decrease in range of IOL prediction error when IOL is implanted secondarily after transplant heals (5.62 D) vs. a triple procedure (9.82 D).

5 D to minus 0.4-1.6 D. This may be a useful clinical tool in such cases.

IOL AXIAL POSITION (ACD or ELP)

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. Because most IOLs today are positioned behind the iris, new terminology has been offered such as Effective Lens Position (ELP.)

ACD is defined as the axial distance between the two lenses (cornea and lens or IOL) or, more exactly, the distance from the central front surface (anterior vertex) of the cornea to the effective principle plane of the IOL (or front surface of the crystalline lens). This value is required for all formulas and it is incorporated into the A constant specific to each IOL style for SRK formulas or as an ACD, both supplied by the manufacturer. Some have proposed that it would be useful to measure the preoperative anatomic ACD (corneal epithelium to anterior lens capsule) either with an A-scan unit or by optical pachymetry. The author performed such a comparison study on 44 eyes and showed that the optical method (Haag-Streit Optical Pachymeter II) resulted in a mean 0.20 (±0.35) mm deeper ACD than obtained by immersion ultrasound using 1548 m/sec (3.14 vs. 2.93 mm).

The IOL position has been considered the least important of the three variables as a cause of IOL power error but IOL position has received the most attention from formula authors over the past fifteen years. The major effort has been toward better prediction of where the IOL will ultimately rest.

WARNING: An IOL intended for capsular bag placement should be decreased by 0.75-1.50 D (depending upon the IOL power) when placed in the ciliary sulcus.

Retinal Detachment Eyes: Hoffer Double-AL Method

This method, proposed by the author in 2000, uses two ALs. The PO retinal detachment (RD) AL of the eye is used to calculate the IOL power. Since most post-encircling band RD eyes have a 1.0 mm increase in AL, and the ACD is not affected by the encircling band, we use the AL-1 mm in the part of the formula that calculates the predicted ELP. This amounts to making the IOL a little weaker than would be predicted using all the modern formulas. Alternatively, one would just lower the power of the recommended IOL in such RD eyes.

FORMULAS

The first IOL power formula was published by Fyodorov[9] in 1967. Colenbrander[10] wrote his in 1972 followed by the Hoffer[11] formula in 1974. In 1982, the author[12,13] demonstrated a direct relationship between the position of a PMMA posterior chamber IOL and the axial length and presented a formula to better predict ACD. In 1988, Holladay[14] proposed a direct relationship between the steepness of the cornea and the position of the IOL (Holladay I.) In 1992, the Hoffer Q formula[15] was developed using a tangent function to accomplish the same effect. In 1990, Olsen[16] proposed using the preoperative ACD and other factors to better estimate the postoperative IOL position and published algorithms for this. After several studies showed the Holladay I formula not as accurate as the Hoffer Q in eyes shorter than 22 mm, Holladay used the preoperative ACD measurement as well as corneal diameter, lens thickness, refractive error and age to calculate an estimated scaling factor (ESF) that multiplies the IOL-specific ACD. This Holladay 2 formula has been promulgated since 1996 but has yet to be published. In 1999, Wolfgang Haigis[17] proposed using three constants to predict the position of the IOL based on the AL and preoperative ACD measurement.

CONCLUSION

Simple steps and attention to detail can be very useful in preventing IOL power errors and recent advances in IOL power range availability has made this problem more easily corrected. Since performing the first American ultrasound IOL power calculation[18] in 1974, the past 37 years have seen great improvement in the accuracy of postoperative refractive prediction. Future improvements may someday eliminate the problems we have left.

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