ADVANCED IOL POWER CALCULATIONS

Jack T. Holladay, MD, M.S.E.E., F.A.C.S.

I. Formulas and Measurements

A. Variables Used to Predict ACD
1. Binkhorst 2 - 1981 - AL
2. Holladay 1 - 1988 - AL, K
3. SRKT - 1990 - AL, K
4. Hoffer Q - 1993 - AL, K
5. Olsen - 1995 - AL, K, ACD
6. Clarke - 1996 - AL, K1, K2 ACD, LT
7. Holladay 2 - 1996 - AL, K, HWTW, REF, ACD, LT, AGE

B. Normal Values for required Measurements
1. Axial Length: mean = 23.5 mm, SD = 1.25 mm
2. Keratometry: mean = 43.81 D, SD = 1.6 D
3. Horizontal White-to-White (Corneal diameter): mean = 11.7 mm, SD = 0.46 mm
4. Preoperative Refraction: mean = plano
5. Anterior Chamber Depth (ultrasonic): mean = 3.1 mm, SD = 0.30 mm
6. Crystalline Lens Thickness (ultrasonic): mean = 4.7 mm, SD = 0.41 mm
7. Age: mean = 72, SD = 12 years

II. Axial length Measurements in Aphakic and Pseudophakic eyes
A. Aphakia - 1532 M/sec
B. Pseudophakia
1. PMMA - 2718 M/sec
2. Silicone - 980 M/sec
3. Acrylic - 2120 M/sec

III. Determination of corneal power following Keratorefractive Sx (PRK, LASIK, RK)
A. Manual Keratometry
B. Automated Keratometry
C. Corneal Topography
D. Calculation from pre- keratorefractive surgery K’s
E. Determination from hard contact lens trial

IV. Data Screening Techniques on Preoperative Measurements
A. Probability of unusual measurements (one eye only)
B. Probability of asymmetrical measurements (both eyes)

V. IOL Calculations requiring Axial Length Measurements
A. Standard Cataract Removal with IOL
1. Piggy-Back IOL’s: Use 34 D IOL posterior in bag
2. Multifocal IOL’s: Target distance plano, near for -3.00 D.
3. Toric IOL’s: IOL Cylinder to Corneal Cylinder ~ 1.46, but not exact for low (1.75) and high (1.20) power IOLs
a. Optimization of Cataract Incision Location: Normal 4 locations for zero residual astigmatism
b. Back calculation for surprise: 1) P.O. Refraction & 2) P.O. Ks OR Current IOL axis
B. Cataract Removal with IOL and Silicone in Vitreous: use convexplano ~ 3 D more, for biconvex ~ from 5 - 6 D more in IOL.

VI. IOL Calculations not requiring Axial Length
A. Secondary Implant for Aphakia: in sulcus or anterior chamber angle
B. AC IOL in phakic patient: High myopia (- IOL) & High hyperopia (+ IOL)
C. Secondary Piggy-Back IOL for high hyperopia (or myopia within 1 year)

VII. Pediatric IOL calculations
A. Ideal Postoperative Target Refraction: plano to -1.00 D.
B. Expected Myopic Shift with age: 4 D from age 2 to age 21.

VIII. Minimizing Prediction Error
A. Personalizing Formula Constants (A-const, ACD or Surgeon Factor)
B. Prediction Error vs. IOL Power
C. Creating personalized constants for subgroups
1. Axial Length (< 22 mm or > 26 mm)
2. Keratometry (< 40 D or > 48 D)
3. Preoperative Refraction (< -4 D or > +4 D)

IX. Calculating SIRC (Surgically induced refractive change)
A. From pre and post operative refraction
B. From pre and post operative keratometry
C. Secondary Piggy-Back IOL for high hyperopia (or myopia within 1 year)

X. Outcomes Analysis
A. Prediction Error Analysis: Mean absolute prediction error should be < 0.50 D.
B. Formula Comparisons: more predictors, better results in unusual eyes
C. SIRC Results: Astigmatic Analysis
D. Visual Acuity Results
1. Best corrected
2. Uncorrected

XI. Back-calculations
A. For determining source of error with refractive surprise
B. Comparison of back-calculated lens constant and actual lens constant

Jack T. Holladay, M.D., M.S.E.E., F.A.C.S.

Clinical Professor of Ophthalmology
Baylor College of Medicine
Houston, Texas, USA

Fax: 713 668 7336
Measurements taken for Predictors of ELP
- Axial Length
- Average K
- Horizontal WTW
- ACD
- LT
- Pre-op Refraction
- Age

Normal Physiologic Values
- ACD: 3.1 mm ± 0.30 mm
- LT: 4.7 mm ± 0.41 mm
- Age: 72 years ± 12.0 years

Critical Data
- Corneal Power
- "Optical" Axial Length
- Horizontal "White-to-White" (11.7)
- AC angle = WTW + 1.0 (12.7)
- Sulcus = WTW + 1.5 (13.2)
- Bag = WTW – 1.0 (10.7)

Decision Making
- Small
- Normal
- Large

CONCLUSION
Eye Model must include NINE types of eyes not only THREE

FORMULA PERFORMANCE
- Prediction Errors in Short Eyes: significantly improved by more measurements
- Prediction Errors in Long Eyes: due to bad Axial Lengths: B-Scan

CONCLUSIONS
- More Measurements
- More Accuracy

Relative Importance of Predictors for ELP
- Axial Length: 100
- Average K: 78
- Horizontal WTW: 24
- Refraction: 18
- ACD: 8
- LT: 7
- Age: 1

THE HOLLADAY 2 FORMULA
More Measurements
More Accuracy

THE HOLLADAY 2 FORMULA
More Measurements
More Accuracy

Zeiss-Humphrey IOL Master LenStar
Difficult Cases
Asteroid Hyalosis (vitr. debris)
Extremes Length (26.5 mm)
Uses Average Index Too Long
Extremes Short (< 21 mm)
Pseudophakic Eyes
Silicone in Vitreous

Preoperative Assessment
- Endothelial Cell Count
- Pachymetry
- Direct Ophthalmoscope @ 16°
- Corneal Topography
- Determining Corneal Power
- IOL Calculation

Cataract Surgery ...
IOL Power Calculations
Following Refractive Surgery

Myopic Staphyloma
Corneal Power after LASIK, PRK, RK

Ideally, calculation from both surfaces.
Calculation from Prior Data Trial
Hard Contact Lens
Corneal Topography
Automated Keratometry
Manual Keratometry

Pachymetry and Posterior Corneal Surface
New patented laser cross for measurement of posterior corneal surface and optical pachymetry

2. Calculation from Prior Data (Post Std. K’s & Δ MR only)
Post Mean K = 40.58 D
Change in SEQ Ref = -4.50 D
STD K’s = -0.24 * SEQ = -1.08
Calc Mean K = 39.50 D

3. Calculation from Prior Data (Post Ctr Top Power & Δ MR only)
Post Mean K = 40.27 D
Change in SEQ Ref = -4.50 D
Ctr Top = -0.15 * SEQ = -0.77
Calc Mean K = 39.50 D

4. Trial Hard Contact Lens (Rigid Contact lens only)
Plano HCL Base Curve = 41.50 D
SEQ Ref without CL = +0.50 D
SEQ Ref with CL = -1.00 D
Front K = 40.00 D
40.00 D – 10% (4.50) = 39.50 D
Mean K = 39.50 D

Accuracy of EKR
Prior
LASIK
RK

Post-operative
- Initial Hyperopic Shift
- Long Term Hyperopic Drift
- ATR Astigmatism Drift

Jack T. Holladay, MD, MSEE, FACS
Equivalent Keratometric Power

Keratoconus Calculation #1

- Used Ks = 46.5 D => +1.00 D
- Should have used 65% Mean K
  - 45.5 D => plano
  - should have targeted -0.50 D
- 37.7 D => +2.00 D
- If had KKC => 0.50 D
- 9 KKC => +0.50 D

Should have used 65% Mean K
- 37.7 D => +2.00 D
- (0.50 always better than +0.50)

Keratoconus Calculation #2

- Used Ks = 39.60 D => Plano,
  but targeted for -4.00 D
- Should have used 65% Mean K
  - 37.7 D => +2.00 D
- If had KKC => -0.50 D
- 9 KKC => -0.50 D

IOL CALCS in Keratoconus

- Keratoconus Case #3

Summary

- Optimal Zone
  - LASIK: ±0.56 D
  - RK: ±0.94 D
- Accuracy
  - LASIK: ±0.56 D
  - RK: ±0.94 D
- Error on MYOPIC side

IOL Calcs Using Axial Length

- Cataract or Clear Lens Removal
- Primary Piggy-Back IOL’s
- Multifocal IOL’s
- Toric IOL’s
- Silicone in Vitreous Compartment
- Phakia
- Aphakia
- Pseudophakia
- Silicone AL 1532
- PMMA AL 1532
- Silicone AL 1532
- Acrylic AL 1532
Primary Piggy-Back IOL’s
- Current Formulas are very inaccurate
  - ELP underestimated due to AL
  - Back lens displaced posteriorly
- Severe hyperopic errors (+5 D)

Primary PIGGY-BACK INTRAOCULAR LENSES

Primary Piggy-Back Complications
Acrylic
  - Interlenticular membrane
  - 3 to 6 D hyperopic shift @ 3 yr
Silicone
  - Interlenticular membrane
  - Flat Spot

Minimizing Prediction Error
- Holladay 2 Formula
- Personalize Constant
- Prediction Error vs. IOL power
- Constants for Sub-groups
  - Axial Length, K’s and Refraction

Toric IOL’s
- Current Formulas do not work because calculate different ELP for steep and flat meridian
- Predicted ELP must be the same for each meridian — only one IOL position

Toric IOL’s
- Calculate IOL power for steep and flat meridian using same ELP
- Difference in IOL powers is the toricity necessary to completely correct corneal astigmatism

Ideal Toricity is 3.0 D
\[ z \]

Neutral Toricity
\[ z \]

Always choose toricity to undercorrect corneal astigmatism — WRONG!

Polyseudophakia
“Up to 4 IOL’s

Always choose toricity to undercorrect corneal astigmatism – WRONG!
LEAVE MIN RESIDUAL CYL!

Steep calc yields 24.0 D

Flat calc yields 27.0 D

Flat Spot

Axial Length, K’s and Refraction

SURGICAL PLAN

Silicone in Vitreous Cavity
- Use Convexo-Plano IOL to minimize effect of Silicone (add 3 D to calculated IOL)
- If Biconvex IOL (add 6 D to calculated IOL)
- When Silicone removed — 2 to 5 D of induced myopia

IOL Calculations
using a
Refractive Formula
(ignore axial length)

Silicone in Vitreous Cavity
- Use Convexo-Plano IOL to minimize effect of Silicone (add 3 D to calculated IOL)
- If Biconvex IOL (add 6 D to calculated IOL)
- When Silicone removed — 2 to 5 D of induced myopia

IOL Calculation without AL
- Secondary AC or PC IOL for Aphakia
- Secondary Piggy-Back AC or PC IOL for Pseudophakia
- Primary AC IOL in Phakia

Primary AC IOL in Phakia
Secondary Piggy-Back AC or PC IOL for Pseudophakia
Primary AC IOL in Phakia

Jane Leidlein  Myra Cherchio
J.T. Holladay  James P. Gills

Primary Piggy-Back

Intraocular Lenses.

Primary Piggy-Back Intraocular Lenses.

July 1996
Blue Journal"
### Phakic IOL Calculations

#### FROM REFRACTION
- + IOL's to Specs ~ 1.5 to 1
- - IOL's to Specs ~ 1.0 to 1
- Approximation only

#### FROM KERATOMETRY
- Best Results
  - + IOL's to Specs ~ 1.5 to 1
  - - IOL's to Specs ~ 1.0 to 1
  - Approximation only

### Phakic IOL’s
- Compete with corneal refractive procedures for high myopia and med & high hyperopia
- ACL, IOL or Iris Clip?

### Phakic IOL’s (Secondary Piggy Back IOL’s)

#### Refraction

**Refractive Formula**

\[ \text{IOL Power} = \frac{13.6}{0.001 \times \text{ACD} + 0.40} \]

**Effective Lens Position (ELP)**

- **Old ACD**
  - Viscian ICL Avg ELP = 4.00 mm
  - Aacd (20 y/o) = 3.60 mm
  - Aacd + 0.67 mm = ELPx

- **New ACD**
  - Viscian ICL Avg ELP = 4.00 mm

**Pediatric IOL Calculations**

- Ideal Refraction: plano to -1 D
- Expect average of 4 D myopic shift from age 2 to 20
- Much easier to correct myopia at age 20 than amblyopia

---

**References**

- AACD (20 y/o) = 3.60 mm
- Verisye Avg ELP = 4.27 mm
- Visian ICL Avg ELP = 4.00 mm
- Minimizing Prediction Error
- Personalize Constant
- Prediction Error vs. IOL power
- Constants for Sub-groups
  - Axial Length, K’s and Refraction

---

**Thank you!**
**Outcome Analysis**
- Prediction Error (50% < 0.50 D)
- Formula Comparisons
- Induced Astigmatism (SiRC)
- Visual Acuity
  - Best Corrected
  - Uncorrected

**Back-Calculations**
- Helpful in determining cause of refractive surprise
- Back-calculated K, AL and IOL power compared to pre-op & to post-op remeasured values
- Back-calculated ELP compared to preoperative prediction by formula

Thank you!