Biometry in the post refractive surgery patient

The Frontiers of Cataract Surgery

Royal Society of Medicine

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Background

- A significant number of patients coming for cataract / RLE surgery will have had previous laser refractive surgery
- With increasing use of “premium lenses”, accuracy of IOL calculation is critical
- Patient expectations are forever on the increase

Outline

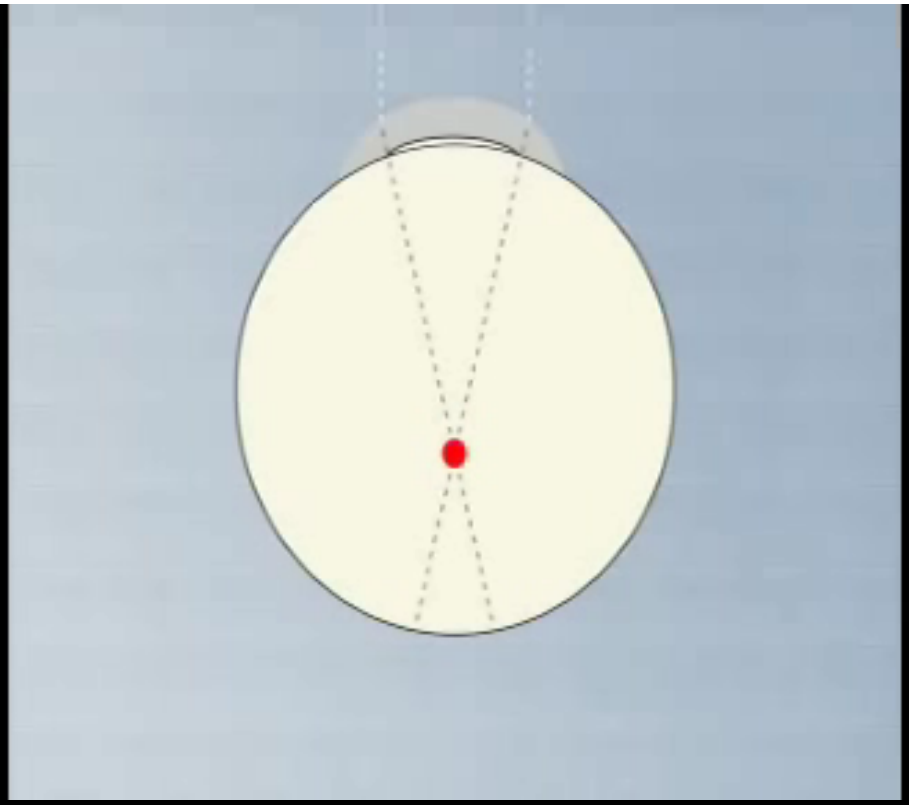
- Why miscalculations occur
- Methods to improve accuracy of IOL calculations
- Clinical Approach
- Options when faced with a refractive surprise

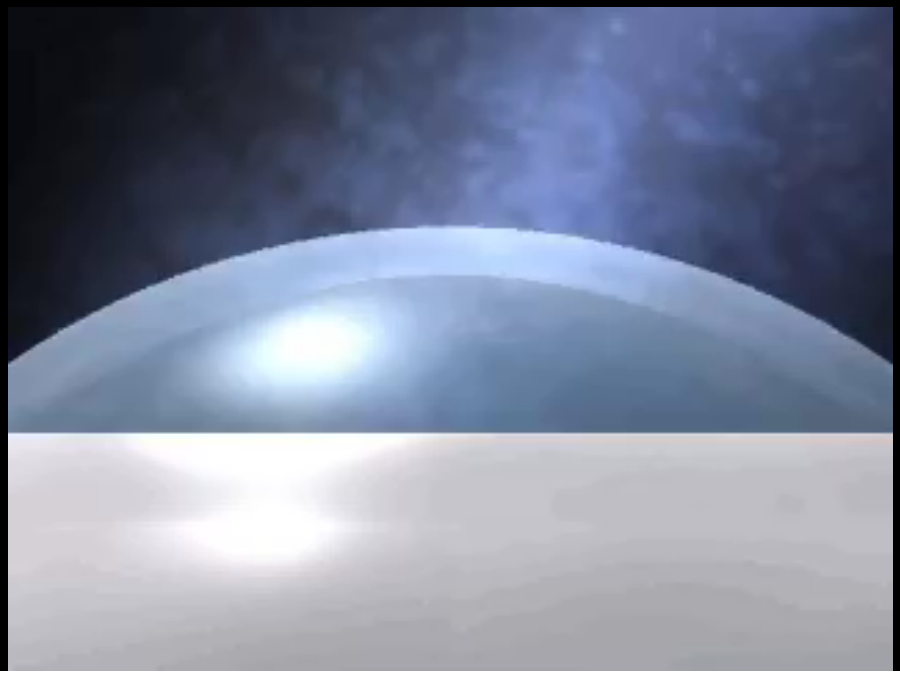
Variables in IOL Power Formulas

- Corneal Power (Average K)
- Axial Length
- Effective Lens Position (Calculation of AC Depth)
- White to White Diameter (WTW)
- Lens thickness

Corneal Power is main problem

- Most manual keratometers / topography systems use a corneal index of refraction of 1.3375
- Assumption that the posterior radius of curvature is 1.2 mm less than the anterior ROC
- Assumption that the anterior and posterior ROC's are parallel
- Corneal power is used in the prediction of effective lens position (ELP), which is the depth of the IOL relative to the cornea





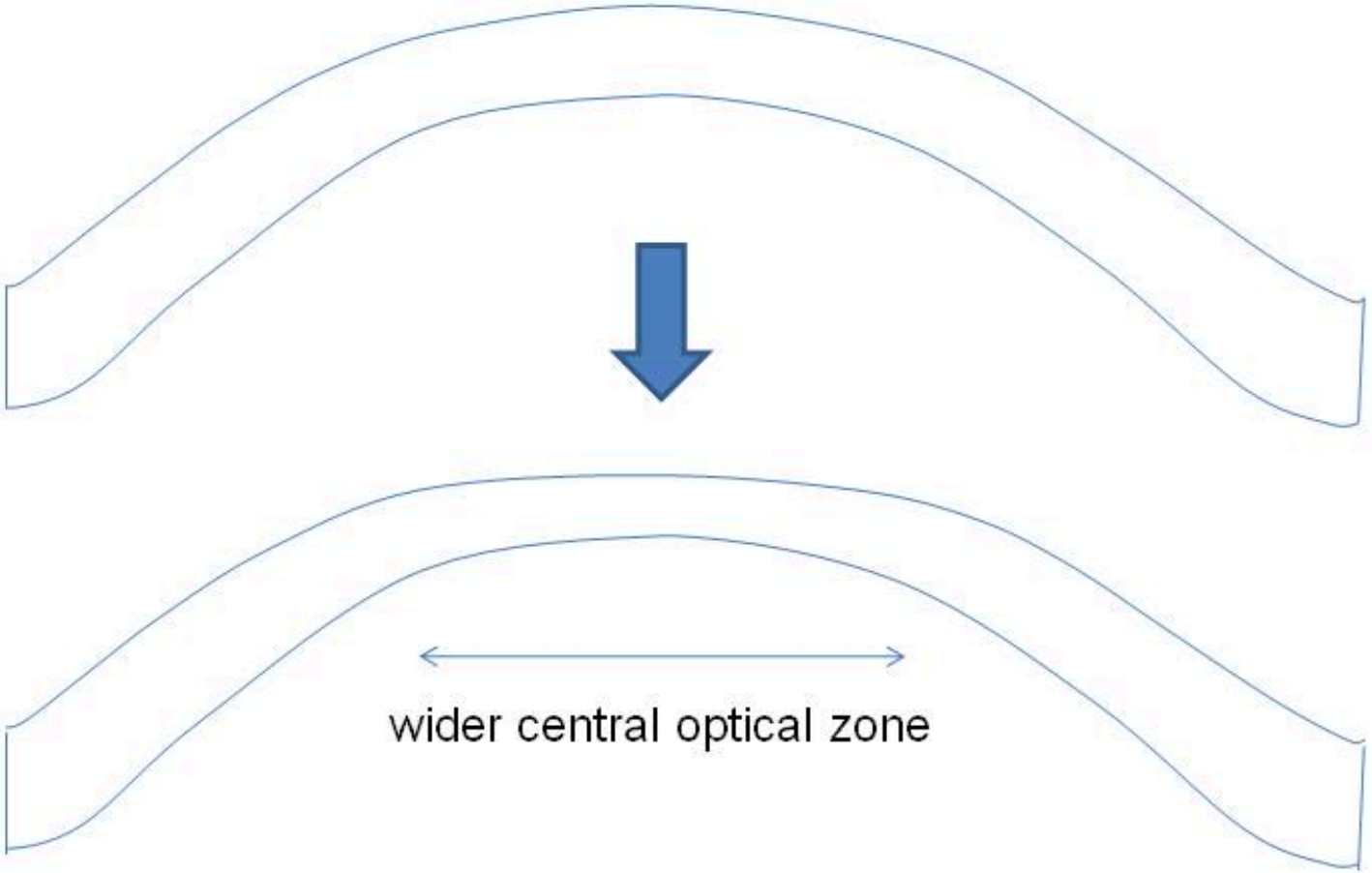


Figure 1. Laser vision correction alters the anterior corneal curvature but not the posterior curvature. This alters the normal anterior/posterior corneal curvature ratio.

Why is the corneal power inaccurate?

Calculation of Total Corneal Power:

Power (D)= $(n^c - n^a) / r$

n^c= index of refraction of the cornea (Typically 1.3375)

n^a= index of refraction of air (normally 1)

r= anterior radius of curvature of the cornea

Why is the corneal power inaccurate?

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Power (D)= $(n^c - n^a) / r$

n^c= index of refraction of the cornea (Typically 1.3375)

n^a= index of refraction of air (normally 1)

r= anterior radius of curvature of the cornea

After LASIK / PRK

- Change in anterior radius of curvature
- No change in posterior ROC
- Therefore, there is inaccurate calculation of the corneal power from a correctly measured anterior radius of curvature
- Myopic treatments reduce the power of the cornea- results in under-estimation of lens power
- Hyperopic treatments results in over-estimation of lens power

Measured Corneal Power

- Over-estimation of the true corneal power

Seitz B et al. Underestimation of intraocular lens power for cataract surgery after myopic PRK. Ophthalmology 1999; 106:693-702

- Manual Keratometry over-estimates by 36%
- Topography over-estimates by up to 56%
- Corneal power over-estimation worse the higher the laser correction e.g. correction of –5.00 leads to a 1 Dioptre over-correction of corneal power

Methods to calculate true corneal power

- Different formulas used based on the data available i.e. if we have pre-op K's and refraction or not

Clinical History Method
(Holladay, Hoffer)

Pre KR Mean K	=	44.00 D
Change in SEQ Ref	=	-4.50 D
Calc Mean K	=	39.50 D

Subtraction of 24% SEQ Change
(Holladay)

e.g. SEQ change is -5D

24% of 5D= 1.2

New K= Post-op Measured K – 1.2 (24% SEQ Change)

Other Methods

- Double K Method-

Aramberri et al J Cat Refract Surg 2003;29:2063-2068

- Regression Formula-

Masket et al J Cat Refract Surg 2006;32:430-434

- Latkany Method, Feiz & Mannis Method, Corneal bypass method

Appendix

Double-K SRK/T Formula

Equation 1: Preoperative corneal radius of curvature:

$$r_{pre} = 337.5/Kpre$$

Equation 2: Corrected axial length (LCOR):

$$\text{If } L \leq 24.2, \text{LCOR} = L$$

$$\text{If } L > 24.2, \text{LCOR} = -3.446 + 1.716 \times L - 0.0237 \times L^2$$

Equation 3: Computed corneal width (Cw):

$$Cw = -5.41 + 0.58412 \times \text{LCOR} + 0.098 \times Kpre$$

Equation 4: Corneal height (H):

$$H = r_{pre} - \text{Sqrt}\,[r_{pre}2 - (Cw2/4)]$$

Equation 5: Offset value:

$$\text{Offset} = ACD_{const} - 3.336$$

Equation 6: Estimated postoperative ELP (ACD):

$$ACD_{est} = H + \text{Offset}$$

Equation 7: Constants:

$$V = 12;\ n_a = 1.336;\ n_c = 1.333;\ n_cm1 = 0.333$$

Equation 8: Retinal thickness (RETHICK) and optical axial length (LOPT):

$$\text{RETHICK} = 0.65696 - 0.02029 \times L$$

$$\text{LOPT} = L + \text{RETHICK}$$

Equation 9: Postoperative corneal radius of curvature:

$$r_{post} = 337.5/Kpost$$

Equation 10: Emmetropia IOL power (IOL_{emme}):

$$IOL_{emme} = [1000 \times n_a \times (n \times r_{post} - n_cm1 \times \text{LOPT})]/[(\text{LOPT} - ACD_{est}) \times (n_a \times r_{post} - n_cm1 \times ACD_{est})]$$

Variables

L = axial length; Kpre = pre refractive surgery K-value; Kpost = post refractive surgery K-value; ACDconst = IOL constant (can be computed from A-constant).

Corneal bypass method

- IOL power is calculated using the post-LASIK axial length and the pre-LASIK keratometry
- Target refraction is set for the pre-LASIK spherical equivalent
- Bypasses the post LASIK corneal power

Pre-op Biometry (pre-LASIK)

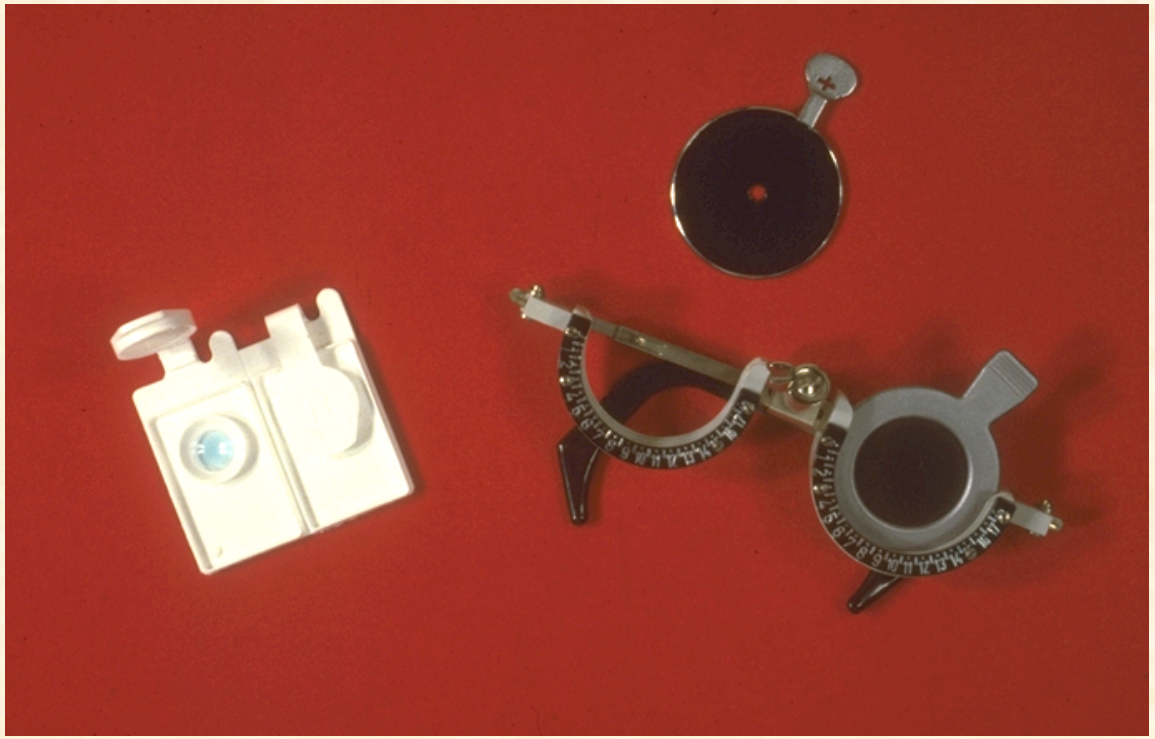
Pre-op manifest SEQ = -4.00 (Av. K=44.5, AL=26)

Pre-op Biometry:

Power (D)	Target Ref.	Power (D)	Target Ref.
10.5	0.68	16.5	-3.41
11.0	0.36	17.0	-3.78
11.5	0.03	17.5	-4.15
12.0	-0.29	18.00	-4.53
12.5	-0.62	18.53	-4.91

No pre-op data?

- Hard Contact Lens Method



Hard Contact Lens Method

Plano HCL Base Curve = 41.00 D

SEQ Ref without CL = +0.50 D

SEQ Ref with CL = -1.00 D

Mean K = 41.00 - 1.50 (Change in Refraction)

= 39.50 D

Haigis L

- *r corr* = 331.5/-5.1625 X *r meas* + 82.2603 - 0.35
- *D corr* = 337.5 / *r corr*

- Built in software of the IOL Master
- Regression formula based on statistics
- Accuracy decreases on the edges of normal distribution

Other Formulas

- Modified Maloney Method

- Shammas-PL formula- Shammas et al- *J Cataract Refract Surg* 2007;33:31-36

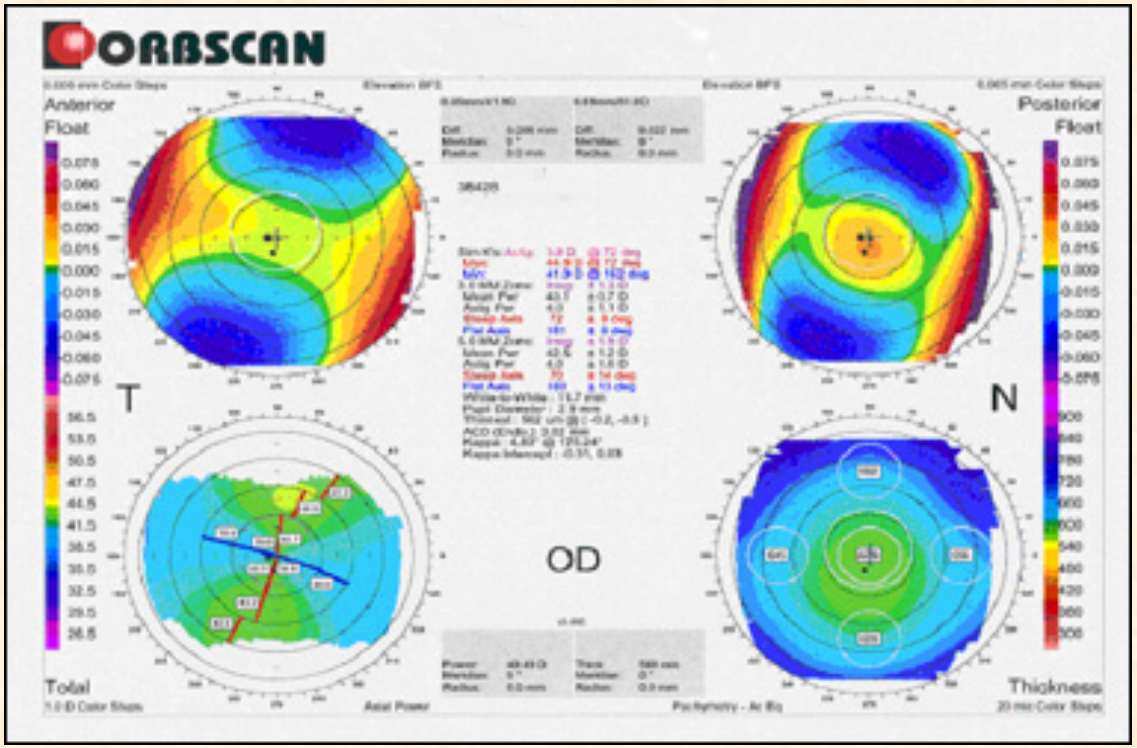
- Besst Formula- Borasio et al- *J Cataract Refract Surg*. 2006 Dec;32(12):2004-14.

(information derived from the pentacam)

Bestt Formula MEH

- Bestt Formula, Smith et al , JCRS 2006
- Requires Pentacam's measurements
  - Ant and Posterior Radii of curvature
  - Central corneal thickness
  - Axial length
- No need for pre-refractive surgery info
- 46 % eyes within 0.5 and 100 % within 1 diopters

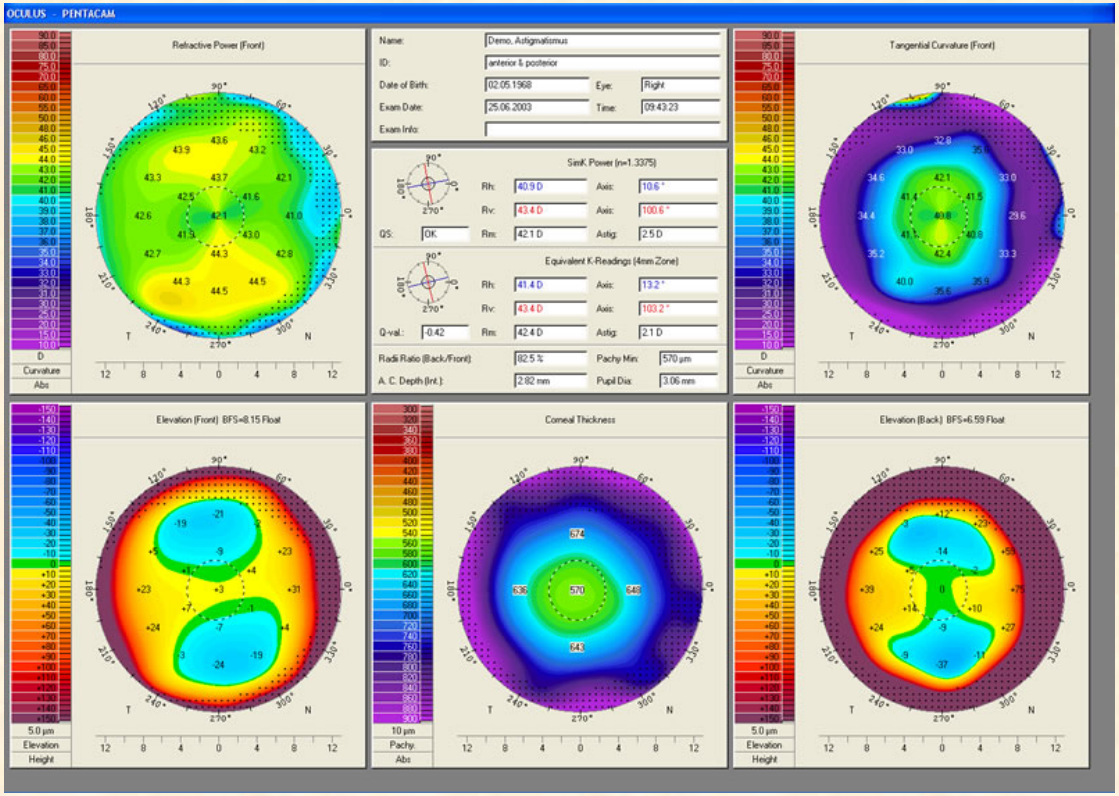
Qazi et al J Determining corneal power using Orbscan II videokeratography for intraocular lens calculation after excimer laser surgery for myopia. *J Cataract Refract Surg* 2007;33:21-30



5.0 mm total axial power & 4mm total optical power from the Orbscan II (Don't rely on the index of refraction 1.3375)

Statistically better than the History method in their 21 eyes

Holladay Report / Pentacam



Measures central cornea and the anterior and posterior corneal surface very precisely which is the key for the “Holladay Report”.

Available as an upgrade for the Pentacam

Consensus “K” method

- Randleman et al JCRS 2007;33:1892
- Use several K prediction methods
- Exclude High/Low outliers
- Average the rest
- Showed much better prediction than using individual methods

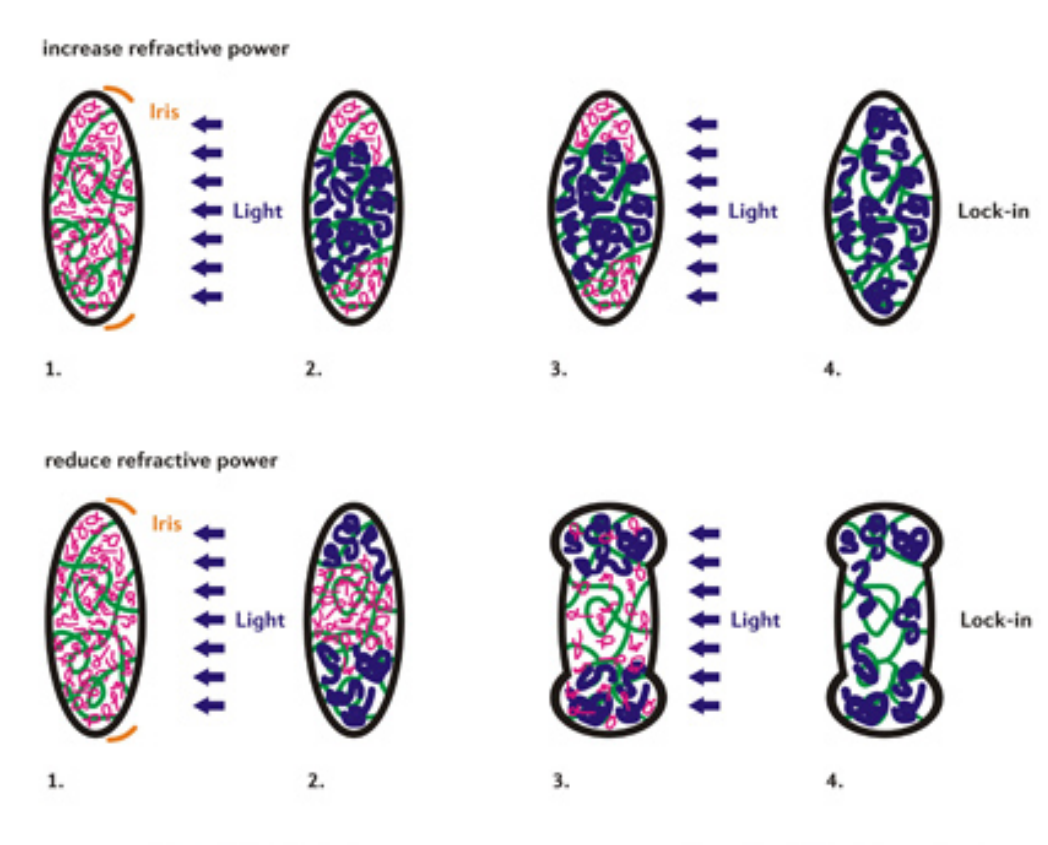
Intra-operative biometry

- Introduced in 2005
- Lanchulev et al JCRS 2005
- ALCON
- Wavetec
- ORA
- Problems with view / accuracy but improving with every software upgrade

Ray Tracing

- Lots of excitement
- Results as good as the Haigis L, Hoffer Q (double K) and Olsen 2 (double K)
- Lots of work going into this
- Promising technology as does not rely on Gaussian Optics i.e. no assumptions!
- Does not rely on IOL formula

Light Adjustable lens



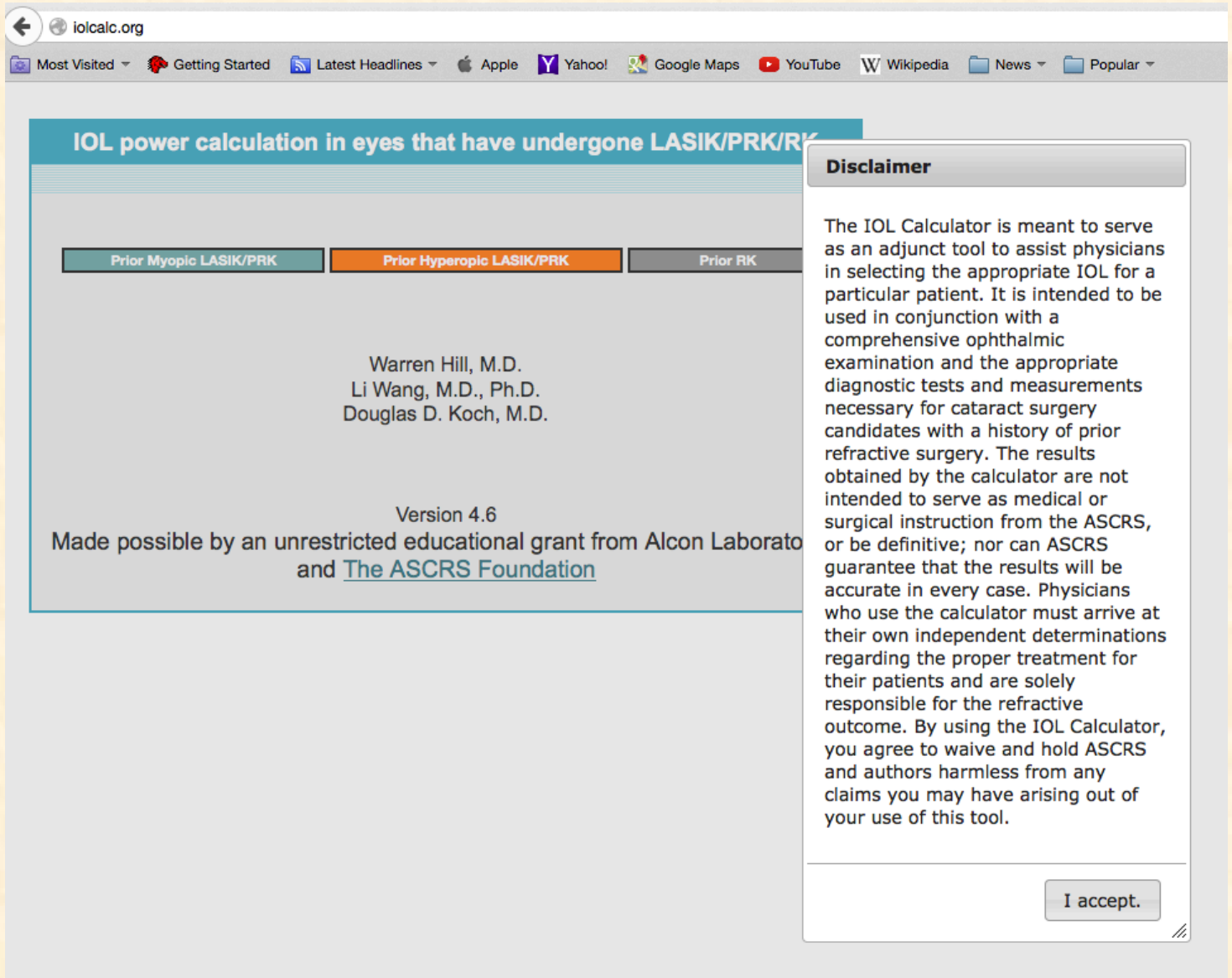
- Could be a place for this technology
- Can only correct +/- 1.00 D at present

Clinical Approach-Counselling

- Realistic Expectations
- Target Refraction (consider doing non-dominant eye first)
- Topography (beware irregular topography)
- IOL Choice

What do I do?

ASCRS Website Calculator



IOL power calculation in eyes that have undergone LASIK/PRK/RK

Prior Myopic LASIK/PRK | Prior Hyperopic LASIK/PRK | Prior RK

Warren Hill, M.D.
Li Wang, M.D., Ph.D.
Douglas D. Koch, M.D.

Version 4.6

Made possible by an unrestricted educational grant from Alcon Laborator
and The ASCRS Foundation

Updates

2015 Updates:

1. We have added the Barrett True K formula for myopic LASIK/PRK eyes, hyperopic LASIK/PRK eyes, and RK eyes.
2. We have added the OCT-based IOL power calculation formula (RTVue, Optovue) for myopic LASIK/PRK eyes, hyperopic LASIK/PRK eyes, and RK eyes.
3. For myopic LASIK/PRK eyes, we have added the Potvin-Hill Pentacam method using the Pentacam value.
4. Because of the reduced accuracy of the formulas that entirely depend on historical data, we have removed methods in the column "Using Pre-LASIK/PRK Ks + ?MR".

I accept.

Please enter all data available and press "Calculate"

Doctor Name: Ali Mearza | Patient Name: previous patient-MK | Eye: OD | IOL Model: Rayner | Target Ref (D): -0.25

Pre-LASIK/PRK Data:

Refraction* Sph(D): 1.75 Cyl(D)*: -1.00 Vertex (If empty, 12.5 mm will be used): 12

Keratometry K1(D): 41.7 K2(D): 40.2

Post-LASIK/PRK Data:

Refraction*§ Sph(D): 1.50 Cyl(D)*: -1.00 Vertex(mm): 12

Topography EyeSys EffRP | Atlas 9000 4mm zone | Tomey ACCP / Nidek#ACP/APP | Galilei TCP** | (•) V5.2.1 or later ( ) V5.2 or earlier

Pentacam TNP_Apex_4.0 mm Zone

Atlas Ring Values 0mm | 1mm | 2mm | 3mm

OCT (RTVue or Avanti XR) Net Corneal Power | Posterior Corneal Power | Central Corneal Thickness

Optical (IOLMaster/Lenstar)/Ultrasound Biometric Data:

Ks K1(D): 43.86 K2(D): 45.16 Keratometric Index (n)***: (•) 1.3375 ( ) 1.332 ( ) Other

AL(mm): 22.83 ACD(mm): 2.76 Lens Thick (mm): 4.68 WTW (mm): 12.79

Lens Constants**** A-const(SRK/T): 118.7 SF(Holladay1)

Haigis a0 | Haigis a1 | Haigis a2

*If entering "Sph(D)", you must enter a value for "Cyl(D)", even if it is zero.
§Most recent stable refraction prior to development of a cataract.
Magellan ACP or OPD-Scan III APP 3-mm manual value (personal communication Stephen D. Klyce, PhD).
**Select the version of your Galilei device: "V5.2 or earlier" or "V5.2.1 or later".
***Select the keratometric index (n) of your device. Instruments in North America typically default to 1.3375.
****Enter any constants available; others will be calculated from those entered. If ultrasonic AL is entered, be sure to use your ultrasound lens constants.

Calculate | Reset Form

Optical (IOLMaster/Lenstar)/Ultrasound Biometric Data:

Ks	K1(D)	43.86	K2(D)	45.16	Keratometric Index (n)***	1.3375 1.332 Other	
	AL(mm)	22.83	ACD(mm)	2.76	Lens Thick (mm)	4.68	WTW (mm) 12.79
Lens Constants****	A-const(SRK/T)	118.7	SF(Holladay1)				
	Haigis a0		Haigis a1		Haigis a2		

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****Enter any constants available; others will be calculated from those entered. If ultrasonic AL is entered, be sure to use your ultrasound lens constants.

Please check Pre-LASIK/PRK refraction.

Calculate Reset Form

IOL calculation formulas used: Double-K Holladay 1[1], Shammas-PL[2], Haigis-L[3], OCT-based[4], & Barrett True K[5]

Using ΔMR		Using no prior data	
[1]Adjusted EffRP	--	[2]Wang-Koch-Maloney	--
[2]Adjusted Atlas 9000 (4mm zone)	--	[2]Shammas	**23.20 D**
[1]Adjusted Atlas Ring Values	--	[3]Haigis-L	**23.27 D**
Masket Formula	**22.36 D**	[1]Galilei	--
Modified-Masket	**22.25 D**	[2]Potvin-Hill Pentacam	--
[1]Adjusted ACCP/ACP/APP	--	[4]OCT	--
[5]Barrett True K	**22.34 D**	[5]Barrett True K No History	**23.30 D**

Average IOL Power (All Available Formulas): 22.79 D

Min: 22.25 D

Max: 23.30 D

	Pentacam TNP_Apex_4.0 mm Zone	42.45					
Atlas Ring Values	0mm		1mm		2mm		3mm	
OCT (RTVue or Avanti XR)	Net Corneal Power		Posterior Corneal Power		Central Corneal Thickness		

Optical (IOLMaster/Lenstar)/Ultrasound Biometric Data:

Ks	K1(D)	43.86	K2(D)	45.16	Keratometric Index (n)***	1.3375 1.332 Other	
	AL(mm)	22.83	ACD(mm)	2.76	Lens Thick (mm)	4.68	WTW (mm) 12.79
Lens Constants****	A-const(SRK/T)	118.7	SF(Holladay1)				
	Haigis a0		Haigis a1		Haigis a2		

*If entering "Sph(D)", you must enter a value for "Cyl(D)", even if it is zero.
§Most recent stable refraction prior to development of a cataract.
♯ Magellan ACP or OPD-Scan III APP 3-mm manual value (personal communication Stephen D. Klyce, PhD).
**Select the version of your Galilei device: "V5.2 or earlier" or "V5.2.1 or later".
***Select the keratometric index (n) of your device. Instruments in North America typically default to 1.3375.
****Enter any constants available; others will be calculated from those entered. If ultrasonic AL is entered, be sure to use your ultrasound lens constants.

Please check Pre-LASIK/PRK refraction.

Calculate Reset Form

IOL calculation formulas used: Double-K Holladay 1[1], Shammas-PL[2], Haigis-L[3], OCT-based[4], & Barrett True K[5]

Using ΔMR		Using no prior data	
[1]Adjusted EffRP	--	[2]Wang-Koch-Maloney	--
[2]Adjusted Atlas 9000 (4mm zone)	--	[2]Shammas	**23.20 D**
[1]Adjusted Atlas Ring Values	--	[3]Haigis-L	**23.27 D**
Masket Formula	**22.36 D**	[1]Galilei	--
Modified-Masket	**22.25 D**	[2]Potvin-Hill Pentacam	**22.70 D**
[1]Adjusted ACCP/ACP/APP	--	[4]OCT	--
[5]Barrett True K	**22.34 D**	[5]Barrett True K No History	**23.30 D**

Average IOL Power (All Available Formulas): 22.78 D

Min: 22.25 D

Max: 23.30 D

*If entering "Sph(D)", you must enter a value for "Cyl(D)", even if it is zero.
**Not manual/SimKs from other devices.
***Select the keratometric index (n) of your device. Instruments in North America typically default to 1.3375.
****Enter the constant available; the other will be calculated. If ultrasonic AL is entered, be sure to use your ultrasound lens constants.

Calculate Reset Form

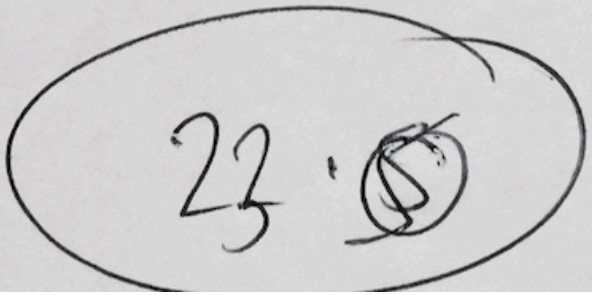
IOL Powers Calculated Using Double-K Holladay 1[1], Shammas-PL[2], & Haigis-L[3]

Using Pre-LASIK/PRK Ks + ΔMR		Using ΔMR		Using no prior data	
Clinical History	25.76 D	[1]Adjusted EffRP	--	[2]Shammas	21.94 D
Feiz-Mannis	25.76 D	[1]Adjusted Atlas 0-3	--	[3]Haigis-L	21.18 D
Corneal Bypass	25.77 D	Masket Formula	21.99 D		
		Modified-Masket	21.89 D		

Average IOL Power: 23.47 D

Min: 21.18 D

Max: 25.77 D



Doctor Name: ALI MEARZA | Patient Name: Previous pt-FK | Eye: OS | IOL Model: Topcon | Target Ref (D): -0.25

Pre-LASIK/PRK Data:

Refraction* Sph(D) | Cyl(D)* | Vertex (If empty, 12.5 mm will be used)

Keratometry K1(D) | K2(D)

Post-LASIK/PRK Data:

Refraction*§ Sph(D): 1.00 | Cyl(D)*: -0.50 | Vertex(mm): 12

Topography | EyeSys EffRP | Atlas 9000 4mm zone | Tomey ACCP | Nidek#ACP/APP | Galilei TCP** | (•) V5.2.1 or later ( ) V5.2 or earlier

Pentacam TNP_Apex_4.0 mm Zone

Atlas Ring Values | 0mm | 1mm | 2mm | 3mm

OCT (RTVue or Avanti XR) | Net Corneal Power | Posterior Corneal Power | Central Corneal Thickness

Optical (IOLMaster/Lenstar)/Ultrasound Biometric Data:

Ks | K1(D): 46.4 | K2(D): 46.9 | Keratometric Index (n)***: (•) 1.3375 ( ) 1.332 ( ) Other

AL(mm): 22.13 | ACD(mm): 2.94 | Lens Thick (mm) | WTW (mm): 12.3

Lens Constants**** | A-const(SRK/T): 118.4 | SF(Holladay1)

Haigis a0 | Haigis a1 | Haigis a2

IOL calculation formulas used: Double-K Holladay 1[1], Shammas-PL[2], Haigis-L[3], OCT-based[4], & Barrett True K[5]

Using ΔMR		Using no prior data	
[1]Adjusted EffRP	--	[2]Wang-Koch-Maloney	--
[2]Adjusted Atlas 9000 (4mm zone)	--	[2]Shammas	**22.09 D**
[1]Adjusted Atlas Ring Values	--	[3]Haigis-L	**23.25 D**
Masket Formula	--	[1]Galilei	--
Modified-Masket	--	[2]Potvin-Hill Pentacam	--
[1]Adjusted ACCP/ACP/APP	--	[4]OCT	--
[5]Barrett True K	--	[5]Barrett True K No History	**22.12 D**

Average IOL Power (All Available Formulas): **22.49 D**

Min: **22.09 D**

Max: **23.25 D**

IOL calculation formulas used: Double-K Holladay 1[1], Shammas-PL[2], Haigis-L[3], OCT-based[4], & Barrett True K[5]

Using ΔMR		Using no prior data	
[1]Adjusted EffRP	--	[2]Wang-Koch-Maloney	--
[2]Adjusted Atlas 9000 (4mm zone)	--	[2]Shammas	**22.09 D**
[1]Adjusted Atlas Ring Values	--	[3]Haigis-L	**23.25 D**
Masket Formula	--	[1]Galilei	--
Modified-Masket	--	[2]Potvin-Hill Pentacam	**22.10 D**
[1]Adjusted ACCP/ACP/APP	--	[4]OCT	--
[5]Barrett True K	--	[5]Barrett True K No History	**22.12 D**

Average IOL Power (All Available Formulas): **22.39 D**

Min: **22.09 D**

Max: **23.25 D**

ASCRS Website calculator

- Using ΔMR- Beware in eyes with cataracts
- Cataracts can induce refractive error and as such can change the refraction
- If not considered- will get a surprise!
- Regression formulae usually quite accurate
- Exclude outliers and go for the average
- Put the print out in the notes

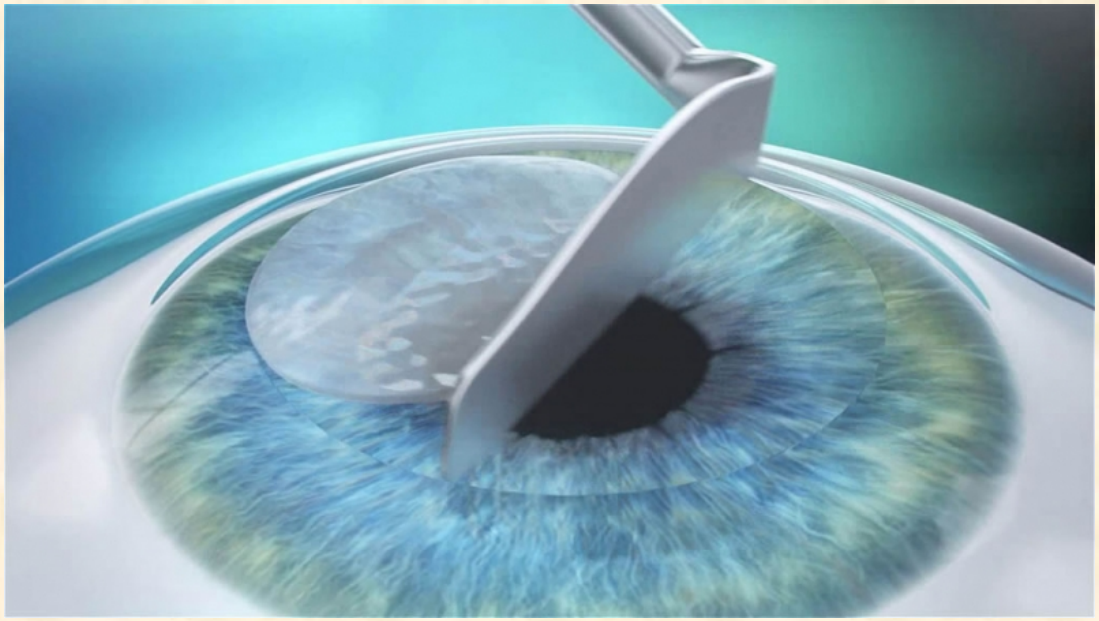
How to deal with a refractive surprise

- Be honest
- The management will depend on the degree of refractive error and whether hyperopic or myopic
- A -6.00 or +6.00 error won't "heal"
- Small errors may be amenable to glasses wear

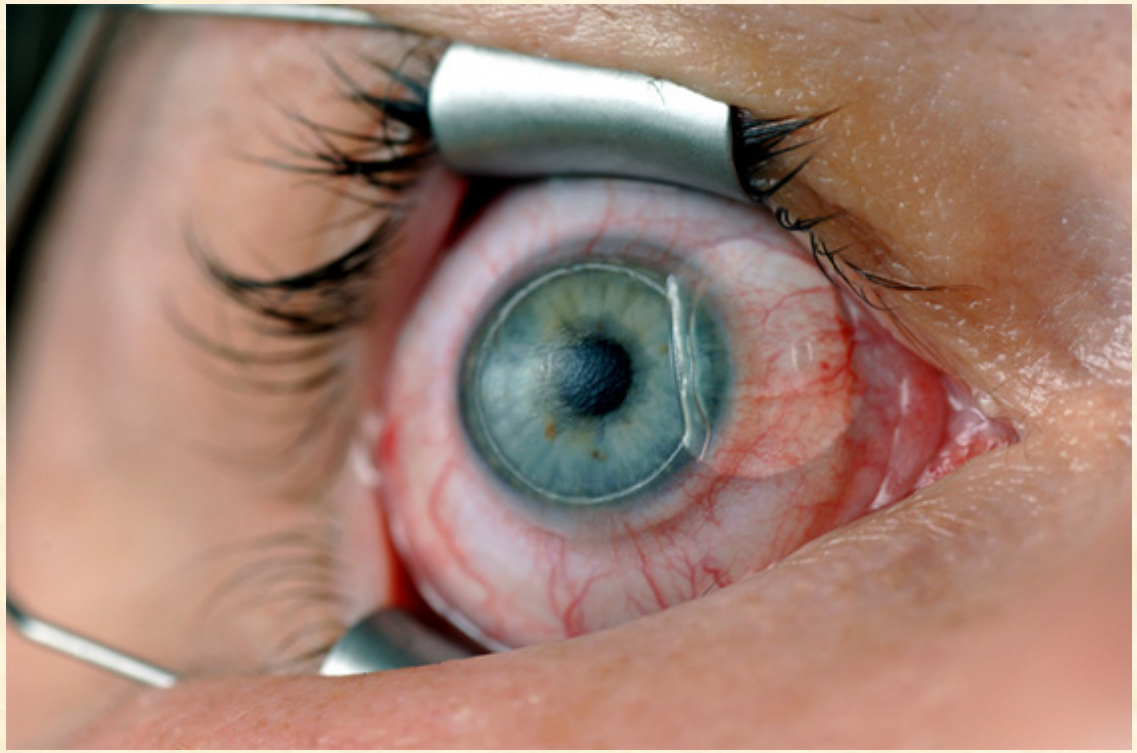
I’m not happy, what can you do for me?

Contact Lens

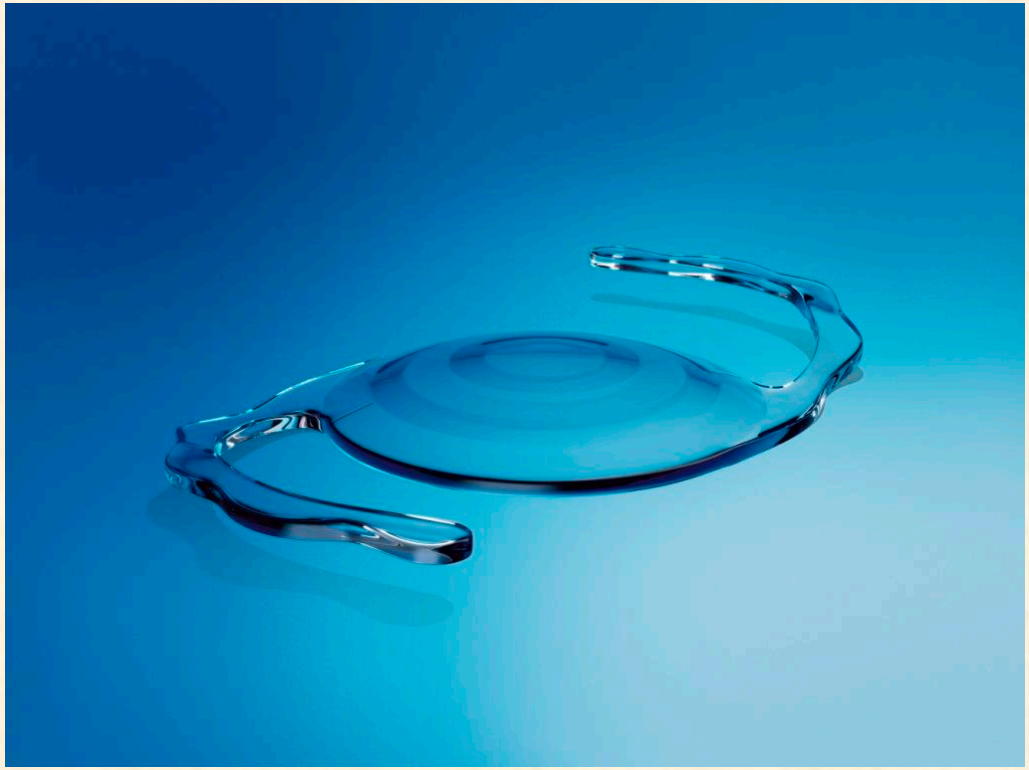
PRK



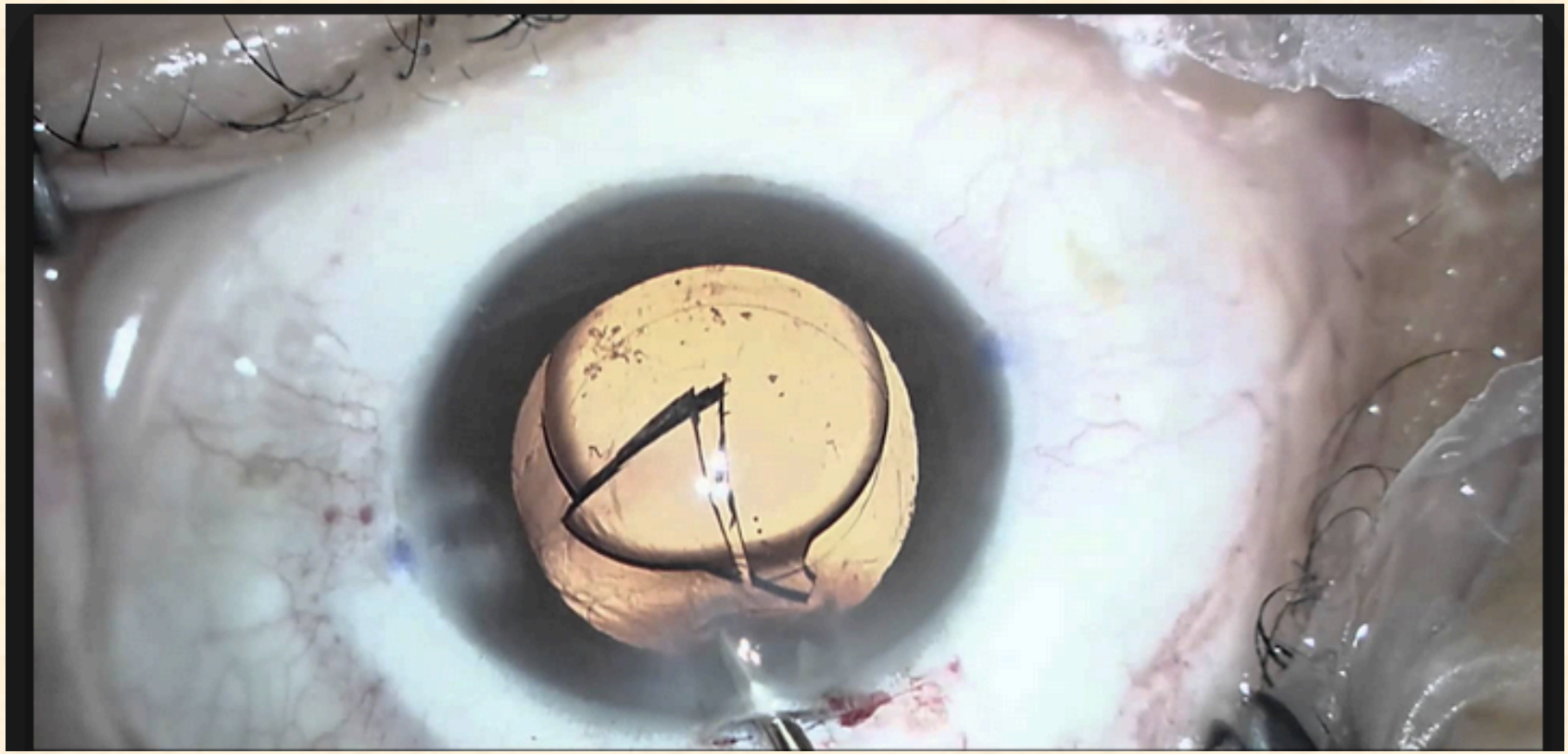
LASIK



Supplementary Lens



IOL Exchange



Jones JJ, Jones YJ, Jin GJ. Indications and outcomes of intraocular lens exchange during a recent 5-year period. Am J Ophthalmol. 2014;157(1):154-162

Conclusions

- Anterior corneal curvature changes post-laser refractive surgery but posterior curvature stays the same
- Adjusted calculations need to be made to avoid refractive surprises
- Good pre-operative counselling is the key to maintaining a good relationship if there are surprises
- Set realistic expectations
- Explain what the options will be if there is an untoward outcome so there are no surprises

Conclusions

- Aim on the myopic side
- Consider doing the non-dominant eye first
- Formulas getting better and good evidence to support raytracing as a better tool in the future
- Use the ASCRS Calculator!
- Look for agreement between the formulae and exclude any outliers then average the rest
- For refractive surprise- aim for the least invasive option.


Thank You!