3rd IOL POWER CLUB POWER CALCULATION COURSE

Course 4157 Room 252-254

Wolfgang Haigis PhD — Würzburg, Germany
Ultrasound Biometry

Giacomo Savini MD — Bologna, Italy
Toric IOL Calculations

Kenneth J Hoffer MD — Santa Monica, CA
Formulas & AL Instuments

Jaime Aramberri MD — San Sebastian, Spain
IOL Power in Corneal Refractive Eyes

Thomas Olsen MD — Aarhus, Denmark
Short and Long Eye Issues

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IOL POWER CLUB CALCULATION COURSE: Formulas & Biometers

POWER CLUB

Course 4157
Room 252

Kenneth J Hoffer, MD
Santa Monica, CA
Clinical Professor of Ophthalmology
Stein Eye Institute, UCLA

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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"

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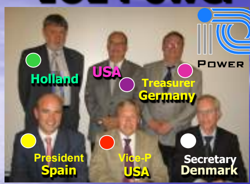
IOL Power Club

Formed SEP 7, 2005
San Sebastian, Spain



POWER CLUB

- Jaime Aramberri MD
- Wolfgang Haigis PhD
- Kenneth J Hoffer MD
- Sverker Norrby PhD
- Thomas Olsen MD
- H John Shammas MD

Honorary Members:
S. Fyodorov
J. Retzlaff
R. Van der Heidje
Sverker Norrby

Members
Scott McClatchey MD
Han Bor Fam MD
Giacomo Savini MD
Oliver Findl MD
Douglas Koch MD
Gabor Koranyi MD
Claudio Carbonara MD
Massimo Camellin MD
John Moran MD
Jean-Pierre Colliac MD
Edmondo Borasio MD

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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

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IOL Power Club Today

POWER CLUB

EXECUTIVE COMMITTEE

- Jaime Aramberri MD
- Wolfgang Haigis PhD
- Kenneth J Hoffer MD
- Thomas Olsen MD
- Giacomo Savini MD
- H John Shammas MD

10th Anniversary SEP 2015
San Sebastian, Spain



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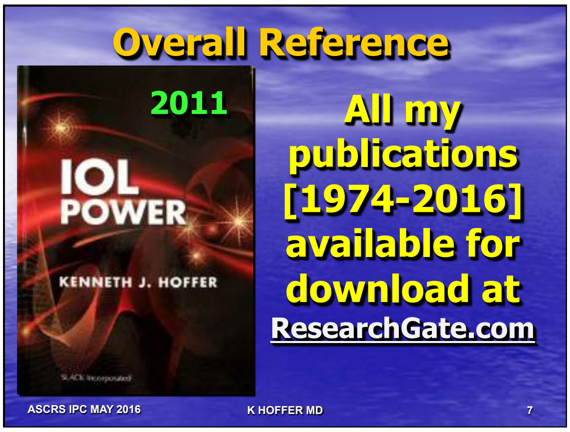
Overall Reference
2011
IOL POWER
KENNETH J. HOFFER
All my publications [1974-2016] available for download at
ResearchGate.com
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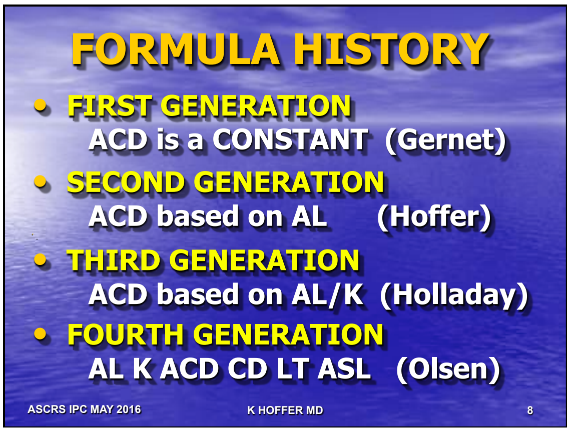
FORMULA HISTORY
FIRST GENERATION
ACD is a CONSTANT (Gernet)
SECOND GENERATION
ACD based on AL (Hoffer)
THIRD GENERATION
ACD based on AL/K (Holladay)
FOURTH GENERATION
AL K ACD CD LT ASL (Olsen)
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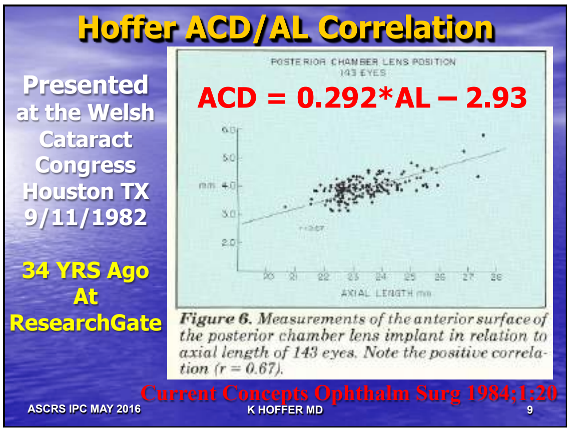
Hoffer ACD/AL Correlation
Presented at the Welsh Cataract Congress Houston TX 9/11/1982
34 YRS Ago At ResearchGate
ACD = 0.292*AL – 2.93
POSTERIOR CHAMBER LENS POSITION
143 EYES
AXIAL LENGTH mm
Figure 6. Measurements of the anterior surface of the posterior chamber lens implant in relation to axial length of 143 eyes. Note the positive correlation (r = 0.67).
Current Concepts Ophthalm Surg 1984;1:20
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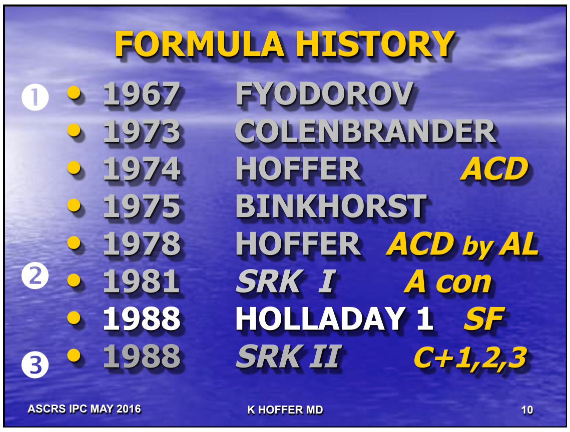
FORMULA HISTORY
① 1967 FYODOROV
1973 COLENBRANDER
1974 HOFFER ACD
1975 BINKHORST
1978 HOFFER ACD by AL
② 1981 SRK I A con
1988 HOLLADAY 1 SF
③ 1988 SRK II C+1,2,3
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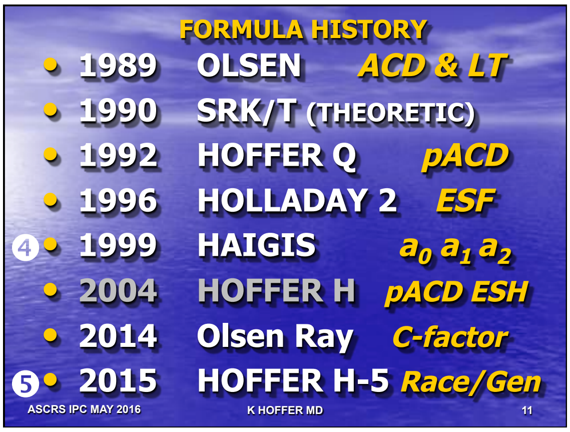
FORMULA HISTORY
1989 OLSEN ACD & LT
1990 SRK/T (THEORETIC)
1992 HOFFER Q pACD
1996 HOLLADAY 2 ESF
④ 1999 HAIGIS a_0 a_1 a_2
2004 HOFFER H pACD ESH
2014 Olsen Ray C-factor
⑤ 2015 HOFFER H-5 Race/Gen
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SRK REGRESSION
SRK I SRK II
"REGRESSION FORMULAS ARE 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
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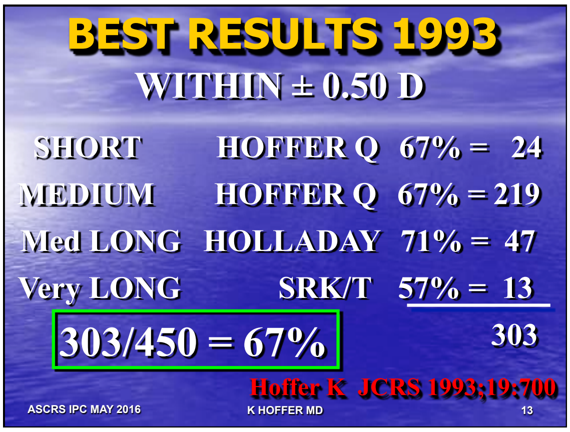
BEST RESULTS 1993
WITHIN ± 0.50 D
SHORT HOFFER Q 67% = 24
MEDIUM HOFFER Q 67% = 219
Med LONG HOLLADAY 71% = 47
Very LONG SRK/T 57% = 13
303/450 = 67% 303
Hoffer K JCRS 1993;19:700
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I proved it statistically in 836
<22 mm short eyes from
James Gills 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
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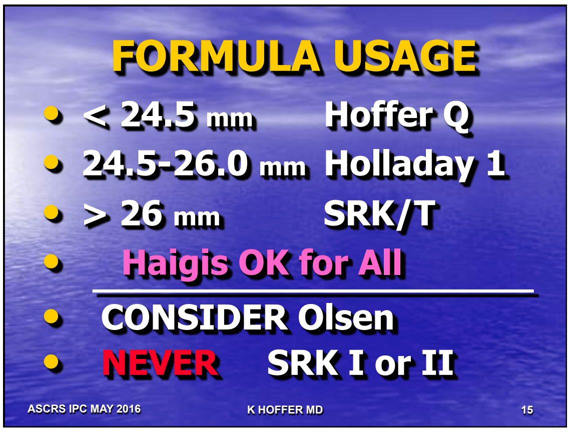
14


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
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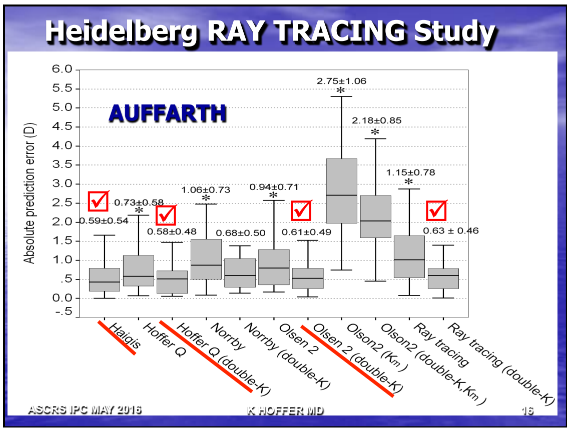
Heidelberg RAY TRACING Study
AUFFARTH
Absolute prediction error (D)
0.59±0.54
0.73±0.58
0.58±0.48
1.06±0.73
0.68±0.50
0.94±0.71
0.61±0.49
2.75±1.06
2.18±0.85
1.15±0.78
0.63 ± 0.46
Haigis
Hoffer Q
Hoffer Q (double-K)
Norrby
Norrby (double-K)
Olsen 2
Olsen 2 (double-K)
Olson2 (Km)
Olson2 (double-K,Km)
Ray tracing
Ray tracing (double-K)
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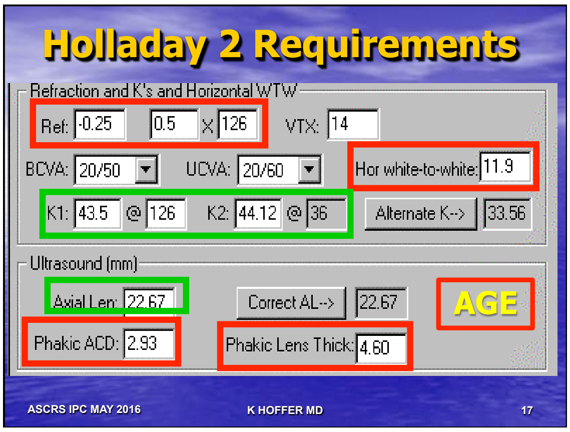
Holladay 2 Requirements
Refraction and K's and Horizontal WTW
Ref: -0.25 0.5 X 126 VTX: 14
BCVA: 20/50 UCVA: 20/60 Hor white-to-white: 11.9
K1: 43.5 @ 126 K2: 44.12 @ 36 Alternate K--> 33.56
Ultrasound (mm)
Axial Len: 22.67 Correct AL--> 22.67 AGE
Phakic ACD: 2.93 Phakic Lens Thick: 4.60
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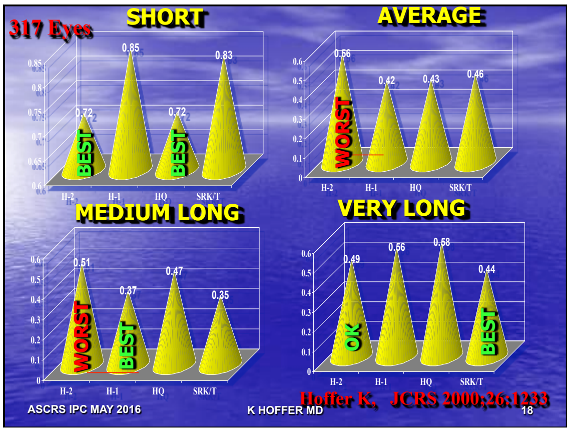
317 Eyes
SHORT
AVERAGE
MEDIUM LONG
VERY LONG
BEST
WORST
OK
H-2 H-1 HQ SRK/T
Hoffer K, JCRS 2000;26:1233
ASCRS IPC MAY 2016
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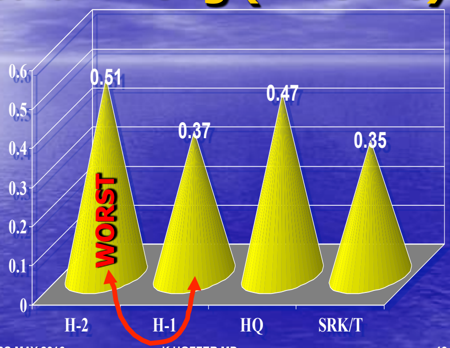
Medium Long (24.5-26)



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

Hoffer H-5 Formula Basis

Holladay Course Slide 1996

Holladay 2 Formula

$$\log(ESF_i) = +1.18\log\left(\frac{AL}{23.45}\right) - 0.89\log\left(\frac{43.81}{K}\right) + 0.28\log\left(\frac{Hwtw}{11.7}\right) + 0.21\log\left(\frac{1-Ref*|Ref|}{400}\right) - 0.18\log\left(\frac{ASL_i}{ASL_a}\right)$$

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

GENDER Differences

are real and consistent in all races

# Eyes	AL	K	ACD	LT
212,740	23.43	44.02	3.09	4.46
MALE 39,156	23.74	43.61	3.14	4.33
FEMALE 50,576	23.22	44.18	2.99	4.35
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

MALE	AL	K	ACD	LT	MALE 23,182
Western	23.77	43.45	3.12	4.65	
Latino	23.80	43.35	3.48	4.40	2,337
Oriental	24.00	44.46	2.89	4.32	2,809
Middle East	23.42	43.49	3.18	4.30	2,494
Indian	23.68	43.95	3.24	4.01	5,696

FEMALE 30,297	FEMALE	AL	K	ACD	LT
	Western	23.23	44.14	2.93	4.65
3,252	Latino	23.33	43.95	3.36	4.36
3,981	Oriental	23.33	43.75	2.77	4.44
3,468	Middle East	22.99	44.00	3.13	4.26
6,314	Indian	23.23	44.70	3.14	3.89

H-5 GLOBAL STUDY

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

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Truly a Global Endeavor

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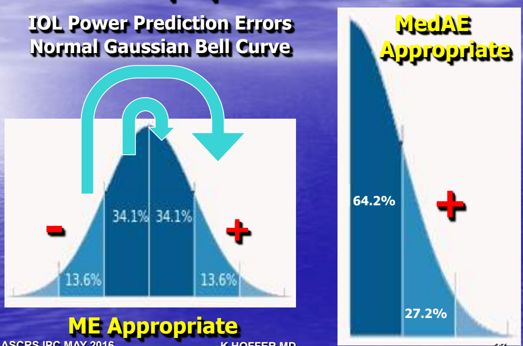
Reporting Accuracy: MAE Improper

Absolute Errors Are Not Gaussian Curve



ME Appropriate

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Results: 2,186 Eyes ±0.25 D PE

EYES	Race	%	FORMULA	MedAE	ME	MAE
4503	WEST	56%				
2405	ASIAN	30%	HOFFER Q	0.149	0.00	0.17
534	A-IND	7%	HOLLADAY 1	0.122	0.00	0.14
257	LAT	4%	SRK/T	0.139	0.00	0.17
257	MidE	3%	HOFFER H-5	0.105	0.00	0.11
8034	TOTAL					

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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

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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

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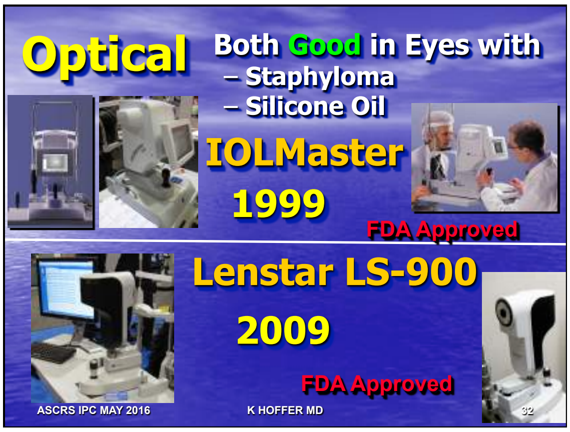

Hoffer/Shammas/Savini Study

RESULTS of 61 Right EYES

	LS-900	IOLMaster	Diff/P Value
AL	23.66 ±1.04	23.64 ±1.04	+0.02/0.055
K	43.55 ±1.90	43.68 ±1.88	-0.13/0.0001
ACD	3.05 ±0.44	2.92 ±0.45	+0.13/0.0001

1 Eye With Each Could not Get a Reading

JCRS 2010;36:644

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RESULTS of 105 EYES (63 Bil)

	LS-900	IOLMaster	Diff/P Value
AL	? ±?	? ±?	+0.02/0.84
K	44.06 ±1.56	44.12 ±1.54	-0.06/0.001
ACD	3.15 ±0.36	3.05 ±0.39	+0.10/0.001

7 Eyes With Each Could not Get a Reading

Epitropoulos Clin Oph 2014;8:1369

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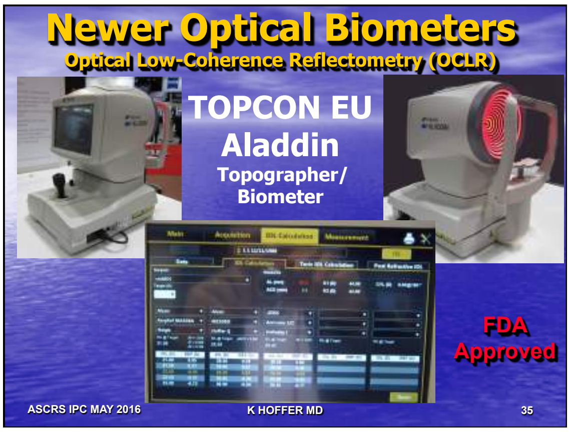

Hoffer/Shammas/Savini Study

RESULTS of 60 USA R EYES

	Aladdin	IOLMaster	Diff/P Value
AL	23.59 ±0.99	23.58 ±1.00	+0.01/0.0770
K	43.77 ±1.67	43.90 ±1.67	-0.14/0.0001
ACD	3.13 ±0.43	2.95 ±0.44	+0.16/0.0001

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

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Hoffer/Shammas/Savini/Huang Study

RESULTS of 56 Chinese R EYES

	Aladdin	IOLMaster	Diff/P Value
AL	25.13 ±1.02	25.13 ±1.03	-0.01/0.0620
K	43.61 ±1.60	43.74 ±1.64	-0.14/0.0001
ACD	3.72 ±0.25	3.67 ±0.27	+0.05/0.0001

Young Chinese Pts 26 ±3 yo JCRS 2016;42(1):62

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Compare US & Chinese EYES

Older American Cataract Pts 75 ±10 yo — Young Chinese Pts 26 ±3 yo

	USA Diff/P Value	China Diff/P Value
AL	+0.01/0.0770	-0.01/0.0620
K	-0.14/0.0001	-0.14/0.0001
ACD	+0.16/0.0001	+0.05/0.0001

JCRS 2016;42(1):62

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Newer Optical Biometers

NIDEK AL-Scan

BUILT-IN US PROBE

Hoffer/Shammas/Savini Study Submitted

FDA Approved

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AL RESULTS of 87 EYES Age 72

	AL-Scan	IOLMaster	P Value
AL	23.46 ±0.99	23.46 ±0.99	n.s. p=0.44
95% LoA	+0.03	to -0.03	No Statistical Difference

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AVG K RESULTS of 87 EYES Age 72

	AL-Scan	IOLMaster	Diff	P Value
K2.4	43.83 ±1.49	43.76 ±1.46	-0.07	0.015
95% LoA	+0.43	to -0.57		Statistically Different
K3.3	43.79 ±1.44	43.76 ±1.46	-0.03	n.s. 0.40
95% LoA	+0.53	to -0.58		No Statistical Difference

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

	AL-Scan	IOLMaster	P Value
ACD	2.96 ±0.38	2.83 ±0.38	<0.0001
95% LoA	+0.18	to -0.44	Statistically Different

AL-Scan 0.13 MM DEEPER

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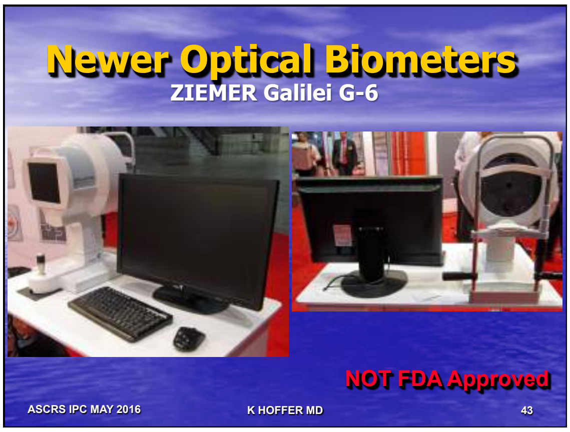
Newer Optical Biometers
ZIEMER Galilei G-6
NOT FDA Approved
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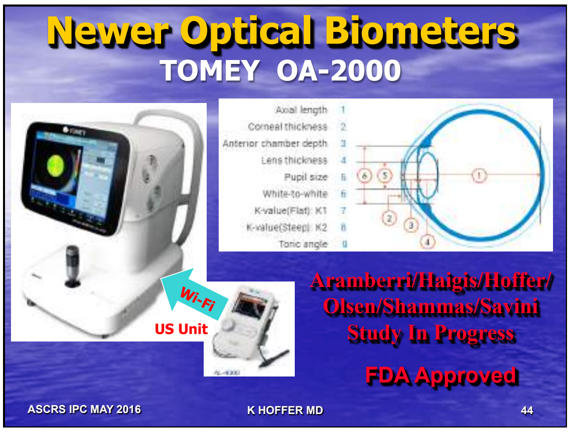
Newer Optical Biometers
TOMEY OA-2000
Axial length 1
Corneal thickness 2
Anterior chamber depth 3
Lens thickness 4
Pupil size 5
White-to-white 6
K-value(Flat): K1 7
K-value(Steep): K2 8
Toric angle 9
Wi-Fi
US Unit
Aramberri/Haigis/Hoffer/
Olsen/Shammas/Savini
Study In Progress
FDA Approved
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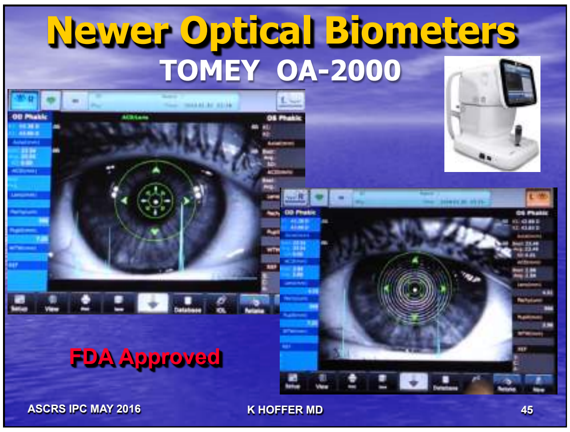
Newer Optical Biometers
TOMEY OA-2000
FDA Approved
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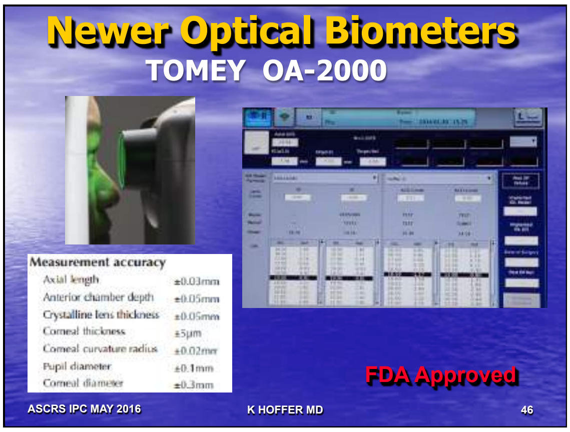
Newer Optical Biometers
TOMEY OA-2000
Measurement accuracy
Axial length ±0.03mm
Anterior chamber depth ±0.05mm
Crystalline lens thickness ±0.05mm
Corneal thickness ±5μm
Corneal curvature radius ±0.02mm
Pupil diameter ±0.1mm
Corneal diameter ±0.3mm
FDA Approved
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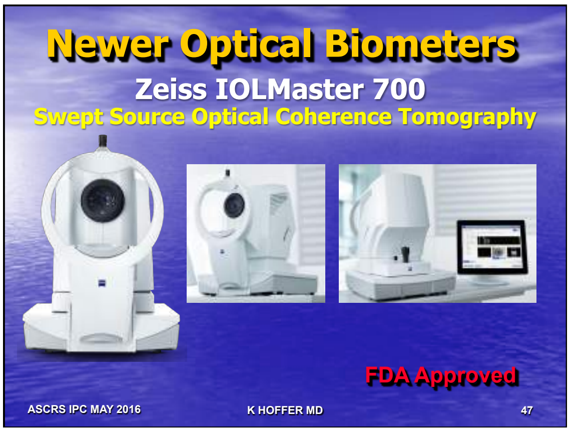
Newer Optical Biometers
Zeiss IOLMaster 700
Swept Source Optical Coherence Tomography
FDA Approved
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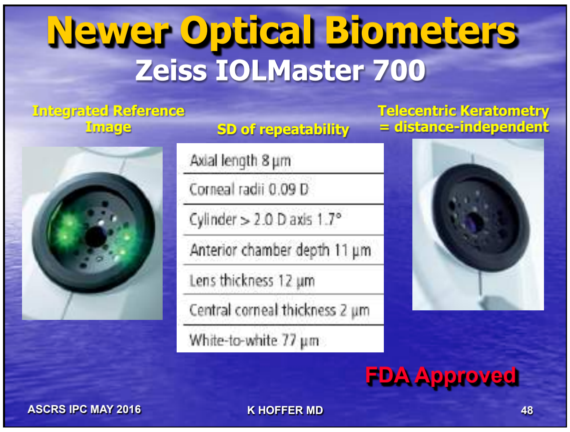
Newer Optical Biometers
Zeiss IOLMaster 700
Integrated Reference Image
SD of repeatability
Telecentric Keratometry = distance-independent
Axial length 8 μm
Corneal radii 0.09 D
Cylinder > 2.0 D axis 1.7°
Anterior chamber depth 11 μm
Lens thickness 12 μm
Central corneal thickness 2 μm
White-to-white 77 μm
FDA Approved
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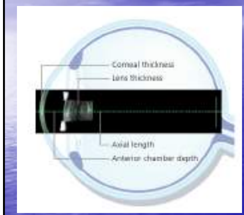
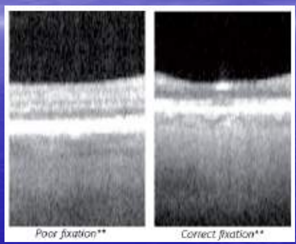
Newer Optical Biometers
Zeiss IOLMaster 700





FDA Approved

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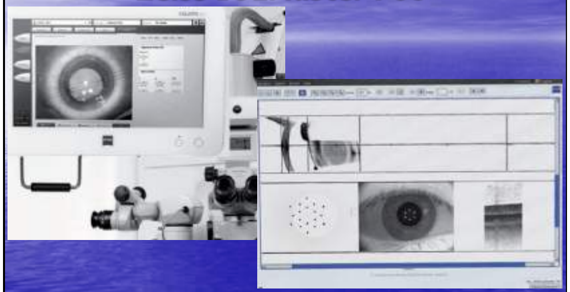
Newer Optical Biometers
Zeiss IOLMaster 700



FDA Approved

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Hoffer/Hoffmann/Savini Study

RESULTS of 182 R EYES

	ILM 700	Lenstar	Diff/P Value
AL	23.61 ±1.27	23.60 ±1.27	-0.01/<0.001
K	43.84 ±1.43	43.82 ±1.43	-0.02/0.0271
ACD	3.22 ±0.44	3.19 ±0.44	-0.03/<0.001

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

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Hoffer/Hoffmann/Savini Study

RESULTS of 182 R EYES

	ILM 700	Lenstar	Diff/P Value
LT	4.59 ±0.43	4.62 ±0.44	+0.03/<0.001
CCT	553.5 μ ±36	559.2 μ ±37	+5 μ /<0.001
Med AE	0.29 D HQ form	0.30 D HQ form	≤ ±0.50D 85% = in Both

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

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Newer Optical Biometers

MOVU Argos

NOT FDA Approved

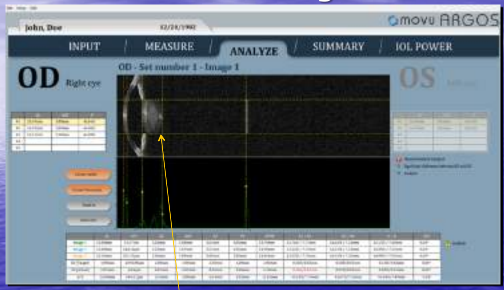
ASCRS IPC MAY 2016 K HOFFER MD 53

Newer Optical Biometers
MOVU Argos
Swept Source Optical Coherence Tomography

Tracking system for ease of alignment NOT FDA Approved

ASCRS IPC MAY 2016 K HOFFER MD 54

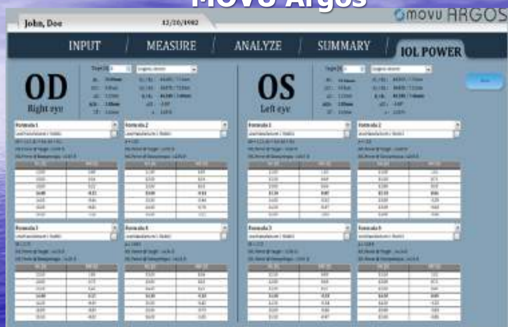
Newer Optical Biometers
MOVU Argos



Analysis Mode

NOT FDA Approved

Newer Optical Biometers
MOVU Argos



Shammas/Chong Study
RESULTS of 42 R EYES

	ILM 500	Argos	Diff/P Value
AL	23.34 ±0.97	23.35 ±0.95	+0.01/<0.001
K	44.06 ±1.82	44.00 ±1.76	-0.06/0.0271
ACD	2.89 ±0.32	3.06 ±0.31	+0.17/<0.001

Cataract Pts 74 ±9 yo (54-89) JCRS 2016;42(1):50

Shammas/Chong Study
RESULTS of 42 R EYES

	Lenstar	Argos	Difference
LT	4.48 ±0.40	4.70 ±0.37	+0.22
CD	11.81 ±0.62	12.15 ±0.65	+0.24
CCT	0.53 ±0.04	0.53 ±0.04	+0.00

LT 0.22 Thicker with Argos SS-OCT JCRS 2016;42(1):50

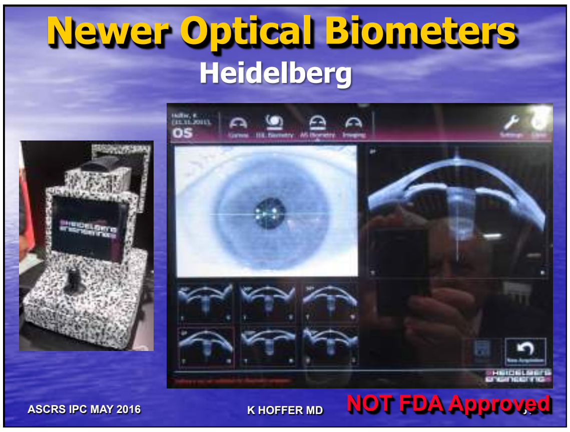
ACD Comparisons of Six Biometers

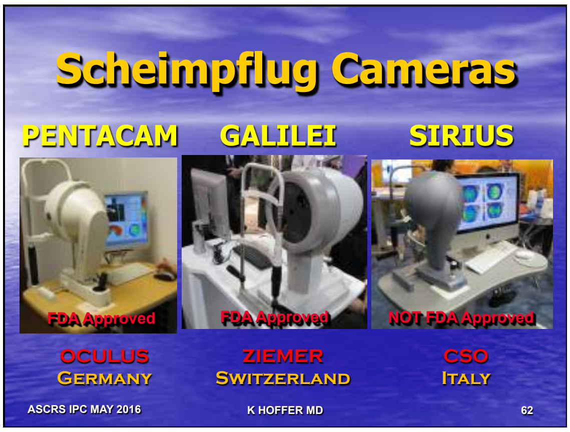
	Eyes	Diff		P Value
IOLM 500	---	------	------	------
LenStar	61	+0.13	DEEPER	0.001
Aladdin	60	+0.16	DEEPER	0.001
AL-Scan	86	+0.13	DEEPER	<0.001
ILM 700	182	+0.27	DEEPER	<0.001
Argos	42	+0.17	DEEPER	?

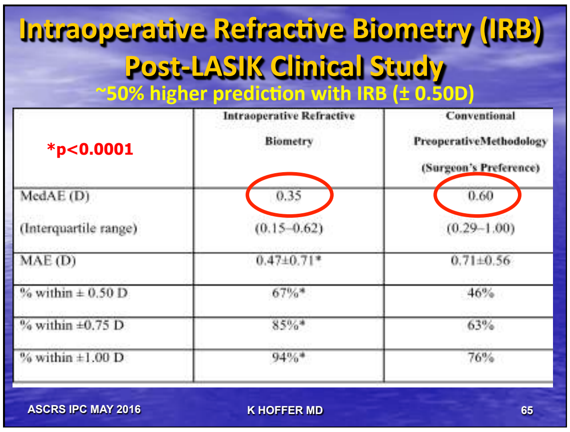
ILM 500 measures ~0.20 mm shallower ACD (0.13-0.27)

Newer Optical Biometers
Heidelberg 2015

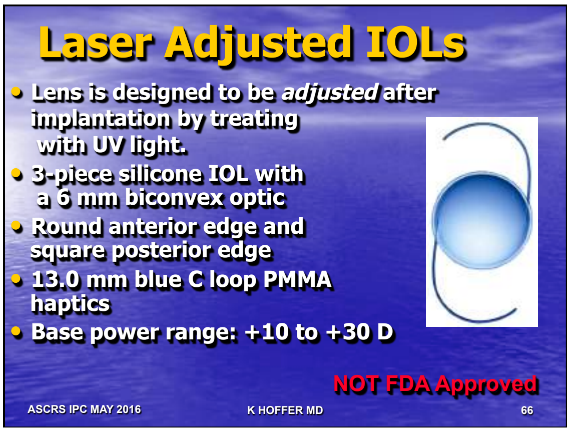
NOT FDA Approved

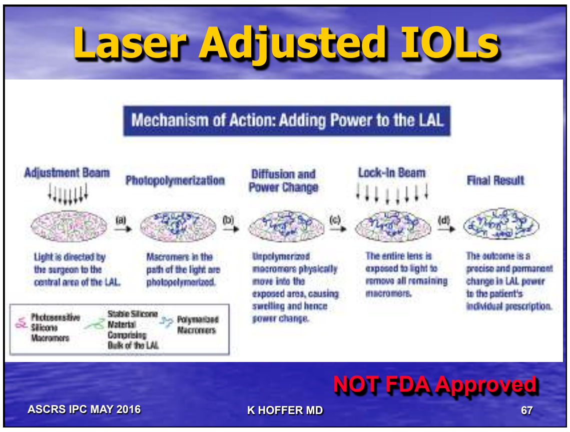






*p<0.0001	Intraoperative Refractive Biometry	Conventional PreoperativeMethodology (Surgeon's Preference)
MedAE (D) (Interquartile range)	0.35 (0.15–0.62)	0.60 (0.29–1.00)
MAE (D)	0.47±0.71*	0.71±0.56
% within ± 0.50 D	67%*	46%
% within ±0.75 D	85%*	63%
% within ±1.00 D	94%*	76%




Laser Adjusted IOLs
Mechanism of Action: Adding Power to the LAL
Adjustment Beam
Photopolymerization
Diffusion and Power Change
Lock-In Beam
Final Result
(a)
(b)
(c)
(d)
Light is directed by the surgeon to the central area of the LAL.
Macromers in the path of the light are photopolymerized.
Unpolymerized macromers physically move into the exposed area, causing swelling and hence power change.
The entire lens is exposed to light to remove all remaining macromers.
The outcome is a precise and permanent change in LAL power to the patient's individual prescription.
Photosensitive Silicone Macromers
Stable Silicone Material Comprising Bulk of the LAL
Polymerized Macromers
NOT FDA Approved
ASCRS IPC MAY 2016
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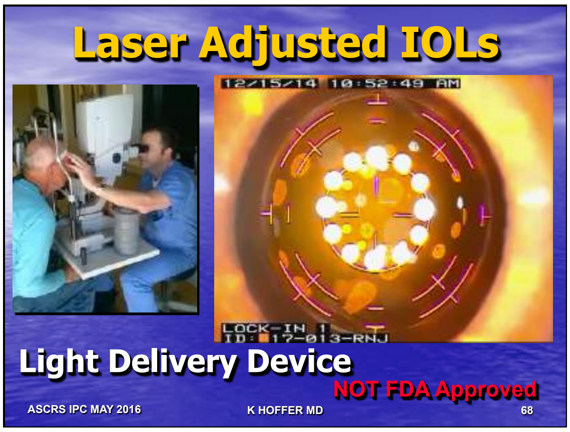
67


Laser Adjusted IOLs
12/15/14 10:52:49 AM
LOCK-IN 1
Light Delivery Device
NOT FDA Approved
ASCRS IPC MAY 2016
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68


Thank You
SANTA MONICA
66
End of the Trail
SANTA MONICA
YACHT HARBOR
SPORT FISHING ★ BOATING
Danke
Shukran
Efcharisto
Grazie
Dziekuje
Gracias
Obrigado
Arigato
Děekuji
KhoKhun
Takk
Tack
Toda
Kitos
YekooE
Mauruuru
Merci
Spasibo
Köszönöm
Shukriya
Dakujem
KHofferMD@AOL.com
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ASCRS San Diego
2015

The short and the long eye issues

Thomas Olsen, MD
University Eye Clinic
Aarhus, Denmark

Financial disclosure

Thomas Olsen MD

- CEO of IOL Innovations
  (www.PhacoOptics.com)
- Consultant to Haag-Streit AG

T Olsen 2015 2

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

T Olsen 2015 3

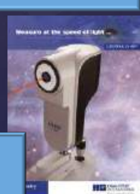
The short eye

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

T Olsen 2015 4

The laser can measured the axial length with surprising accuracy

Biometry is no longer a signficant source of error !



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

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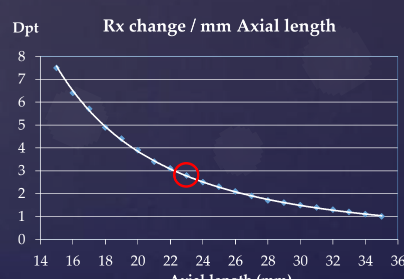
The effect of axial length error



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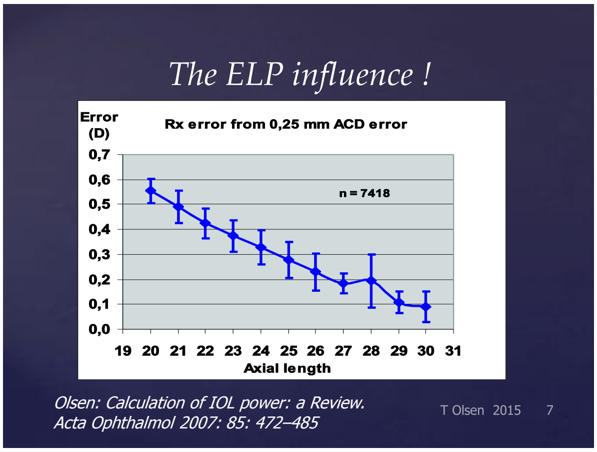
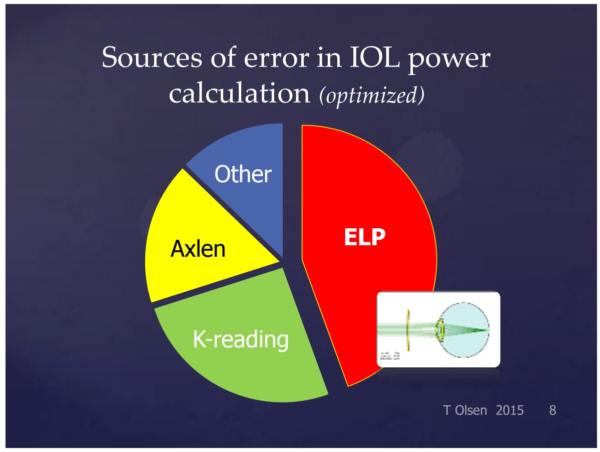
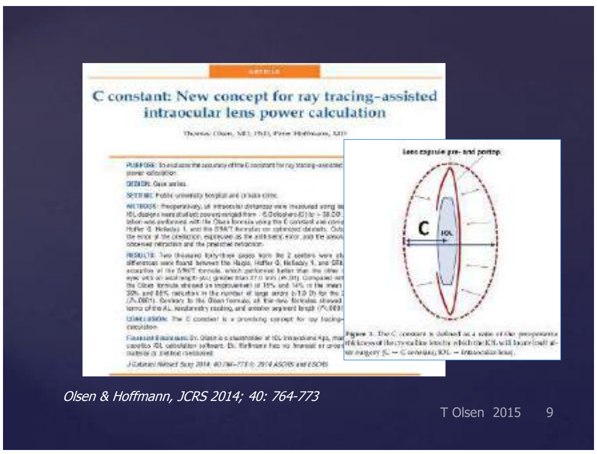
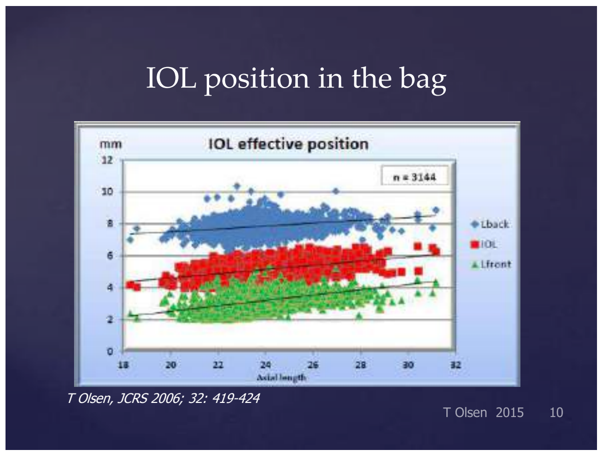
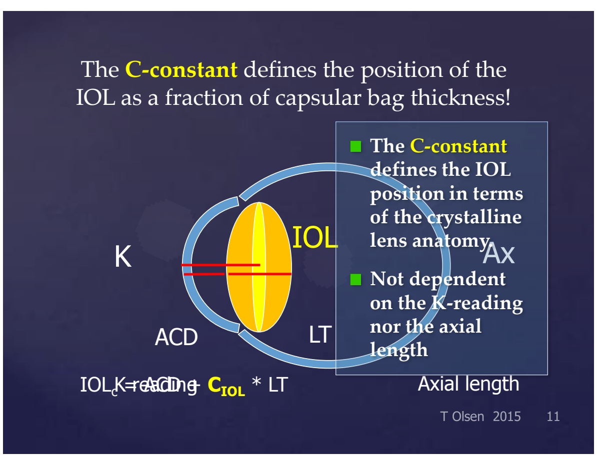
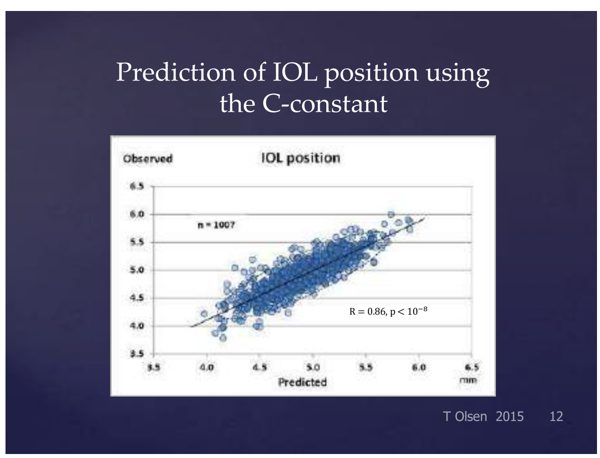

The ELP influence !
Rx error from 0,25 mm ACD error
Error (D)
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
n = 7418
19 20 21 22 23 24 25 26 27 28 29 30 31
Axial length
Olsen: Calculation of IOL power: a Review.
Acta Ophthalmol 2007: 85: 472–485
T Olsen 2015 7


Sources of error in IOL power calculation (optimized)
Other
ELP
Axlen
K-reading
T Olsen 2015 8

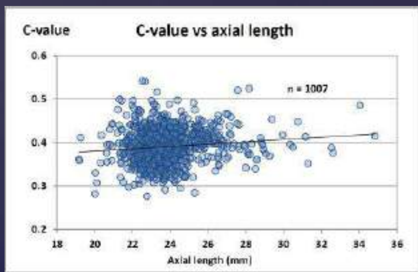

C constant: New concept for ray tracing–assisted intraocular lens power calculation
C
IOL
Olsen & Hoffmann, JCRS 2014; 40: 764-773
T Olsen 2015 9


IOL position in the bag
IOL effective position
mm
12
10
8
6
4
2
0
n = 3144
Lback
IOL
Lfront
18 20 22 24 26 28 30 32
Axial length
T Olsen, JCRS 2006; 32: 419-424
T Olsen 2015 10


The C-constant defines the position of the IOL as a fraction of capsular bag thickness!
The C-constant defines the IOL position in terms of the crystalline lens anatomy
Not dependent on the K-reading nor the axial length
K
IOL
Ax
ACD
LT
IOLc = ACD + CIOL * LT
K-reading
Axial length
T Olsen 2015 11


Prediction of IOL position using the C-constant
Observed
IOL position
6.5
6.0
5.5
5.0
4.5
4.0
3.5
n = 1007
R = 0.86, p < 10⁻⁸
3.5 4.0 4.5 5.0 5.5 6.0 6.5
Predicted
mm
T Olsen 2015 12

No dependence on axial length



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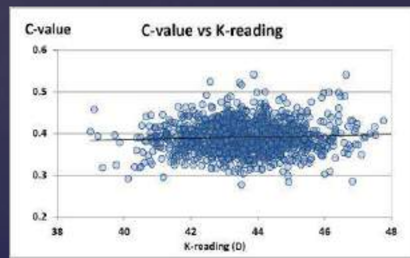
No dependence on K-reading



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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

*) ***www.PhacoOptics.com***

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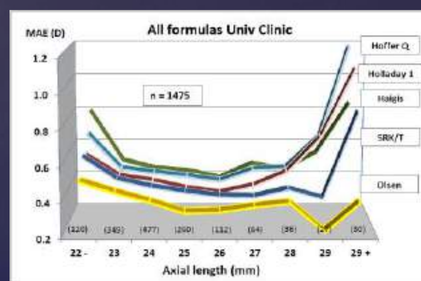
Formula comparison



Olsen & Hoffmann, JCRS 2014; 40: 764-773

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Overall results Olsen formula
Routine cases

- 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

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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*

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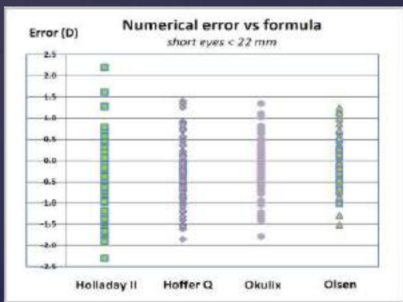
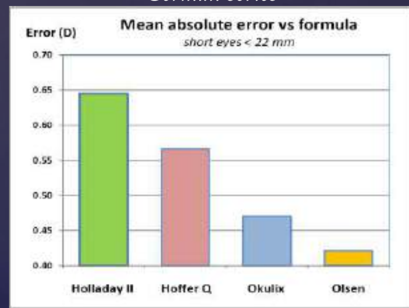
Short eye study
- German series



T Olsen 2015 19

Short eye study
- German series



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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

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Let's take a fresh look on

The corneal power

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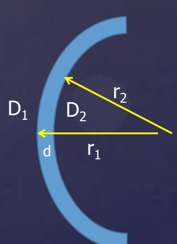
Corneal power – what kind of melon is it?



$$D_1 = \frac{1.376 - 1}{r_1}$$

$$D_2 = \frac{1.336 - 1.376}{r_2}$$

$$D_{12} = D_1 + D_2 - d * D_1 * D_2$$

"K" = (n – 1) / r
n = 1.3375 (wrong!)
n = 1.3315 (better!)

Olsen T: Br J Ophthalmol 70: 152-154, ***1986***

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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?

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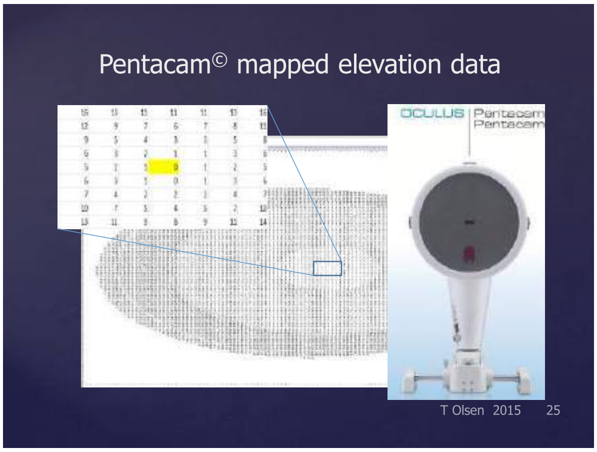
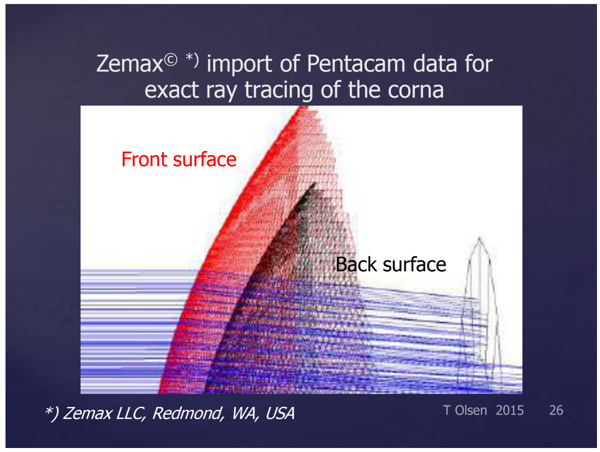
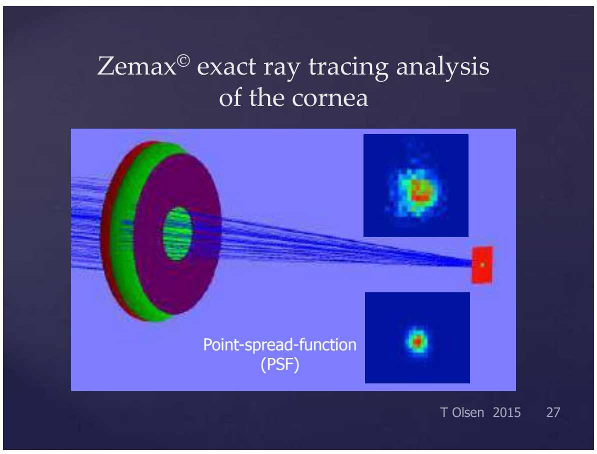
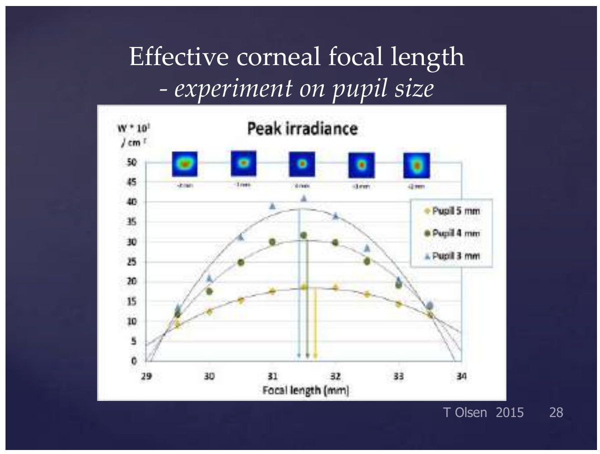
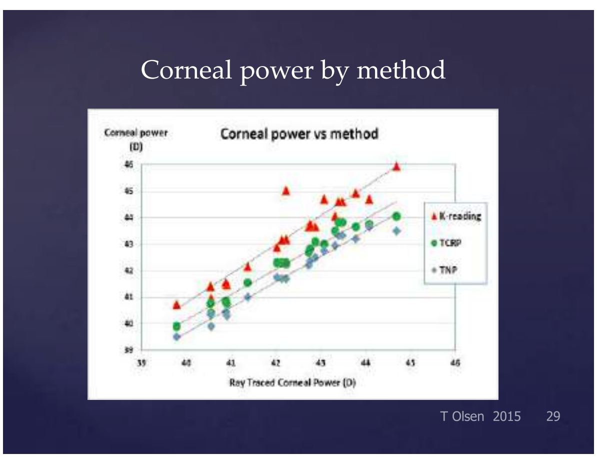
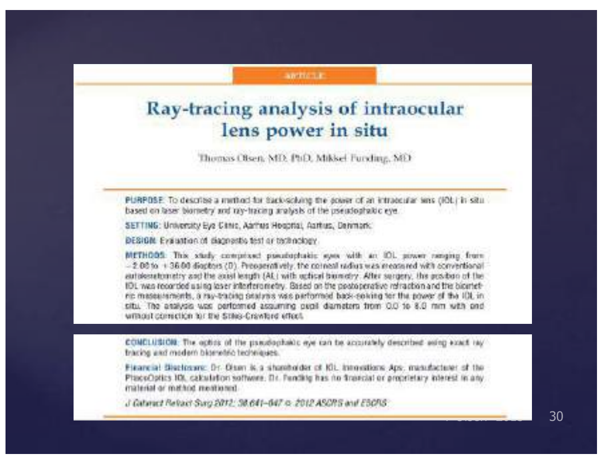











ARTICLE

Ray-tracing analysis of intraocular lens power in situ

Thomas Olsen, MD, PhD, Mikkel Funding, MD

PURPOSE: To describe a method for back-solving the power of an intraocular lens (IOL) in situ based on laser biometry and ray-tracing analysis of the pseudophakic eye.

SETTING: University Eye Clinic, Aarhus Hospital, Aarhus, Denmark.

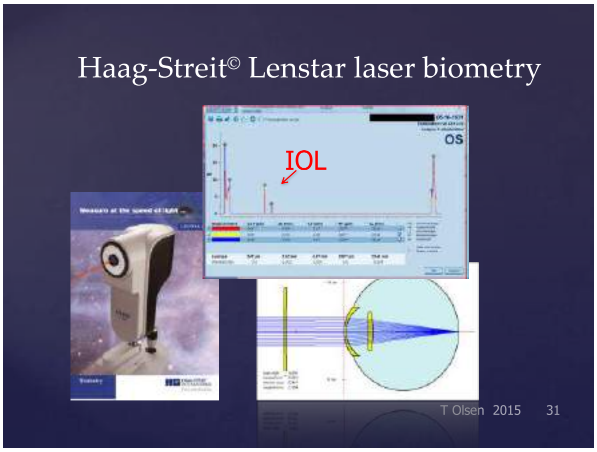
DESIGN: Evaluation of diagnostic test or technology.

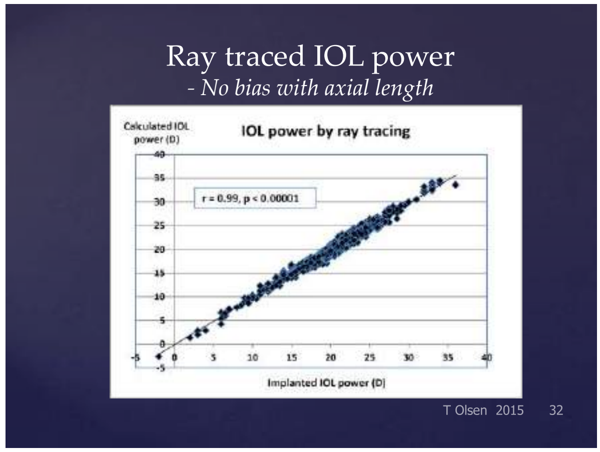
METHODS: This study comprised pseudophakic eyes with an IOL power ranging from −2.00 to +36.00 diopters (D). Preoperatively, the corneal radius was measured with conventional autokeratometry and the axial length (AL) with optical biometry. After surgery, the position of the IOL was recorded using laser interferometry. Based on the postoperative refraction and the biometric measurements, a ray-tracing analysis was performed back-solving for the power of the IOL in situ. The analysis was performed assuming pupil diameters from 0.0 to 8.0 mm with and without correction for the Stiles-Crawford effect.

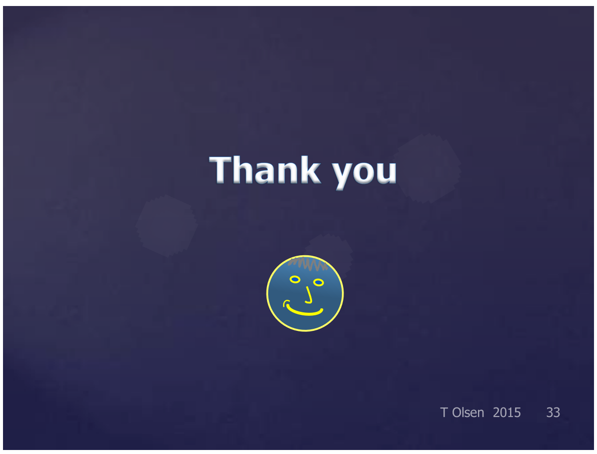
CONCLUSION: The optics of the pseudophakic eye can be accurately described using exact ray tracing and modern biometric techniques.

Financial Disclosure: Dr. Olsen is a shareholder of IOL Innovations Aps, manufacturer of the PhacoOptics IOL calculation software. Dr. Funding has no financial or proprietary interest in any material or method mentioned.

J Cataract Refract Surg 2012; 38:641–647 © 2012 ASCRS and ESCRS


Haag-Streit© Lenstar laser biometry
IOL
OS
T Olsen 2015 31


Ray traced IOL power
- No bias with axial length
IOL power by ray tracing
Calculated IOL power (D)
r = 0.99, p < 0.00001
Implanted IOL power (D)
T Olsen 2015 32


Thank you
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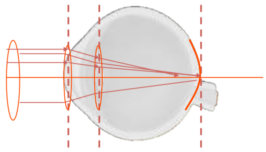
Post LASIK/PRK IOL calcs

BEGITEK
Ókular
Vitoria-Gasteiz

Jaime Aramberri

Calculating IOL power = Modelling the pseudophakic eye



Solving for IOL power

	METHOD	VARIABLES	EXAMPLES
Vergence formula	Calculate planes using vergence of light	Power; distances	Haigis; Hoffer Q; Holladay 1 and 2; SRK/T;
Paraxial ray tracing	Calculate angles and heigth of light rays (paraxial region)	Radii; distances; n.	Optical software: Zemax; OSLO, Winlens…) Norrby JCRS 2004
Exact ray tracing	Calculate angles and heigth of light rays (exact refraction, Aberrations considered)	Radii at each point; Distances; n.	Okulix Optical software: Zemax; OSLO, Winlens…) Phacooptics

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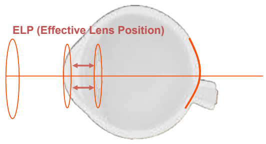
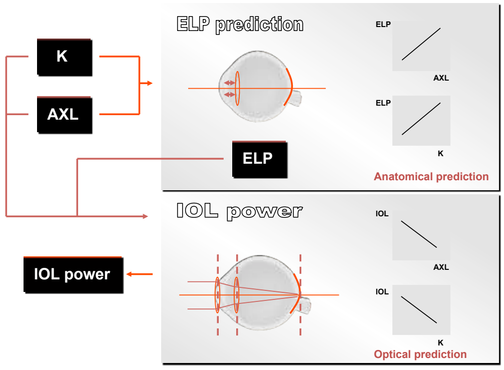
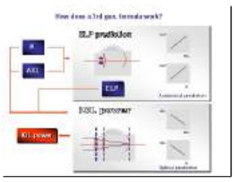
All methods need a precise IOL position (ELP) predicting algorithm

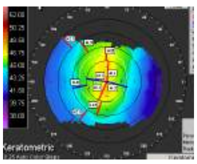


ELP predicting Algorithm / Predicting variable	AXL	K / r	ACD	HWTW	Lens Thickn	Rx	Age
SRK/T	●	●					
Hoffer Q	●	●					
Holladay 1	●	●					
Holladay 2	●	●	●	●	●	●	●
Haigis	●		●				
Olsen (2006)	●	●	●		●	●	

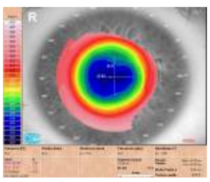
How does a 3rd gen. formula work?







HYPEROPIC LASIK/PRK



MYOPIA

HYPEROPIA

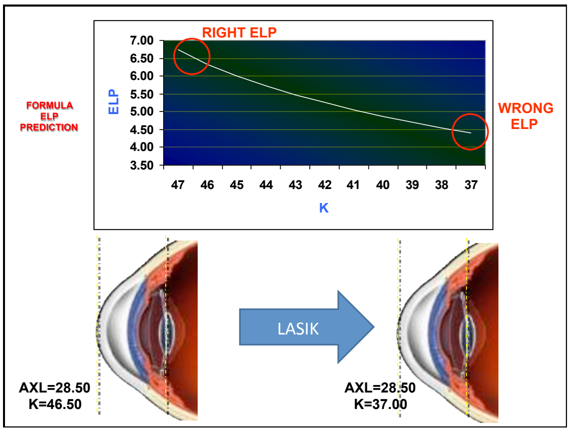
MYOPIC LASIK/PRK

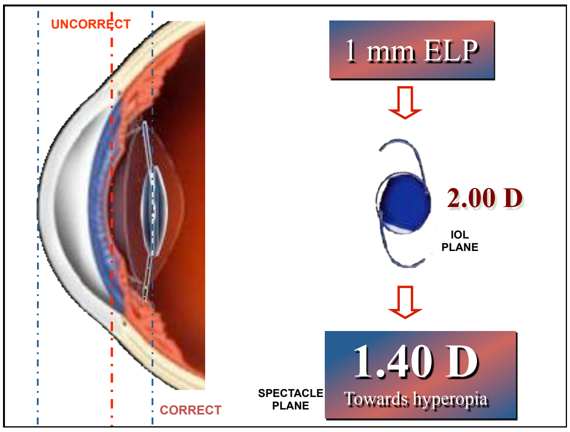
The errors

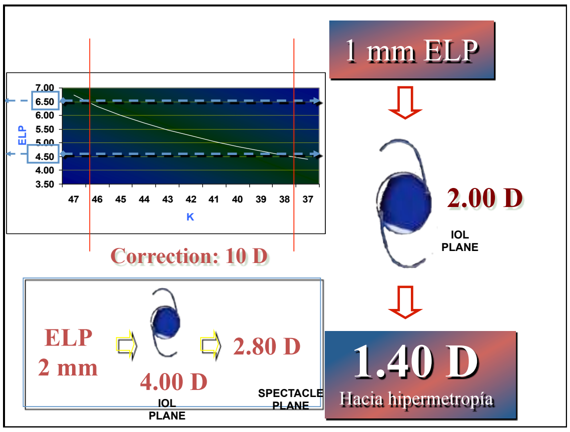
1.- Uncorrect ELP prediction if K dependent ELP predicting formula is used with present (post LASIK) K value (SRK/T; Holladay; Hoffer Q; Olsen…)

2.- Uncorrect corneal power measurement by topo-graphers and keratometers

Uncorrect ELP prediction







The solution

1.- Use a formula that doesn´t use K for ELP

Haigis: ELP = a0 + a1 ACD pre + a2 AXL   Aramberri: 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

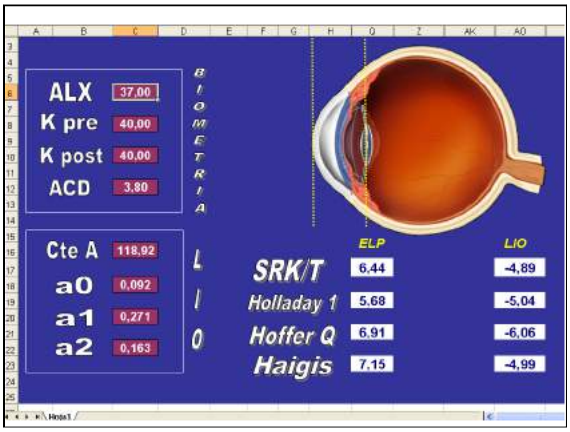
K post: For the optical calculation

-Program it yourself (recommended)

-Use comercial software: Hoffer Program; Holladay IOL Consultant (Holladay 2);…

-Some biometry devices have it: 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 ⇨ 337.5 / 7.91 = **42.77**

Best option

K pre error influence in refraction error

Improve 3 gen. Formula performance with Kpre:

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

ACD + LT (mm)	K pre (D)
< 7.5	42
7.5 – 8.10	43.5
> 8.10	45

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 topo-graphers and keratometers

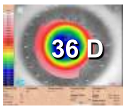
corneal power measurement

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 unaccurate

2.- Change of corneal asphericity:

- Enlarge area of analisys
- Decrease optical power (best focus plane anterior to paraxial calculation)

K post calculation:

1.- Present K non dependent methods

Don´t need present topography/keratometry

a.- Clinical History method

K pre – (Corrected D at corneal plane)

2.- Present K dependent methods

Need present topography/keratometry

a.- K corrected methods

- K – (15 to 19 % of corrected D) (Hamed et al.; Wang et al.)
- Empirical formula: 1,14 * K – 6,8 (Shammas at al)
- Theoretical formula: 1,119 * K – 5,78 (Haigis)

b.- Total corneal power (Scheimpflug/OCT)

(devices that measure ant+posterior cornea)

Power = distance → from the focal plane to a reference plane in the cornea

$P = P_1 + P_2 - P_1 P_2 \frac{d}{n}$

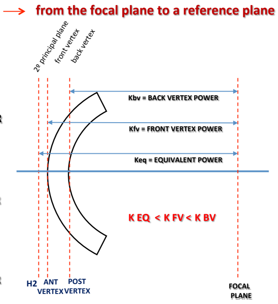
Keq = EQUIVALENT POWER

$P_f = P_1 + \frac{P_2}{1 - \frac{P_2 d}{n}}$

Kfv = FRONT VERTEX POWER

$P_b = P_2 + \frac{P_1}{1 - \frac{P_1 d}{n}}$

Kbv = BACK VERTEX POWER



Pentacam True Net Power 40.8

Orbscan Mean Total Power 40.7

Pentacam Total Corneal Refractive Power 41.5

Galilei Total Corneal Power (<5.2) 41.5

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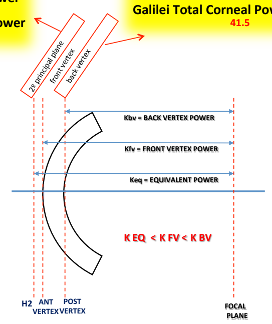
Kbv = BACK VERTEX POWER



Pentacam True Net Power 40.8

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Galilei Total Corneal Power (<5.2) 41.5

Sim K / K 42

$P = P_1 + P_2 - P_1 P_2 \frac{d}{n}$

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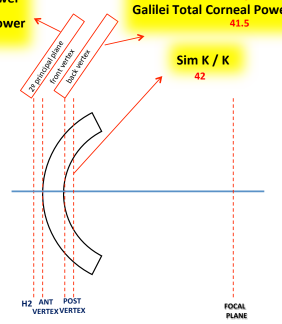


From K_{total} to K_{post}

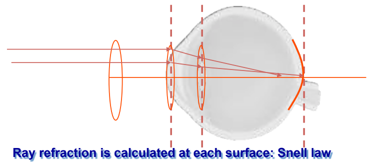
Remember that the formula is waiting for a K (n=1,3375) value: Conversion is needed

PENTACAM (True Net Power) →	K real + 1,20
PENTACAM (Total Refractive Power) →	K real + 0.33
ORBSCAN (Mean Total Power) →	K real + 1,25
GALILEI (Total Corneal Power) before v. 5.00 →	K real + 0,35
GALILEI (Total Corneal Power) after v. 5.00 →	K real + 1,80

The next step

real numbers for a real world

Ray tracing thick lens models



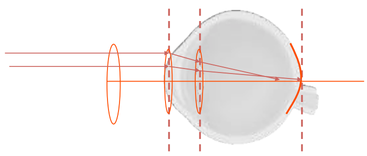
Ray refraction is calculated at each surface: Snell law
Angle of refraction allows calculation height of the ray at next surface

There is a difference between paraxial and marginal rays: Higher order Aberrations (HOA)

Different levels of complexity:

- Curvature radii and asphericities (only spherical aberration)
- Cornea and IOL elevation data (all HOA)

EXACT RAY TRACING CALCULATION



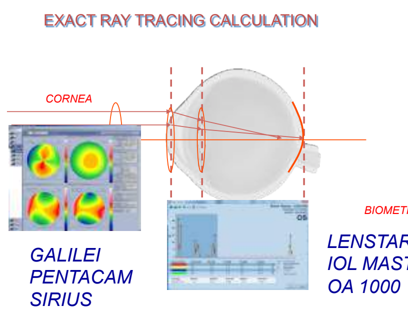
- Curvature radii and asphericities (only spherical aberration)

EXACT RAY TRACING CALCULATION

CORNEA

IOL

Radii
Asphericity
Thickness
n



BIOMETRY

GALILEI
PENTACAM
SIRIUS

LENSTAR (Lens thicknes
IOL MASTER
OA 1000

- Curvature radii and asphericities (only spherical aberration)

Sim K	39.95
r cornea ant	8.45
r cornea post	7.04
conic ant	0.82
conic post	0.75
Paqui	0.50
Grosor cristal	4.65
ACD	5.46
AXL	26.88
ACDps	6.68
Pupila	0.50

LIO	Rx asférico	Rx paraxial	LIO	Rx asférico	Rx paraxial	LIO	Rx asférico	Rx paraxial
6	8.02	8.37	13.5	4.41	4.65	21	0.19	0.41
6.5	7.80	8.14	14	4.14	4.38	21.5	-0.12	0.07
7	7.57	7.91	14.5	3.88	4.11	22	-0.44	-0.24
7.5	7.34	7.67	15	3.61	3.83	22.5	-0.76	-0.55
8	7.11	7.43	15.5	3.33	3.56	23	-1.08	-0.87
8.5	6.88	7.19	16	3.12	3.35	23.5	-1.41	-1.20
9	6.64	6.94	16.5	2.84	3.06	24	-1.75	-1.57
9.5	6.40	6.70	17	2.56	2.78	24.5	-2.08	-1.88
10	6.17	6.46	17.5	2.28	2.49	25	-2.43	-2.25
10.5	5.92	6.21	18	1.99	2.21	25.5	-2.64	-2.45
11	5.68	5.96	18.5	1.70	1.92	26	-3.00	-2.80
11.5	5.43	5.70	19	1.41	1.62	26.5	-3.35	-3.15
12	5.18	5.45	19.5	1.11	1.31	27	-3.70	-3.51
12.5	4.92	5.18	20	0.80	1.00	27.5	-4.07	-3.87
13	4.67	4.92	20.5	0.50	0.69	28	-4.44	-4.23

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

Error #1 solved

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

Error #2 solved

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

Thank You

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Calculations for toric IOLs

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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
- Ratio $\dfrac{\text{Cylinder @ IOLplane}}{\text{Cylinder @ corneal plane}}$

Posterior corneal astigmatism

OCULUS PENTACAM | CSO SIRIUS | ZIEMER GALILEI | TOMEY TMS-5

Corneal astigmatism

- Keratometric astigmatism: corneal power calculated with 1.3375 keratometric index, aiming to provide "fictitious" information about <u>total corneal power</u>, although measurements are taken <u>from the anterior surface only</u>
- 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)

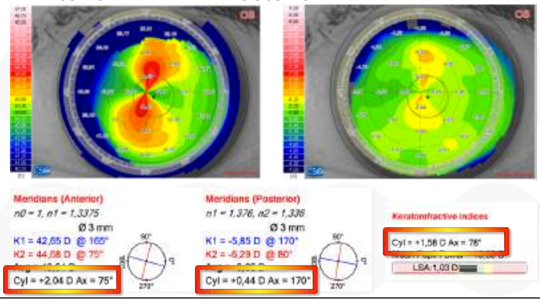
Posterior corneal astigmatism

- 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 2009
2 - Koch et al. JCRS 2012
3 - Savini et al. JCRS 2014
4 - Tonn et al. IOVS 2015

Posterior corneal astigmatism

Anterior Posterior



Posterior corneal astigmatism

Posterior corneal astigmatism

Table 1. Mean astigmatism values. Polar values along fixed meridians of 0/45 degrees (equations 3 and 4) were used to calculate the various mean net astigmatisms.

Parameter	Eyes (n)	KA (D)	CA_{Ant} (D)	CA_{Post} (D)	TCA (D)
Total	157	1.80 @ 93	1.99 @ 93	0.52 @ 3	1.57 @ 93
WTR	132	2.35 @ 92	2.61 @ 92	0.60 @ 3	2.13 @ 92
ATR	18	1.84 @ 1	2.05 @ 1	0.01 @ 168	2.00 @ 1
Oblique	7	1.39 @ 127	1.54 @ 125	0.40 @ 19	1.27 @ 131

ATR = against the rule; CA_{Ant} = anterior corneal astigmatism; CA_{Pos} = posterior corneal astigmatism; KA = keratometric astigmatism; TCA = total corneal astigmatism; WTR = with the rule

Posterior corneal astigmatism

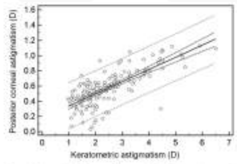


Figure 2. Correlation between the magnitude of posterior corneal astigmatism and keratometric astigmatism across the whole sample. The outer dotted lines represent the 95% prediction. The inner dotted lines represent the 95% confidence interval.

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

Posterior corneal astigmatism

Keratometric vs Total Corneal Astigmatism

- Keratometric astigmatism overestimates WTR astigmatism by 0.22±0.32 D
- Keratometric astigmatism underestimates ATR astigmatism by 0.21±0.26 D

Savini et al - JCRS 2014

Posterior corneal astigmatism

- 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

Savini et al – JCRS 2014

Posterior corneal astigmatism

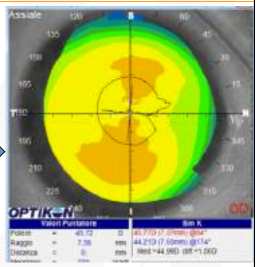
- A difference in astigmatism magnitude of ≥0.50 D was detected in 16.6% of eyes.
- The difference in the location of the steep meridian was higher than 10° in 3.8% of eyes

Savini et al – JCRS 2014

POSTERIOR CORNEAL ASTIGMATISM

Example 1 (phaco + IOL)

Keratometric Astigmatism

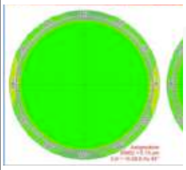


Keratron (CA_{SimK}) = 1.56@84 D

POSTERIOR CORNEAL ASTIGMATISM

Example 1 (phaco + IOL)

Intentional undercorrection



Total Corneal Astigmatism

Sirius = 0.59@86 D

Pentacam = 0.60@100 D

Ring Diameter		1.0 mm	2.0 mm	3.0 mm
Sagittal Front	K1	44.3 (10.3°)	44.1 (8.2°)	44.2 (6.1°)
	K2	45.0 (100.3°)	45.8 (98.2°)	45.0 (96.1°)
True Net Power	K1	43.3 (6.5°)	43.2 (8.5°)	43.1 (10.5°)
	K2	43.8 (96.5°)	43.7 (98.5°)	43.6 (100.5°)
Tot. Refr. Power	K1	43.3 (6.4°)	43.4 (8.3°)	43.5 (10.5°)
	K2	43.9 (96.4°)	43.8 (98.3°)	44.1 (100.5°)

POSTERIOR CORNEAL ASTIGMATISM

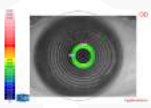
Example 1 (phaco + IOL)

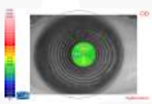
Intentional undercorrection

- Suggested IOL = T4 (astigmatism = 1.55 D)
- Implanted IOL = T2 (astigmatism = 0.67 D)
- Final RX = plano

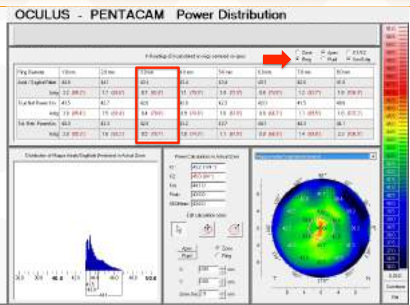
Central Astigmatism

- SimK measurements are taken on a 3mm diameter ring
- More central reading may be more accurate

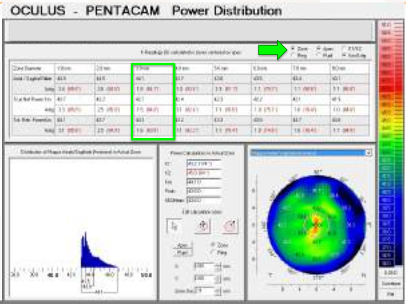




Central Astigmatism



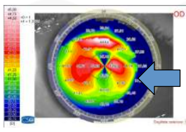
Central Astigmatism



CENTRAL ASTIGMATISM

Example 2 (phaco + IOL)

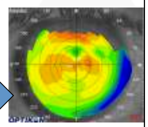
Unwanted undercorrection

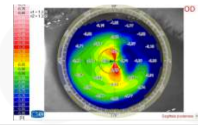


Keratometric Astigmatism (SimK)

Sirius = 1.80@179 D

Keratron = 1.89@178 D





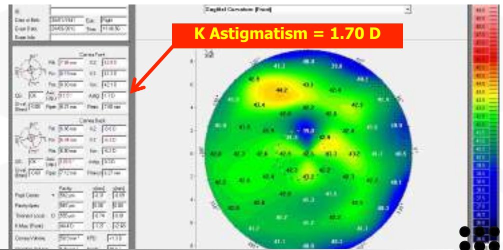
Posterior Astigmatism

Sirius = 0.32@10 D

CENTRAL ASTIGMATISM

Example 2 (phaco + IOL)

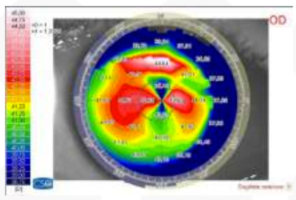
Unwanted undercorrection

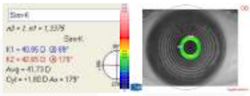


CENTRAL ASTIGMATISM

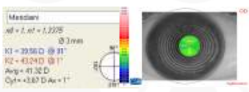
Example 2 (phaco + IOL)

Unwanted undercorrection





Keratom. Astigmatism = 1.80 D



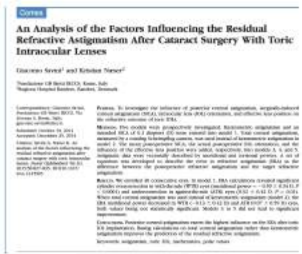
Central Astigmatism = 3.67 D

CENTRAL ASTIGMATISM

Example 2 (phaco + IOL)

- 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)

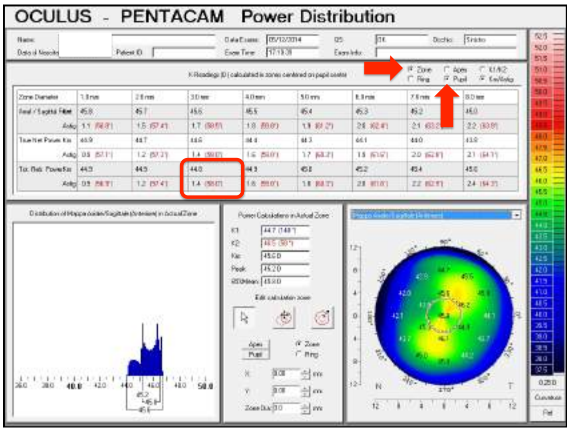
	Keratometric astigmatism (D)	Total corneal astigmatism (D)
WTR	-0.59 +/-0.34	-0.13 +/-0.42
ATR	0.32 +/-0.42	0.07 +/-0.59

Overcorrection

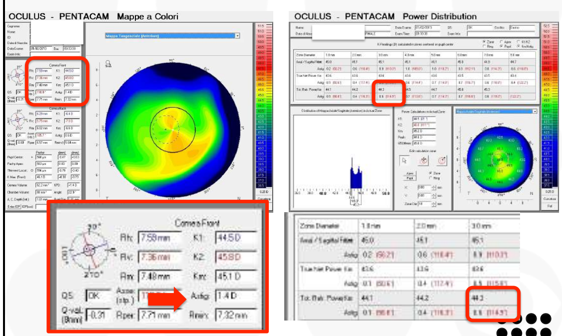
Undercorrection

Curvital power

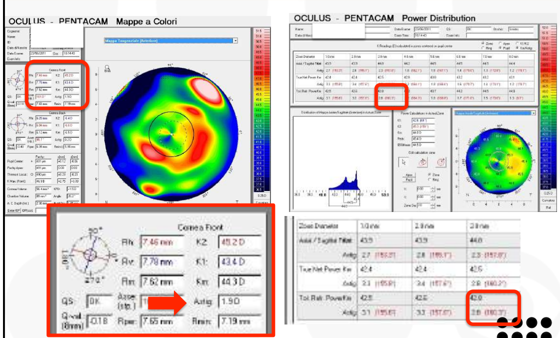
Negative = overcorrection
Positive = undercorrection



Examples



Examples



CONCLUSIONS

Keratometric Astigmatism leads to:

- ✓ overcorrection of WTR astigmatism
- ✓ undercorrection of ATR astigmatism

If you don't have total corneal astigmatism measurements..

BARRETT TORIC CALCULATOR

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

BARRETT TORIC CALCULATOR

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

BARRETT TORIC CALCULATOR

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

BAYLOR TORIC IOL NOMOGRAM

Baylor Toric IOL Nomogram, Version 2

Effective IOL cylinder power at corneal plane (D)	WTR (D)	ATR (D)
0	≤ 1.69 (>1.0: PCRI)	≤ 0.39
1.00	1.70 - 2.19	0.40* - 0.79
1.50	2.20 – 2.69	0.80 - 1.29
2.00	2.70 – 3.19	1.30 – 1.79
2.50	3.20 – 3.79	1.80 – 2.29
3.00	3.80 – 4.39	2.30 – 2.79
3.50	4.40 – 4.99	2.80 – 3.29
4.00	5.00 –	3.30 – 3.79

0.7 D ↑ 0.7 D ↓

*Especially if specs have more ATR

Based on Galilei total corneal astigmatism.

It accounts for the ATR shift with age. New target for postop astigmatism = 0.4 WTR

BAYLOR TORIC IOL NOMOGRAM

Alcon SN6ATx	WTR (D)	ATR (D)
0	≤ 1.69 (PCRI if >1.00)	≤ 0.39
T3 (1.03)	1.70 - 2.19	0.40* - 0.79
T4 (1.55)	2.20 – 2.69	0.80 - 1.29
T5 (2.06)	2.70 – 3.19	1.30 – 1.79
T6 (2.57)	3.20 – 3.79	1.80 – 2.29
T7 (3.08)	3.80 – 4.39	2.30 – 2.79
T8 (3.60)	4.40 – 4.99	2.80 – 3.29
T9 (4.11)	5.00 –	3.30 – 3.79

0.7 D ↑ 0.7 D ↓

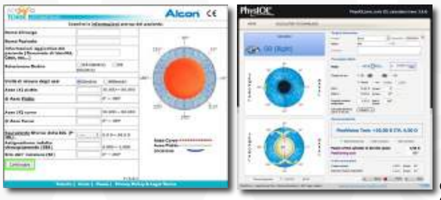
*Especially if specs have more ATR

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

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

Some toric calculators use a fixed ratio (1.46) that is good for average eyes, but not for short and long eyes



RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

TABLE 1
Range of Astigmatic Corrections Available for the AcrySof Toric IOL*

AcrySof Model	Cylinder Power at IOL Plane (D)	Cylinder Power at Corneal Plane (D)
T2	1.00	0.67
T3	1.50	1.03
T4	2.25	1.55
T5	3.00	2.08
T6	3.75	2.57
T7	4.50	3.08
T8	5.25	3.60
T9	6.00	4.11

IOL = intraocular lens; D = diopters
**Conversion from the lens to the corneal plane is calculated, according to manufacturer, by means of a fixed ratio (1.46).*
The AcrySof Toric IOL is manufactured by Alcon Laboratories, Inc., Fort Worth, TX.

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

- 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

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER


LABORATORY SCIENCE

Influence of axial length and corneal power on the astigmatic power of toric intraocular lenses

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SETTING: Private practice, Bologna, Italy.

DESIGN: Noninterventional theoretical study.

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

- Ratio = 1.29
- 6.00 D (IOL Plane) > 4.65 D (cornea)
- Ratio = 1.46
- 6.00 D (IOL Plane) > 4.11 D (cornea)
- Ratio = 1.86
- 6.00 D (IOL Plane) > 3.22 D (cornea)

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

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


Meridional analysis for calculating the expected spherocylindrical refraction in eyes with toric intraocular lenses

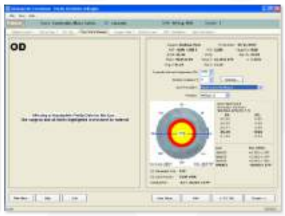
RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

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

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

ASSORT (Alpins)

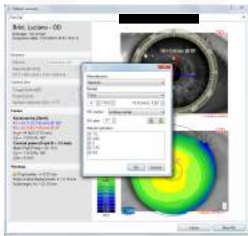


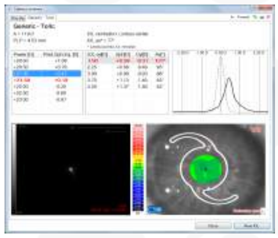
Holladay

RATIO OF IOL CYLINDER TO CORNEAL CYLINDER

PhacoOptic

RAY-TRACING BY SIRIUS





Thank you

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