IOL Power Calculations…
Achieving accurate results in LACS era

Hany Helaly, MD
Lecturer of Ophthalmology,
Alexandria university, Egypt.

• IOL power calculations have become a focal point of cataract surgery.

• In the UK (2006): "benchmark" standard for refractive outcomes for normal eyes after cataract surgery should be within ±0.50D for 55% of cases and within ±1.00D for 85% of cases.
Today, it is possible to be within ±0.50 D for >70% of cases and ±1.00 D for >90% of cases.

Sources of error in IOL power calculation

- Error from instrumentation and technique of measurement:
  - Axial length measurement
  - Keratometric error
- Errors from wrong choice of calculation formulas.
- Errors from implant power labeling.
- Errors resulting from operative technique and post-operative changes.
Methods of Measuring Keratometric Power

- Manual keratometer
- Automated keratometer (AK)
- Corneal Topography
- Pentacam (Oculus, Germany)
- Optical biometers: IOLMaster, Lenstar

IOLMaster

- reflects six points of light, arranged in a 2.3 mm-diameter hexagonal pattern.
- separation of opposite pairs of lights is measured, and the toroidal surface curvatures are calculated from three fixed meridians.
LENSTAR LS 900

- Based on **optical low coherence reflectometry (OLCR)** using a wavelength of 820 μm.

- To calculate K readings, it evaluates 32 points at 2.3 and 1.65 mm optical zones.

A-scan Biometry (Applanation).

- **Variable corneal compression.**

- The applanation technique yields a shorter axial length than immersion, as a result it would require a lower lens constant.

  - a: Initial spike (probe tip and cornea)
  - b: Anterior lens capsule
  - c: Posterior lens capsule
  - d: Retina
  - e: Sclera
  - f: Orbital fat
**A-scan Biometry (Immersion).**

- Better reproducibility than the applanation method.
- Coupling fluid prevents compression.
- Making the change from the applanation to immersion is well worth the small learning curve.

**A-scan Biometry (Immersion).**

- a: Probe tip. (moved away from cornea)
- b: Cornea. (Double-peaked)
- c: Anterior lens capsule.
- d: Posterior lens capsule.
- e: Retina. (sharp 90 degree take-off from the baseline)
- f: Sclera.
- g: Orbital fat.
**Immersion Vector A/B-scan Biometry**

- A-scan vector is adjusted so as to pass through the middle of the cornea as well as the anterior and posterior lens echoes.

- Such alignment assures that the vector will intersect the retina in the region of the fovea.

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**Optical Biometry (advantages)**

- 9x the resolution of a 10 MHz sound wave.

- Measures to the center of the macula → it gives the refractive axial length.

- Contact with the cornea is not needed.

- Avoid operator variations.
**LENSTAR LS 900**

- Pachymetry
- Lens Thickness
- Keratometry
- Pupillometry
- Eccentricity of the Visual Axis
- ACD
- Axial Length
- White to White
- Retinal Thickness

**Comparing the accuracy of OLCR vs. PCI**

- *Study published in DJO 2013.*

- *Authors: Prof. Dr. Ahmed A. El-Massry, Dr. Hany A. Helaly.*

- *A prospective study that included 50 eyes of 50 patients scheduled for cataract surgery.*
### Comparing the accuracy of OLCR vs. PCI

<table>
<thead>
<tr>
<th></th>
<th>Lenstar LS 900</th>
<th>IOLMaster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± Standard deviation (Range)</td>
<td>Mean ± Standard deviation (Range)</td>
</tr>
<tr>
<td>Axial Length (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>different recalibration algorithm</td>
<td>$23.93 ± 1.74$ (21.7 to 29.2)</td>
<td>$23.92 ± 1.73$ (21.69 to 29.0)</td>
</tr>
<tr>
<td>Average K readings (D)</td>
<td>43.74 ± 1.05 (41.42 to 46.20)</td>
<td>43.83 ± 0.96 (42.27 to 46.34)</td>
</tr>
<tr>
<td>32 points vs 6 points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior Chamber Depth (mm)</td>
<td>3.17 ± 0.24 (2.80 to 3.90)</td>
<td>3.11 ± 0.24 (2.70 to 3.80)</td>
</tr>
<tr>
<td>optical biometry vs. image analysis</td>
<td></td>
<td></td>
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</tbody>
</table>

### Comparing the accuracy of OLCR vs. PCI

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<tr>
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<th>Lenstar LS 900</th>
<th>IOLMaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean arithmetic error (D) ± SD</td>
<td>$-0.017 ± 0.56$</td>
<td>$-0.0048 ± 0.60$</td>
</tr>
<tr>
<td>Mean absolute error (D) ± SD</td>
<td>$0.428 ± 0.36$</td>
<td>$0.472 ± 0.37$</td>
</tr>
<tr>
<td>Range (D)</td>
<td>(-1.40 to +1.00)</td>
<td>(-1.45 to 0.98)</td>
</tr>
<tr>
<td>Prediction error</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within ± 0.5 D</td>
<td>68 %</td>
<td>70 %</td>
</tr>
<tr>
<td>Within ± 1 D</td>
<td>94 %</td>
<td>90 %</td>
</tr>
<tr>
<td>Within ± 2 D</td>
<td>100 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>
**IOLMaster 700 (next generation)**

- The first Swept Source OCT-based biometer (the entire eye is scanned three dimensionally).

**IOLMaster 700 (next generation)**

- Provides an image-based measurement, allowing one to view the complete longitudinal section of the eye—from the cornea to the retina.

- It can also be used to identify irregular eye geometries, such as lens tilt.
**IOLMaster 700 (next generation)**

- Preoperative crystalline lens position and tilt (top) and postoperative IOL position and tilt in horizontal (0°) B-Scan image (bottom).

![B-Scan image](image)

**IOLMaster 700 (next generation)**

- Imaging of the fovea → alert the user to insufficient fixation during measurements.

*Poor (left) vs. correct (right) fixation*
**IOLMaster 700 (next generation)**

- It has a built-in **toric IOL calculator (Haigis-T)**.

- It acquires a reference image of scleral & conjunctival vessels → CALLISTO eye computer in the OR → connected to the LUMERA microscope → During surgery, the image allows intraoperative matching with the live eye image.

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**The VERION™ Image Guided System**
The VERION™ Image Guided System

Optical Biometry (Lens Constants)

• Always higher than those of applanation A-scans and very close to those of immersion A-scans (because of no corneal contact).

• Suggested Initial IOLMaster SRK/T Aconstant:

\[ A_{\text{Optical Biometry}} = A_{U/S} + 3 \times (A_{L_{\text{Optical Biometry}}} - A_{L_{U/S}}) \]
IOL power calculation formulas

- The term “effective lens position” was recommended by the FDA in 1995 to describe the position of the lens in the eye, since the term anterior chamber depth (ACD) is not anatomically accurate for lenses in the posterior chamber and can lead to confusion for the clinician.

The Haigis Formula.

- $a_0$ constant moves the power prediction curve up or down (similar to A-constant).
- $a_1$ constant is tied to the measured anterior chamber depth.
- $a_2$ constant is tied to the measured axial length.
- Both the $a_1$ and the $a_2$ constants are used to vary the shape of the power prediction curve.
Choice of IOL power calculation formulas

- For axial lengths from 22.50 mm to 26.00 mm, and central corneal powers ranging from 41.00 D to 46.00 D, almost any modern IOL power calculation formula will give good outcomes.

- **Short eyes**: Hoffer Q, Haigis.
- **Long eyes**: Holladay, SRK/T
- **4th generation formulas**: Holladay 2 & Haigis.

Bag vs. Sulcus IOL Power

- decrease in lens power is often necessary (optic is shifted more anterior).
- The amount of this change is dependent on the "base power" of the intraocular lens. The greater the power, the greater the difference.

<table>
<thead>
<tr>
<th>Power at Capsular Bag</th>
<th>Bag / Sulcus Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>+30.00 D</td>
<td>-1.45 D</td>
</tr>
<tr>
<td>+22.00 D</td>
<td>-1.00 D</td>
</tr>
<tr>
<td>+12.00 D</td>
<td>-0.50 D</td>
</tr>
<tr>
<td>+5.00 D</td>
<td>-0.20 D</td>
</tr>
</tbody>
</table>
**Corneal Transplantation**

- There is **no method** that can be used to accurately carry out IOL power calculations prior to corneal transplantation combined with cataract removal.

- This is because it is **impossible to know the central power of the donor graft prior to surgery**.

**Corneal Transplantation**

- Either use a "best guess" of post-operative corneal power (such as 44.0 D) → often lead to an unpleasant post-operative refractive surprise.

- Or carry out corneal transplantation with cataract removal, but without intraocular lens implantation. The lens implantation would then be carried out at a later time, as a *secondary procedure*.
Primary Polypseudophakia

Understanding Silicone Oil

- There are presently two viscosities of silicone oil in use:
  - 1,000 mPa.s. silicone oil: slows sound waves to 980 m/sec.
  - 5,000 mPa.s. silicone oil: slows sound waves to approximately 1,040 m/sec.
Understanding Silicone Oil

- Use optical biometry.

- Adjust U/S speed in the machine.

- Multiply result $\times \frac{980 \text{(silicone speed)}}{1532}$.

- Use 2ry IOL implantation.

Understanding Silicone Oil

- If the silicone oil is to remain in the eye for an extended period of time after cataract surgery:

  For an eye of average dimensions, the additional power needed for a convex-plano PMMA intraocular lens is typically between +3.0 D to +3.5 D.
**Posterior Staphyloma**

- Failure to recognize a posterior staphyloma can result in an unpleasant refractive surprise following cataract surgery.

- **Anatomic axial length** (the distance from the corneal vertex to the posterior pole) may differ from the **re refractive axial length** (the distance from the corneal vertex to the fovea).

**Posterior Staphyloma**

- The simplest method: measure axial length by **optical biometry**. If the patient's visual acuity is good enough, have him look directly at the red fixation light.

- If not possible, an **immersion vector-A / B-scan** can be used to measure the axial length to the center of the macula.
IOL power calculation following Keratorefractive surgery

• Measured average k-reading + standard IOL power calculation formulas → overestimation (postop. hyperopia)

IOL power calculation following Keratorefractive surgery

• After myopic LASIK: postop. hyperopia
• After hyperopic LASIK: postop. myopia

• Error 1 D in IOL power → 0.71 D error at the spectacle plane

**Formula error**

- The estimation of effective lens position (ELP) by the third- or fourth-generation formulas is not correct when the postoperative corneal power values are used.

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**Advances in IOL power calculation formulas after keratorefractive surgery**

- The double-k formula.
- Holladay 2 formula.
- Haigis-L formula.
- Shammas-PL formula.
### The double-k formula

- For 3rd generation formulas:
  - SRK/T.
  - Holladay 1.
  - Hoffer Q.
- This method uses **2 k-values**:
  - *pre refractive* for calc of ELP
  - *post refractive* for the vergence formula that finally gives the IOL power

### Holladay 2 formula

- Uses another innovative approach, which is to use measurements of
  - corneal power.
  - corneal diameter.
  - anterior chamber depth (ACD).
  - lens thickness.
  - refractive error.
  - axial length.
  
  to further refine the ELP calculation.
**Haigis-L formula**

- Using a correction curve to correct the current IOLMaster measurement of corneal radius to derive the effective equivalent corneal power.

- Then enter it into the regular Haigis formula.

\[ r_{corr} = \frac{331.5}{(-5.1625 \times r_{meas} + 82.2603 - 0.35)} \]

**Shammas-PL formula**

- Shammas described a corneal power correction method that uses only data available at the time of cataract surgery (i.e. post-LASIK K-readings).

- \[ Kc = (1.14 \times K_{post}) - 6.8 \]
**Shammas-PL formula**

- This corrected K-value is used in the Shammas post-LASIK (Shammas-PL) formula

- In which the ELP does not vary with the corneal curvature that has been altered by the LASIK procedure.

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**radial keratotomy**

- Any map that provides average anterior corneal power over central 2–3 mm → gives an accurate estimation of corneal refractive power.

- Still needs to compensate for potential errors in ELP by using
  - Holladay 2 formula
  - double-K approach with 3rd generation formulas.
Take Home Message

• Immersion A scan is still the gold standard for biometry and worth the effort to shift to.

• Optical biometry is a new simple method to achieve reproducible accurate results comparable to the gold standard.

• Personal optimization of lens constants is mandatory for more accurate postoperative refractive outcome.

THANK YOU