IOL Calculation on the 21st. Century: New Formulas
Intraocular Lenses (IOL) have been used since 1949. (Ridley)

To calculate IOL Power, measurements of Axial Length (AL), Keratometry (K), Anterior Chamber Depth (ACD), Lens Thickness (LT), White to White (WTW) are needed since 1960. (Fyodorov)

Achievement of a target refractive outcome has become an integral part of cataract surgery.

Biometry

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- To calculate IOL Power, measurements of Axial Length (AL), Keratometry (K), Anterior Chamber Depth (ACD), Lens Thickness (LT), White to White (WTW) are needed since 1960. (Fyodorov)
- Achievement of a target refractive outcome has become an integral part of cataract surgery.
The advent of optical biometry and introduction of new IOL calculation formulas has improved our ability to accurately predict cataract surgery refractive outcomes.

Low coherence based biometry is much more accurate than ultrasound-based (US).

Also SS-OCT is used to obtain even more precise measurements.

Accurate measurements minimize IOL calculation errors.

In a review of more than 260,000 eyes, it was found that less than 1% of cataract surgeons attained a ± 0.50 D accuracy of 92% or better, the great majority were clustered around the 78% level.
Optical Biometers

Does the Biometer really makes a difference??
Clinical comparison of a new swept-source optical coherence tomography-based optical biometer and a time-domain optical coherence tomography-based optical biometer

Natchong Srisuwanwong, MD, Channeen Chintapanaru, MD, Phuttarajt Chinthapal, BN, Stevanus I. Leket, MEd

PURPOSE: To evaluate the repeatability and reproducibility of a newer swept-source optical biometer and to compare it with a standard partial coherence interferometry (PCI) biometer.

SETTING: Siriraj Hospital, Mahidol University, Bangkok, Thailand.

DESIGN: Prospective comparative study.

METHODS: One hundred eyes from 100 cataract patients were enrolled in this study. Each patient was measured with 2 optical biometers, a newer swept-source optical biometer (IOLMaster 700) and a standard partial coherence interferometry biometer (IOLMaster 500) by 2 independent operators. The keratometry, axial length (AL), anterior chamber depth, white-to-white corneal diameter, and intraocular lens (IOL) power, calculated by the SRK7T and the Haigis formulas for each device were recorded. Intraoperator repeatability and interoperator reproducibility of both devices were analyzed using intraclass correlation coefficients (ICCs). Agreement of ocular biometry and IOL power between the 2 devices was evaluated using the Bland-Altman method.

RESULTS: The repeatability and reproducibility of the swept-source standard biometers were high for all ocular biometry parameters (ICC, 0.90-1.00). The agreement between the 2 biometers was also high (ICC, 0.90-1.00). The IOL powers obtained from both devices were not distinct. Because of the density of the cataracts, the AL in 5 eyes could be measured only by the swept-source biometer.

CONCLUSIONS: Repeatability and reproducibility of a swept-source optical biometer was excellent and agreement with a standard biometer was very high. Better lens penetration ability and AL measurements were obtained with the swept-source biometer than with the standard biometer.

IOL CALCULATION ON THE 21ST. CENTURY

Does the Biometer really makes a difference?

### Table

<table>
<thead>
<tr>
<th>Preoperative CDVA (logMAR)</th>
<th>Nuclear Opalescent</th>
<th>Nuclear Color</th>
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CDVA = corrected distance visual acuity; LOCS = Lens Opacities Classification System; SS-OCT = swept-source optical coherence tomography

**CONCLUSIONS:** Repeatability and reproducibility of a swept-source optical biometer was excellent and agreement with a standard biometer was very high. Better lens penetration ability and AL measurements were obtained with the swept-source biometer than with the standard biometer.
Does the Biometer really makes a difference??

Results:

IOL Master V 5.4 couldn’t measure AL in 37.7%, IOL Master 500 in 11.1% and Aladdin in 6.6%. IOL Master V 5.4 could measure ACD in 66.6%. IOL Master 500 in 100%. and Aladdin in 100%. IOL Master V 5.4 could measure K readings in 66.6%. IOL Master 500 in 100%. Aladdin in 100%. IOL Master V 5.4 could measure axis of steepest meridian in 66.6%. IOL Master 500 measure axis in 100%. Aladdin measure axis of steepest meridian in 100%. Comparison results showed a P value of <0.01 for Aladdin AL measure and IOL Master 500, <0.01 for Aladdin AL measure and IOL Master V 5.4 and <0.01 for K readings versus Pentacam and IOL Master 500.

Conclusions:

Aladdin Performs as good as the IOL Master 500 in AL measurements and better than IOL Master V 5.4. (no statistical significance). Aladdin performs as Good as IOL Master 500 and Pentacam in measuring K readings (no statistical Significance). All 3 biometer machines perform different in obtaining the axis for the corneal steepest meridian. Further Studies are needed as this new technology advance to get a new gold standard in Biometry through dense cataracts. We continue working and collecting data of more patients to get better statistical analysis.
Does the Biometer really makes a difference??

Results
In only 197 of the 231 eyes (85.3%), it was possible to obtain reliable measurements of AL with all the three devices. It was not possible to determine AL in 16 eyes (6.9%) with Lenstar LS 900; in 19 eyes (8.2%) with Aladdin; and in 20 eyes (8.6%) with IOLMaster 500 possibly related to the severity of lens opacification (the corneas had good transparency in the eyes included in the study). There was a statistically significant difference in AL between IOLMaster 500 and the remaining two biometers \((P = 0.03)\). However, the amount of difference was considered clinically not significant \((0.04 \text{ mm})\). The mean keratometry \((\text{mean } K)\) was determined in 203 eyes \((87.9\%)\) with all the three devices. Differences in mean \(K\) were between \(-0.1\) and \(0.06\) Dioptries \((D)\), which were considered neither statistically \((P > 0.05)\) nor clinically significant. The anterior chamber depth \((\text{ACD})\) was determined in 197 eyes \((85.48\%)\) with all the three biometers. The differences between the three devices \((0.03\) to \(0.13\) mm) were not statistically significant and considered also clinically not significant.

Conclusions
There were no clinically significant differences between these 3 biometers in AL, mean \(K\) and \(\text{ACD}\).
Does the Biometer really makes a difference??
Lens Constants

ocular.de/ulib/

THE CONSTANTS MUST BE OPTIMIZED!!!!!!!
Mathematics and Measurements

\[ P = \left(\frac{1336}{\text{AL-ELP}}\right) - \left(\frac{1336}{\frac{1000}{\left(\frac{1000}{\text{DPostRx}} - V\right) + K} - \text{ELP}}\right) \]

Where
- Net corneal power (K)
- Axial length (AL)
- IOL power (P)
- Effective lens position (ELP)
- Desired refraction (DPostRx)
- Vertex distance (V)
"For axial lengths from 22.50mm to 24.00mm, and central corneal powers ranging from 42.00D to 45.00D and a normal anterior chamber depth, most modern IOL power calculation formulas will give good outcomes”

Warren Hill MD.

• Something to consider: As surgeons, we are being judged by our patients and our peers by our refractive outcomes.

• It seems a little odd to spend thousands of dollars on the most accurate measurement technology, but continue to rely on calculation methods that are not from this century.

• Optimal outcomes require the best possible measurement technology and the best possible calculation methods.
Effective lens position (ELP)

<table>
<thead>
<tr>
<th>Generation</th>
<th>Description</th>
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<tbody>
<tr>
<td>First</td>
<td>Before 1980s, here the ELP was a constant of 4mm in every patient and every lens (mainly for ACIOLs)</td>
</tr>
<tr>
<td>Second</td>
<td>In 1980s, Binkhorst used AL, single variable predictor, as a scaling factor for ELP (9)</td>
</tr>
<tr>
<td>Third</td>
<td>In 1988, two variable predictor, K &amp; AL improved scaling accuracy of ELP (10)</td>
</tr>
<tr>
<td>Fourth</td>
<td>In 1995, Olsen &amp; co-workers improved ELP accuracy by adding 2 more variables – pre op ACD &amp; lens thickness (11)</td>
</tr>
</tbody>
</table>
New Formulas

• The Kane Formula
• The EVO Formula
• The Hill RBF Formula
• The Barrett Suite
• The Olsen Suite
The new Kane formula is based on theoretical optics and incorporates regression and AI to further refine its predictions.

A focus of the formula was to reduce the errors seen at the extremes of the various ocular dimensions which is where the current formulas display larger errors.

Uses AL, K, ACD, and patient gender along with optional variables of lens thickness (LT) and central corneal thickness (CCT) to predict the refractive outcome.

It maintains its accuracy at the extremes of axial length, resulting in a 25.1% reduction in absolute error in long eyes (≥26.0 mm), compared with the SRK/T; and a 25.5% reduction in absolute error in short eyes (≤22.0 mm), compared with Hoffer Q.

Multiple clinical studies have demonstrated that the Kane formula is more accurate than all currently available IOL formulas (including Hill-RBF 3.0, Barrett Universal 2, Olsen, Haigis, Hoffer Q, Holladay 1, SRK/T, EVO and Holladay 2).
The Kane Formula
EVO stands for Emmetropia Verifying Optical, is a new thick lens formula that is based on the theory of emmetropization and generates an 'emmetropia factor' for each eye.

Cornea growth is mainly completed at infancy, and the majority of eye growth occurs in the posterior segment. For a specific corneal power, there is a specific axial length and effective lens position (ELP) to achieve emmetropia.

It uses axial length, keratometry, and anterior chamber depth with optional variables of lens thickness and white-to-white distance.

In a Study published in Ophthalmology last year by R. Mellers et. al. the EVO formula, although more accurate than the Hill-RBF 2.0, was less accurate than the Kane, Olsen, and Barrett formulas.

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.
# The EVO 2.0 Formula

<table>
<thead>
<tr>
<th>EVO Formula IOL CALCULATOR v2.0</th>
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<tbody>
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<tr>
<td>Left Eye</td>
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<tr>
<td>Axial Length</td>
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<tr>
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<td>K2 (Steep)</td>
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<td>Optical ACD</td>
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**Advanced Options (Post Myopic LASIK/PRK)**

<table>
<thead>
<tr>
<th>IOLMaster 700 Total Keratometry</th>
<th>Refractive History</th>
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<tbody>
<tr>
<td>PK1</td>
<td>Pre LASIK SE</td>
</tr>
<tr>
<td>PK2</td>
<td>Post LASIK SE</td>
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The Hill RBF 3.0 Formula

rbfcalculator.com

- The Hill-RBF Calculator is an advanced, self-validating method for IOL power selection employing pattern recognition and a sophisticated form of data interpolation.

- It has been optimized for use with the Haag-Streit LENSTAR LS 900 optical biometer in combination with the Alcon SN60WF biconvex intraocular lens (IOL) and the Alcon MA60MA meniscus design intraocular lens.

- The Hill-RBF on-line calculator may also be used with data from other optical biometers, and with other biconvex IOL models.

- The Hill-RBF 3.0 is more accurate than the third-generation formulas, which indicates that it has improved compared with the original version.

- Nevertheless, it still is less accurate than the Kane, Olsen, Barrett, and EVO formulas, which are all based on optics principles, suggesting that the artificial intelligence regression model that it relies on is not yet as accurate as the optical models.
The Hill RBF 3.0 Formula
The Barrett Suite

calc.apacrs.org/barrett_universal2105/

• The Barrett Suite is a combination of five formulas:
  • Barrett Universal II for non-toric IOL calculation with Keratometry (K) values
  • Barrett Toric for toric IOL calculation with Keratometry (K) values
  • Barrett True K for non-toric IOL calculation for post Laser Vision Correction cases (LASIK, LASEK, PRK) and RK with Keratometry (K) values
  • Barrett TK Toric for toric calculation with Total Keratometry (TK) values

• Barrett Rx for IOL exchange & piggy bag selection after surgical surprises

When using the Barrett True K formula after refractive corneal surgery, Dr. Barrett recommends entering the optional values pre-Lasik ref. and post-Lasik ref. (refraction before and after refractive corneal surgery) if known.
Barrett: Universal II

For non-toric IOL calculation with Keratometry (K) values
Barrett: Toric

For toric IOL calculation with Keratometry (K) values
Barrett: True K

For non-toric IOL calculation post Laser Vision Correction (LASIK, LASEK, PRK) and RK with K values.
Barrett: True K Toric

For toric calculation with Total Keratometry (TK) values
Barrett Rx for IOL exchange & piggy bag selection after surgical surprises
The Barret Suite

IOL CALCULATION ON THE 21ST. CENTURY

- Holladay I
- Hoffer Q
- SRK/T
- Haigis
  - only a2p optimized
- Holladay II
- Olsen
- Barrett II

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  - Scientifically the W-K adjustment is controversial since it depends on the IOL design whether the adjustment is required or not.

** Case has to be taken in eyes with very long AL. Special constants are needed for IOLs that change from symmetrical to asymmetrical geometry at certain power thresholds. This can lead to significant principal plane shifts and to a shift in different ELP positions.**
• Uses exact ray tracing and thick lens considerations to account for the true physical dimensions of an eye’s optical system.

• Uses the same technology employed by physicists to design telescopes and camera lenses.

• A key feature of the Olsen formula is accurate estimation of the IOL’s physical position using a newly developed concept, the C-constant.

• The C-constant can be thought of as a ratio by which the empty capsular bag will encapsulate and fixate an IOL following in-the-bag implantation.

The Olsen Suite

https://ascrs.org/tools
The Olsen Suite

- As input parameter apart from AL and Ks, Olsen uses ACD and LT measurement.

- Warren E. Hill, MD and Edward J. Meier, MD, are currently assessing the performance of the Olsen formula in comparison with the Holladay 2 formula, a fourth-generation multivariable IOL calculation method, using lens thickness measurement as a parameter for improved IOL prediction accuracy.

- In a clinical series on more than 1700 eyes, Dr. Olsen assessed the performance of the Olsen formula as compared to standard formulas like Holladay 1 and SRK/T.
Now what? Which Formula should I use?
In Summary

- Achieving a target refractive outcome is an essential—and complex—aspect of cataract surgery.

- We know the importance of having a healthy corneal surface; it’s important to have not only a good biometer but also some type of topographer.

- Is another formula the solution? It depends... You certainly don’t want to be left behind in the race toward accuracy.

- Of course, the formula you choose will depend in part on the equipment you’re currently using.

- Accurate biometry is one of the most important steps in calculating IOL power.

- You also don’t want to jump off a formula if it’s working well in your practice.

- Evaluate your own results !!!

- How does a clinician know when a measurement is likely to be correct or incorrect? After all, said Dr. Hill, a measurement is only as good as your ability to know what it means.

- The idea of a universal IOL power formula that works in eyes of all shapes and sizes is an attractive one, but it is likely unrealistic for now...
Thank you!!