FINANCIAL DISCLOSURES
I receive licensing fees for the proper programming of the Hoffer® Q and Hoffer® H-5 formulas from:
Haag-Streit, Movu, Nidek, Oculus, Tomey, Topcon EU, Zeiss, Ziemer and all A-scan Biometers

Book Royalties from Slack for “IOL Power”

IOL Power Club Today
• Jaime Aramberri MD
• Wolfgang Haigis PhD
• Kenneth J Hoffer MD
• Sverker Norrby PhD
• Thomas Olsen MD
• H John Shammas MD

IPC Scientific Sessions
- 2005 1st: San Sebastian, Spain
- 2006 2nd: Carmel, CA USA
- 2007 3rd: Aarhus, Denmark
- 2008 4th: St. Pete’s Beach, FL
- 2009 5th: Roses, Spain
- 2010 6th: Venice, Italy
- 2011 7th: Würzburg, Germany
- 2012 8th: Memphis/Nashville TN
- 2013 9th: Haarlem, Holland
- 2014 10th: Ft. Lauderdale, FL
- 2015 11th: San Sebastian, Spain
- 2016 12th: New Orleans, LA

IOL Power Club Formulas & Biometers
Course 4157 Room 252-254
Wolfgang Haigis PhD Würzburg, Germany
Giacomo Savini MD Bologna, Italy
Kenneth J Hoffer MD Santa Monica, CA
Jaime Aramberri MD San Sebastian, Spain
Thomas Olsen MD Aarhus, Denmark

IOL Power in Corneal Refractive Eyes
Toric IOL Calculations
Formulas & Instruments
Short and Long Eye Issues
FORMULA HISTORY

- FIRST GENERATION
  ACD is a CONSTANT (Gernet)

- SECOND GENERATION
  ACD based on AL (Hoffer)

- THIRD GENERATION
  ACD based on AL/K (Holladay)

- FOURTH GENERATION
  AL K ACD CD LT ASL (Olsen)

FORMULA HISTORY

- 1967 FYODOROV
- 1973 COLENBRANDER
- 1974 HOFFER ACD
- 1975 BINKHORST
- 1978 HOFFER ACD by AL
- 1981 SRK I A con
- 1988 HOLLADAY 1 SF
- 1988 SRK II C+1,2,3
- 1989 OLSEN ACD & LT
- 1990 SRK/T (THEORETICAL)
- 1992 HOFFER Q pACD
- 1996 HOLLADAY 2 ESF
- 1999 HAIGIS $a_0 \ a_1 \ a_2$
- 2004 HOFFER H pACD ESH
- 2014 Olsen Ray C-factor
- 2015 HOFFER H-5 Race/Gen

SRK REGRESSION

"REGRESSION FORMULAS ARE OBSOLETE AND NO LONGER RECOMMENDED."

JOHN RETZLAFF SEP 1990/SEP 2015

"USE OF SRK REGRESSION FORMULAS IS THE LEADING CAUSE FOR IOL REMOVAL."

HOFFER 1993
BEST RESULTS 1993
WITHIN ± 0.50 D

SHORT   HOFFER Q  67% = 24
MEDIUM   HOFFER Q  67% = 219
Med LONG HOLLADAY  71% = 47
Very LONG SRK/T  57% = 13

303/450 = 67%

I proved it statistically in 836 <22 mm short eyes from James Gills but never published it.

IT TOOK 18 YEARS, BUT: STATISTICALLY PROVEN BY
Large 8,108 Eye UK study using IOLMaster AL by Aristodemou in 2011
Aristodemou JCRS 2011;37(1):63

FORMULA USAGE
• < 24.5 mm Hoffer Q
• 24.5-26.0 mm Holladay 1
• > 26 mm SRK/T
• Haigis OK for All
• CONSIDER Olsen
• NEVER SRK I or II

Heidelberg RAY TRACING Study

Holladay 2 Requirements
- Refractive Error and Corneal Curvature
  - 0.25 0.5 1.0 1.5 VTX 14
  - DVAK 20/20 UDVA 20/20
  - H-1 1.17< H-2
- Ultrasound (mm)
  - Axial Lens: 22.17
  - Correct AL: 22.67
  - Phakic ACD: 2.53
  - Phakic Lens Thick: 4.60

ASCRS IPC MAY 2016
K. HOFFER MD
How Do You Access the Formulas?

- IOLMaster 500/700, LenStar, Aladdin, AL-Scan, OA-2000, Galilei G6, Pentacam AXL, Argos
- A-scans built-in (Check Licenses)
- Holladay IOL Consultant
  - Double-K for Holladay 2 ONLY
- PhacoOptics Olsen (Ray Tracing)

Beware Errata in SRK/T & Hoffer Q

Software Websites

OLSEN  
HOLLADAY

$1,990  $1,895

Holladay used average AL, K, CD and ASL (LT + ACD) of average western eyes of both genders

Holladay Course Slide 1996

Hoffer H-5 Formula Basis

Holladay 2 Formula

\[
\log(ESF) = 11.85 \log(1 - \frac{K}{40}) + 0.167 \log(LT + ACD)
\]

GENDER Differences

are real and consistent in all races

<table>
<thead>
<tr>
<th># Eyes</th>
<th>AL</th>
<th>K</th>
<th>ACD</th>
<th>LT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>212,740</td>
<td>23.43</td>
<td>44.02</td>
<td>3.09</td>
</tr>
<tr>
<td>Female</td>
<td>39,156</td>
<td>23.74</td>
<td>43.61</td>
<td>3.14</td>
</tr>
<tr>
<td>Female</td>
<td>50,576</td>
<td>23.22</td>
<td>44.18</td>
<td>2.99</td>
</tr>
</tbody>
</table>

Difference:
- +0.52 mm
- -0.56 D
- 0.15 mm
- -0.02 mm

You could remember: "Woman are 0.50 mm shorter and 0.50 D steeper"

Literature Results of Patient Populations

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>23.77</td>
<td>23.37</td>
<td>23.95</td>
<td>23.34</td>
</tr>
<tr>
<td>K</td>
<td>43.05</td>
<td>43.25</td>
<td>43.18</td>
<td>43.49</td>
</tr>
<tr>
<td>ACD</td>
<td>3.12</td>
<td>3.00</td>
<td>3.02</td>
<td>3.02</td>
</tr>
<tr>
<td>LT</td>
<td>4.66</td>
<td>4.00</td>
<td>4.21</td>
<td>4.26</td>
</tr>
</tbody>
</table>

You could remember: "Women are 0.23 mm shorter and 0.23 D steeper"
H-5 GLOBAL STUDY

- Began in November 2013
- 49 Surgeons Submitted Eyes
- 9,826 Eyes to Date (9/1/15)

Reporting Accuracy:
MAE Improper
IOD Power Prediction Errors
Normal Gaussian Bell Curve

Absolute Errors
Are Not Gaussian Curve
MedAE
Appropriate

ME
Appropriate

FORMULAS for LASIK Eyes
SHORT
- < 24.5 mm Hoffer Q
- 24.5-26.0 Holladay 1
- > 26 mm SRK/T

LONG

NEVER SRK I or II
Aramberri Double-K
Haigis-L for LASIK Eyes
Holladay 2 OK Unnecessary
Olsen Ray Tracing
No Hx; Shammas PL

AXIAL LENGTH
Two Modalities to Measure AL
- Ultrasound A-Scan Still Needed
  • Contact Method – WORST
  • Immersion Method – BEST
- Optical Laser Method IDEAL
  • IOLMaster (Zeiss) 1999
  • LenStar (Haag-Streit) 2009
- NEW: Tomey, Aladdin, Argos AL-scan, Galilei G-6, Pent AXL
Other A-SCAN UNITS

**AXIOSONIC**

Make Sure Formulas are Licensed

**ASCRS IPC MAY 2016**

K HOFFER MD

**IOLMaster**

Both Good in Eyes with
- Staphyloma
- Silicone Oil

**Lenstar LS-900**

2009

FDA Approved

**ASCRS IPC MAY 2016**

K HOFFER MD

**RESULTS of 61 Right EYES**

<table>
<thead>
<tr>
<th></th>
<th>LS-900</th>
<th>IOLMaster</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AL</strong></td>
<td>23.66</td>
<td>23.64</td>
<td>+0.02/0.55</td>
</tr>
<tr>
<td>**±1.04</td>
<td>±1.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>43.55</td>
<td>43.68</td>
<td>-0.13/0.0001</td>
</tr>
<tr>
<td>**±1.90</td>
<td>±1.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ACD</strong></td>
<td>3.05</td>
<td>2.92</td>
<td>+0.13/0.0001</td>
</tr>
<tr>
<td>**±0.44</td>
<td>±0.45</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Eye With Each Could not Get a Reading

**Hoffer/Shammas/Savini Study**

**RESULTS of 105 EYES (63 Bil)**

<table>
<thead>
<tr>
<th></th>
<th>LS-900</th>
<th>IOLMaster</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AL</strong></td>
<td>?</td>
<td>?</td>
<td>+0.02/0.84</td>
</tr>
<tr>
<td>**±?</td>
<td>±?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>44.06</td>
<td>44.12</td>
<td>-0.06/0.001</td>
</tr>
<tr>
<td>**±1.56</td>
<td>±1.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ACD</strong></td>
<td>3.15</td>
<td>3.05</td>
<td>+0.10/0.001</td>
</tr>
<tr>
<td>**±0.36</td>
<td>±0.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7 Eyes With Each Could not Get a Reading

**Hoffer/Shammas/Savini Study**

**RESULTS of 60 USA R EYES**

<table>
<thead>
<tr>
<th></th>
<th>Aladdin</th>
<th>IOLMaster</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AL</strong></td>
<td>23.59</td>
<td>23.58</td>
<td>+0.01/0.0770</td>
</tr>
<tr>
<td>**±0.99</td>
<td>±1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>43.77</td>
<td>43.90</td>
<td>-0.14/0.0001</td>
</tr>
<tr>
<td>**±1.67</td>
<td>±1.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ACD</strong></td>
<td>3.13</td>
<td>2.95</td>
<td>+0.16/0.0001</td>
</tr>
<tr>
<td>**±0.43</td>
<td>±0.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Older American Cataract Pts 75 ±10 yo

**Hoffer/Shammas/Savini Study**

**NEWER OPTICAL BIOMETERS**

**Optical Low-Coherence Reflectometry (OCLR)**

**TOPCON EU**

**Aladdin Topographer/Biometer**

FDA Approved

**ASCRS IPC MAY 2016**

K HOFFER MD

**RESULTS of 60 USA R EYES**

<table>
<thead>
<tr>
<th></th>
<th>Aladdin</th>
<th>IOLMaster</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AL</strong></td>
<td>23.59</td>
<td>23.58</td>
<td>+0.01/0.0770</td>
</tr>
<tr>
<td>**±0.99</td>
<td>±1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>43.77</td>
<td>43.90</td>
<td>-0.14/0.0001</td>
</tr>
<tr>
<td>**±1.67</td>
<td>±1.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ACD</strong></td>
<td>3.13</td>
<td>2.95</td>
<td>+0.16/0.0001</td>
</tr>
<tr>
<td>**±0.43</td>
<td>±0.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS of 56 Chinese R EYES

<table>
<thead>
<tr>
<th></th>
<th>Aladdin</th>
<th>IOLMaster</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>25.13 ±1.02</td>
<td>25.13 ±1.03</td>
<td>-0.01/0.0620</td>
</tr>
<tr>
<td>K</td>
<td>43.61 ±1.60</td>
<td>43.74 ±1.64</td>
<td>-0.14/0.0001</td>
</tr>
<tr>
<td>ACD</td>
<td>3.72 ±0.25</td>
<td>3.67 ±0.27</td>
<td>+0.05/0.0001</td>
</tr>
</tbody>
</table>

Young Chinese Pts 26 ±3 yo
ASCRS IPC MAY 2016
K HOFFER MD

Compare US & Chinese EYES

<table>
<thead>
<tr>
<th></th>
<th>USA Diff/P Value</th>
<th>China Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>+0.01/0.0770</td>
<td>-0.01/0.0620</td>
</tr>
<tr>
<td>K</td>
<td>-0.14/0.0001</td>
<td>-0.14/0.0001</td>
</tr>
<tr>
<td>ACD</td>
<td>+0.16/0.0001</td>
<td>+0.05/0.0001</td>
</tr>
</tbody>
</table>

ASCRS IPC MAY 2016
K HOFFER MD

Newer Optical Biometers

NIDEK AL-Scan
BUILT-IN US PROBE
Hoffer/Shammas/Savini Study Submitted
FDA Approved

AL RESULTS of 87 EYES Age 72

<table>
<thead>
<tr>
<th></th>
<th>AL-Scan</th>
<th>IOLMaster</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>23.46 ±0.99</td>
<td>23.46 ±0.99</td>
<td>n.s. 0.44</td>
</tr>
<tr>
<td>95% LoA</td>
<td>+0.03 to -0.03</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ASCRS IPC MAY 2016
K HOFFER MD

AVG K RESULTS of 87 EYES Age 72

<table>
<thead>
<tr>
<th></th>
<th>AL-Scan</th>
<th>IOLMaster</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>K2.4</td>
<td>43.83 ±1.49</td>
<td>43.76 ±1.46</td>
<td>-0.07 0.016</td>
</tr>
<tr>
<td>95% LoA</td>
<td>+0.43 to -0.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K3.3</td>
<td>43.79 ±1.44</td>
<td>43.76 ±1.46</td>
<td>-0.03 n.s. 0.40</td>
</tr>
<tr>
<td>95% LoA</td>
<td>+0.53 to -0.58</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ASCRS IPC MAY 2016
K HOFFER MD

RESULTS of 86 EYES AGE 72
Anterior Chamber Depth (Anterior Cornea Epithelium to Lens)

<table>
<thead>
<tr>
<th></th>
<th>AL-Scan</th>
<th>IOLMaster</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD</td>
<td>2.96 ±0.38</td>
<td>2.83 ±0.38</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>95% LoA</td>
<td>+0.18 to -0.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AL-Scan 0.13 MM DEEPER

ASCRS IPC MAY 2016
K HOFFER MD

JCRS 2016;42(1):62
Young Chinese Pts 26 ±3 yo
Older American Cataract Pts 75 ±10 yo

Hoffer/Shammas/Savini/Huang Study

ASCRS IPC MAY 2016
K HOFFER MD

Newer Optical Biometers
Hoffer/Shammas/Savini Study Submitted
FDA Approved

JCRS 2016;42(1):52

Compare US & Chinese EYES
Young American Cataract Pts 75 ±10 yo
Young Chinese Pts 26 ±3 yo

ASCRS IPC MAY 2016
K HOFFER MD
Newer Optical Biometers
ZIEMER Gailei G-6

NOT FDA Approved

Newer Optical Biometers
TOMEY OA-2000

FDA Approved

Newer Optical Biometers
TOMEY OA-2000

FDA Approved

Newer Optical Biometers
Zeiss IOLMaster 700
Swept Source Optical Coherence Tomography

FDA Approved

Newer Optical Biometers
Zeiss IOLMaster 700
Telecentric Keratometry
Telecentricity Independent

FDA Approved
Newer Optical Biometers
Zeiss IOLMaster 700

FDA Approved

Hoffer/Hoffmann/Saviní Study
RESULTS of 182 R EYES

<table>
<thead>
<tr>
<th>ILM 700</th>
<th>Lenstar</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>23.61 ±1.27</td>
<td>23.60 ±1.27</td>
</tr>
<tr>
<td>K</td>
<td>43.84 ±1.43</td>
<td>43.82 ±1.43</td>
</tr>
<tr>
<td>ACD</td>
<td>3.22 ±0.44</td>
<td>3.19 ±0.44</td>
</tr>
</tbody>
</table>

German Cataract Pts 73 ±8 yo (20-90)
JCRS In Press

Newer Optical Biometers
MOVU Argos

Swept Source Optical Coherence Tomography
Tracking system for ease of alignment

K = Ray of 24 IR LEDs in
combination with the OCT signal

NOT FDA Approved
Newer Optical Biometers
MOVU Argos

Analysis Mode
NOT FDA Approved

Shammas/Chong Study
RESULTS of 42 R EYES

<table>
<thead>
<tr>
<th></th>
<th>ILM 500</th>
<th>Argos</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>23.34</td>
<td>23.35</td>
<td>+0.01/&lt;0.001</td>
</tr>
<tr>
<td>K</td>
<td>44.06</td>
<td>44.00</td>
<td>-0.06/0.0271</td>
</tr>
<tr>
<td>ACD</td>
<td>2.89</td>
<td>3.06</td>
<td>+0.17/ &lt;0.001</td>
</tr>
</tbody>
</table>

Cataract Pts 74 ±9 yo (54-89)

Shammas/Chong Study
RESULTS of 42 R EYES

<table>
<thead>
<tr>
<th></th>
<th>Lenstar</th>
<th>Argos</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT</td>
<td>4.48</td>
<td>4.70</td>
<td>+0.22</td>
</tr>
<tr>
<td>CD</td>
<td>11.81</td>
<td>12.15</td>
<td>+0.24</td>
</tr>
<tr>
<td>CCT</td>
<td>0.53</td>
<td>0.53</td>
<td>+0.00</td>
</tr>
</tbody>
</table>

LT 0.22 Thicker with Argos SS-OCT

ACD Comparisons of Six Biometers

<table>
<thead>
<tr>
<th>Eyes</th>
<th>Diff/P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOLM 500</td>
<td>---/--------</td>
</tr>
<tr>
<td>LenStar</td>
<td>+0.13 DEEPER 0.001</td>
</tr>
<tr>
<td>Aladdin</td>
<td>+0.16 DEEPER 0.001</td>
</tr>
<tr>
<td>AL-Scan</td>
<td>+0.13 DEEPER &lt;0.001</td>
</tr>
<tr>
<td>ILM 700</td>
<td>+0.27 DEEPER &lt;0.001</td>
</tr>
<tr>
<td>Argos</td>
<td>+0.17 DEEPER ?</td>
</tr>
</tbody>
</table>

ILM 500 measures ~0.20 mm shallower ACD (0.13-0.27)
Newer Optical Biometers
Heidelberg

Scheimpflug Cameras
PENTACAM  GALILEI  SIRIUS

i-Optics
Den Hague, Netherlands
CASSINI
Color LED Topographer

Intraoperative Aberrometry
ALCON  WaveTec ORA
Introduced in 2005 (Ianchulev et al, JCRS 2005)

Intraoperative Refractive Biometry (IRB)
Post-LASIK Clinical Study
90% higher prediction with IRB (± 0.50D)

Laser Adjusted IOLs
• Lens is designed to be adjusted after implantation by treating with UV light
• 3-piece silicone IOL with 6 mm biconvex optic
• Round anterior edge and square posterior edge
• 13.0 mm blue C loop PMMA haptics
• Base power range: +10 to +30 D

* p<0.0001
Thank You

Danke
Grazie
Dziekuje
Gradis
Obrigado
Arigato
Děkuji
Shukran
KhoKhun
Efcharisto
Maurururu
Takk
Tack
Toda
Kitos
YekooE
Maaruuru
Mendi
Spasibo
Kósónonom
Shukriya
Dakujem

KHofferMD@AOL.com

KJH
The short and the long eye issues

Thomas Olsen, MD
University Eye Clinic
Aarhus, Denmark

The issue

- Traditionally, formula accuracy breaks down in the short and the long eyes
- I will talk on the spherical IOL power, but the same principles also apply to toric IOL cylinder calculation

The short eye

- All dimensions small, every measurement error counts more!
- A small error in the ELP has a dramatic impact on the refraction!

The laser can measure the axial length with surprising accuracy

Biometry is no longer a significant source of error!

Axial length by:
- Ultrasound: ± 0.20 mm
- Laser interferometry: ± 0.02 mm

The effect of axial length error

Dpt Rx change / mm Axial length

Axial length (mm)
The ELP influence!

Sources of error in IOL power calculation (optimized)

Sources of error in IOL power calculation (optimized)

IOL position in the bag

The C-constant defines the position of the IOL as a fraction of capsular bag thickness!

C-constant: New concept for ray tracing-assisted IOL/capsular lens power calculation

Prediction of IOL position using the C-constant

The C-constant defines the IOL position in terms of the crystalline lens anatomy. Not dependent on the K-reading nor the axial length.

C-constant defines the position of the IOL as a fraction of capsular bag thickness.
The Olsen formula

- Originally described as a paraxial ray tracing ('thick-lens') formula
- Recently modified using exact ray tracing to correct for aberrations of the cornea and the IOL and pupil size
- Based on true corneal power
- Using the C-constant for unbiased prediction of the physical position of the IOL

Formula comparison

Overall results Olsen formula

- The mean absolute error was reduced by 14% as compared to optimum performance of the SRK/T formula
- The number of errors > ± 1 D was reduced up to 85% as compared to the SRK/T

Short eye study - German series

- 99 eyes < 22 mm. Optimized dataset. Comparing accuracy of
  - Holladay II
  - Hoffer Q
  - Okulix (Preussner)
  - PhacoOptics (Olsen)

Author: Peter Hoffmann, Castorp-Rauxel
The long eye

- The longer the eye, the more critical the true optical path of the axial length!
- The ELP prediction is the least significant source of error
- The corneal power as determined by the K-reading is very significant

Let's take a fresh look on

The corneal power

Corneal optics – how?

- We often fit the shape of the cornea to a sphere, ellipsoid, Zernike, Fourier model etc
- Exact ray tracing is recognized as the most effective tool in optical engineering
- Isn’t the eye an optical instrument?
Pentacam® mapped elevation data

Zemax® *) import of Pentacam data for exact ray tracing of the cornea

Zemax® exact ray tracing analysis of the cornea

Effective corneal focal length - experiment on pupil size

Corneal power by method

Ray-tracing analysis of intraocular lens power in situ
Calculating IOL power = Modelling the pseudophakic eye

<table>
<thead>
<tr>
<th>METHOD</th>
<th>VARIABLES</th>
<th>EXAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vergeance formula</td>
<td>Calculate planes using vergence of light</td>
<td>Power, diameters. Haigis-Hoffer; Holladay 1 and 2; SRK/T, Phacooptics ELP.</td>
</tr>
<tr>
<td>Paraxial ray tracing</td>
<td>Calculate angles and length of refraction near optical axis</td>
<td>Radii, distances, n. Optical software: Zemax, OSLO, Winlens.</td>
</tr>
<tr>
<td>Exact ray tracing</td>
<td>Calculate angles and length of light rays exact refraction, aberrations considered</td>
<td>Radii at each point. Distances, n. Norby JCRS 2004, Okulix.</td>
</tr>
</tbody>
</table>

All methods need a precise IOL position (ELP) predicting algorithm

How does a 3rd gen. formula work?

The errors

1. Uncorrect ELP prediction if K dependent ELP predicting formula is used with present (post LASIK) K value (SRK/T; Holladay; Hoffer Q; Olsen…)

2. Uncorrect corneal power measurement by topographers and keratometers
The solution

1.- Use a formula that doesn’t use K for ELP

Height: ELP = a0 + a1 ACD pre + a2 AXL

Haigis: \[ \text{ART: ACD pre / LT} \]

2.- Use the Double K method when K is used for ELP prediction (SRK/T, Holladay, Hoffer Q…)

K pre: For the ELP predicting algorithm
K post: For the optical calculation

- Program it yourself (recommended)
- Use comercial software: Hoffer Program; Holladay IOL Consultant (Holladay 2);…
- Some biometry devices have II: Axis II (Quantel); A Scan (Sonomed);…
- Used in ASCRS website calculator
**K pre determination**

1. The real figure from patient’s records
2. Average number: 43.50 D
3. Guess it from K post and corrected D value
   - K post = 36
   - Corrected D at corneal plane = 8 D
   - K pre = 36 + 8 = 44 D
4. Guess it from posterior r (Scheimpflug/OCT) using the normal ant/post ratio (1.21)
   - r post = 6.54 mm
   - R ant = 6.54 * 1.21 = 7.91 mm
   - From r ant to K: \( \frac{337.5}{7.91} = 42.77 \) D

**K pre error influence in refraction error**

<table>
<thead>
<tr>
<th>K pre</th>
<th>41</th>
<th>18.78</th>
<th>1 D</th>
<th>0.7 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.5</td>
<td>19.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>20.66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**The errors**

1. Uncorrect ELP prediction if K dependent ELP predicting formula is used with present (post LASIK) K value (SRK/T; Holladay; Hoffer Q; Olsen...)
2. Uncorrect corneal power measurement by topographers and keratometers

**Improve 3 gen. Formula performance with Kpre:**

Use an arbitrary Kpre to compensate the blindness of These formulas to the actual anterior segment depth

<table>
<thead>
<tr>
<th>ACD + LT (mm)</th>
<th>K pre (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 7.5</td>
<td>42</td>
</tr>
<tr>
<td>7.5 – 8.10</td>
<td>43.5</td>
</tr>
<tr>
<td>&gt; 8.10</td>
<td>45</td>
</tr>
</tbody>
</table>

**We need Kpost. What is Kpost?**

It is the K value that the formula uses to do the optical calculation of IOL Power

It depends on how the formula was designed: Holladay 1 and 2; Hoffer Q; SRK/T; Haigis... are designed to input K (n=1.3375)
K is overestimated after myopic LASIK/PRK

1. Change of r ant / r post which makes n=1,3375 inaccurate

2. Change of corneal asphericity:
   - Enlarge area of analysis,
   - Decrease optical power (best focus plane anterior to paraxial calculation)

Present K non dependent methods

- Clinical History method
  \[ K_{pre} = \frac{\text{Corrected D at corneal plane}}{n} \]

Present K dependent methods

- K corrected methods
  - Don’t need present topography/keratometry
  - Need present topography/keratometry

- Total corneal power (Scheimpflug/OCT)
  - K – (15 to 19% of corrected D)
  - Empirical formula: \[ 1.14 \times K - 6.8 \]
  - Theoretical formula: \[ 1.119 \times K - 5.78 \]

From \( K_{real} \) to \( K_{post} \)

Remember that the formula is waiting for a K (n=1,3375) value: Conversion is needed

\[ \text{PENTACAM (True Net Power)} \rightarrow K_{real} + 1.20 \]
\[ \text{PENTACAM (Total Refractive Power)} \rightarrow K_{real} + 0.33 \]
\[ \text{ORBSCAN (Mean Total Power)} \rightarrow K_{real} + 1.25 \]
\[ \text{GALILEI (Total Corneal Power)} \rightarrow K_{real} + 0.35 \]
\[ \text{GALILEI (Total Corneal Power)} \rightarrow K_{real} + 1.80 \]
The next step
real numbers for a real world
CONCLUSION

IOL power calculations after LASIK/PRK can be done based on theoretical concepts and formulation.

Double K(or r) formulation must be used when corneal parameters are used for IOL position prediction.

K post determination can be done:
1. Calculate it from measured K (different formulae).
2. Using a K 1,3375 equivalent calculated from Ktotal measured Scheimpflug/OCT.

Exact ray tracing: Just input biometric data and that’s all.

jaimearamberri@telefonica.net
Calculations for toric IOLs

Giacomo Savini, MD

Studio Oculistico d’Azeglio, Bologna, Italy
GB Bietti Foundation, Rome, Italy

The author has NO proprietary interest in the subject of this presentation

Current situation

- Toric IOLs are the preferred choice of most surgeons to correct astigmatism during cataract surgery
- Higher predictability than LRI
- Still some cases of cylinder over / undercorrection

How can we improve our outcomes?

Possible improvements

- Posterior corneal astigmatism
- Central astigmatism
- Cylinder @ IOL plane
- Cylinder @ corneal plane

Posterior corneal astigmatism

Keratometric astigmatism: corneal power calculated with 1.3376 keratometric index, aiming to provide "fictitious" information about total corneal power, although measurements are taken from the anterior surface only.
- Anterior corneal astigmatism: corneal power calculated with 1.376 corneal refractive index, i.e. the power of the anterior corneal surface
- Posterior astigmatism
- Total corneal astigmatism: sum of anterior and posterior corneal astigmatism (better by ray-tracing)

Corneal astigmatism

- The posterior steepest meridian is almost always vertically aligned. 1-4
- Such alignment generates an ATR astigmatism, which partially compensates anterior WTR astigmatism and increases anterior ATR astigmatism.

1 - Ho et al. AJO 2008
2 - Koch et al. JCRS 2012
3 - Savini et al. JCRS 2014
4 - Tonn et al. IOVS 2015

Giacomo Savini, MD
Significant correlation (p<0.001, $r^2=0.5683$) between Posterior Corneal Astigmatism and Keratometric Astigmatism.

Keratometric vs Total Corneal Astigmatism

- Keratometric astigmatism overestimates WTR astigmatism by $0.22\pm0.32$ D.
- Keratometric astigmatism underestimates ATR astigmatism by $0.21\pm0.26$ D.

The over / undercorrection is not fixed.
In about 20% of eyes the opposite relationship occurs.

Using mean values is not accurate.
Direct measurements are mandatory.
Posterior corneal astigmatism

A difference in astigmatism magnitude of ≥0.50 D was detected in 16.6% of eyes.

The difference in the location of the steep meridian was higher than 10° in 3.8% of eyes.

Example 1 (phaco + IOL)

Intentional undercorrection

SimK measurements are taken on a 3mm diameter ring

More central reading may be more accurate
Central Astigmatism

Example 2 (phaco + IOL)

Unwanted undercorrection

Suggested IOL = T4 (astigmatism = 1.55 D)
Implanted IOL = T6 (astigmatism = 2.57 D)
Final RX = cyl -1/110
Right choice = T8 (astigmatism = 3.60 D)

Which are the results?
**RESULTS**

Sample = 40 eyes of 26 patients (mean age = 68.6 years)
- WTR = 25 eyes
- ATR = 15 eyes

In all cases a toric AcrySof (Alcon Lab.) was implanted through a 2.75mm temporal incision
- T2 (n=2)
- T3 (n=19)
- T4 (n=8)
- T5 (n=5)
- T6 (n=4)
- T7 (n=1)
- T9 (n=1)

**RESULTS**

**ERA = Error in Refractive astigmatism**
(difference between predicted and measured astigmatism)

<table>
<thead>
<tr>
<th>Keratometric astigmatism (D)</th>
<th>Total corneal astigmatism (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overcorrection</strong></td>
<td></td>
</tr>
<tr>
<td>WTR</td>
<td>-0.59 +/-0.34</td>
</tr>
<tr>
<td>ATR</td>
<td>0.32 +/-0.42</td>
</tr>
</tbody>
</table>

**Undercorrection**
Curvital power
- Negative = overcorrection
- Positive = undercorrection

**OCTULUS - PENTACAM** Power Distribution

Examples

**CONCLUSIONS**

Keratometric Astigmatism leads to:
- overcorrection of WTR astigmatism
- undercorrection of ATR astigmatism

If you don’t have total corneal astigmatism measurements..
Net astigmatism = total corneal astigmatism that has to be corrected by the toric IOL, including Ks, SIA and the posterior cornea.

Posterior cornea data are not derived from Scheimpflug devices or regression analysis, but from a theoretical model based on the elliptical method of the corneal diameter.

ATR astigmatism is automatically increased (from 2 to 2.52 D)

WTR astigmatism is automatically reduced (from 2 to 1.25 D)

Based on Galilei total corneal astigmatism. It accounts for the ATR shift with age. New target for postop astigmatism = 0.4 WTR

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

Not all online toric IOL calculators take into account the influence of ACD on the conversion of the cylinder from the IOL plane to the corneal plane.
Some toric calculators use a fixed ratio (1.46) that is good for average eyes, but not for short and long eyes.

Actually this ratio can range from 1.29 (AL = 20mm, K = 38 D > shallow ACD) to 1.86 (AL = 30mm, K = 46 D = deep ACD).

Overcorrection of cylinder in hyperopic eyes

Undercorrection of cylinder in myopic eyes

Solution: MERIDIONAL ANALYSIS. Calculating the IOL power for the steep and flat meridians separately: the difference between the two values gives the required IOL toricity for that eye, on condition that the ACD is also separately calculated using the mean corneal power.
Which tools change this ratio?

- Many online calculators by IOL manufacturers
- ASSORT Calculator (N. Alpins, MD, FACS)
- Holladay Consultant software
- PhacoOptics (T. Olsen, MD)
- Ray-tracing software

Thank you

Giacomo Savini
giacomo.savini@alice.it
www.studiodazeglio.it