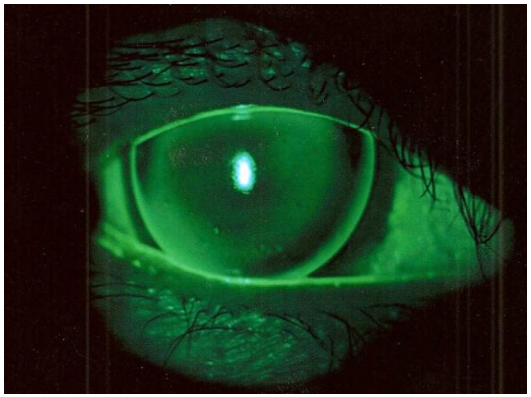
ORTHOKERATOLOGY: From Complexity to A Simple Approach

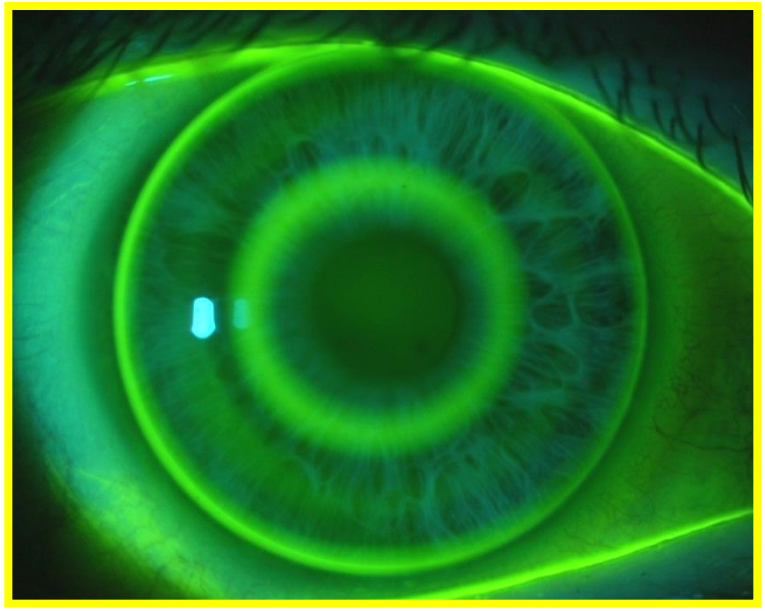
General Theory From A Practitioner's Point of View

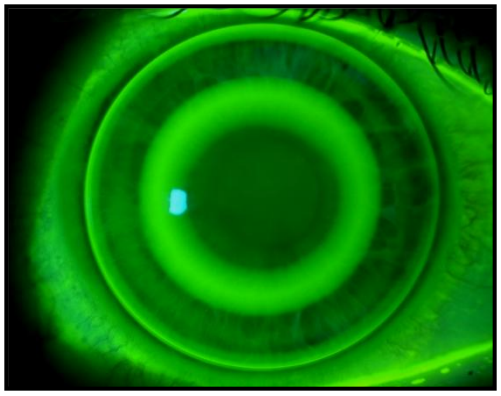
Understanding the Hydrodynamic Principle & Controlled Clearance Philosophy

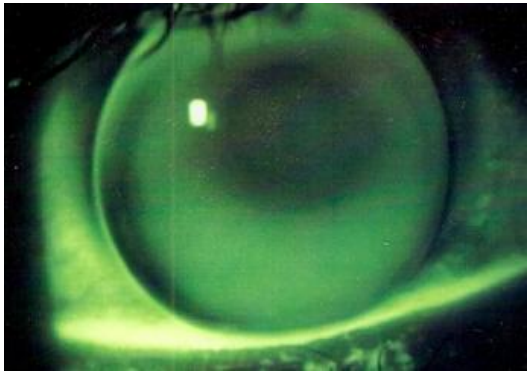
EDWARD CHOW

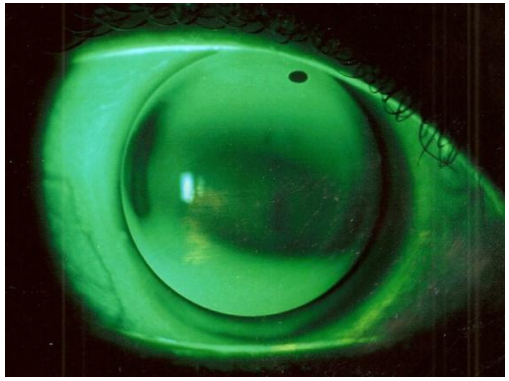
Past And Present

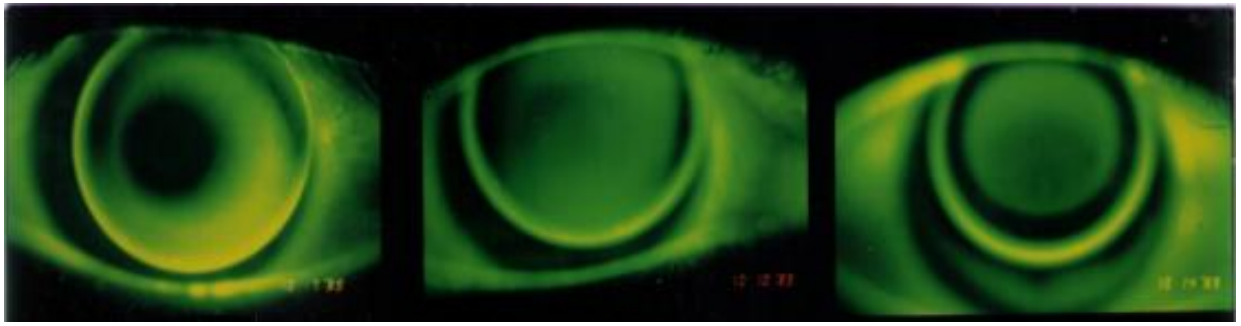


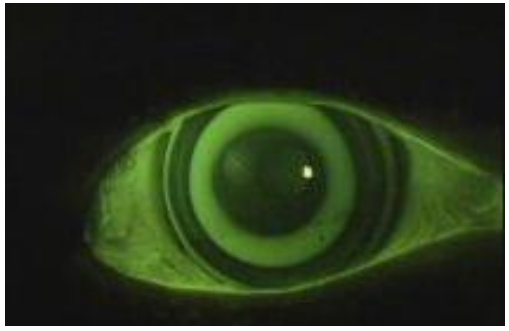








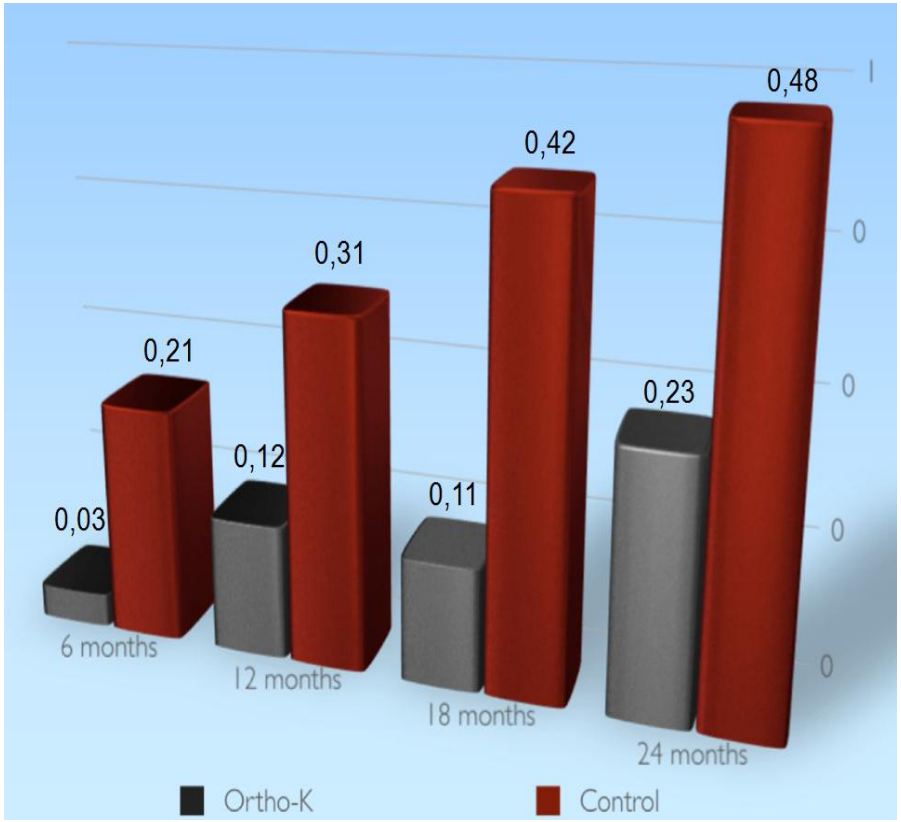




Are We Achieving Myopia Control Effect with Current Applications of OrthoK Designs?

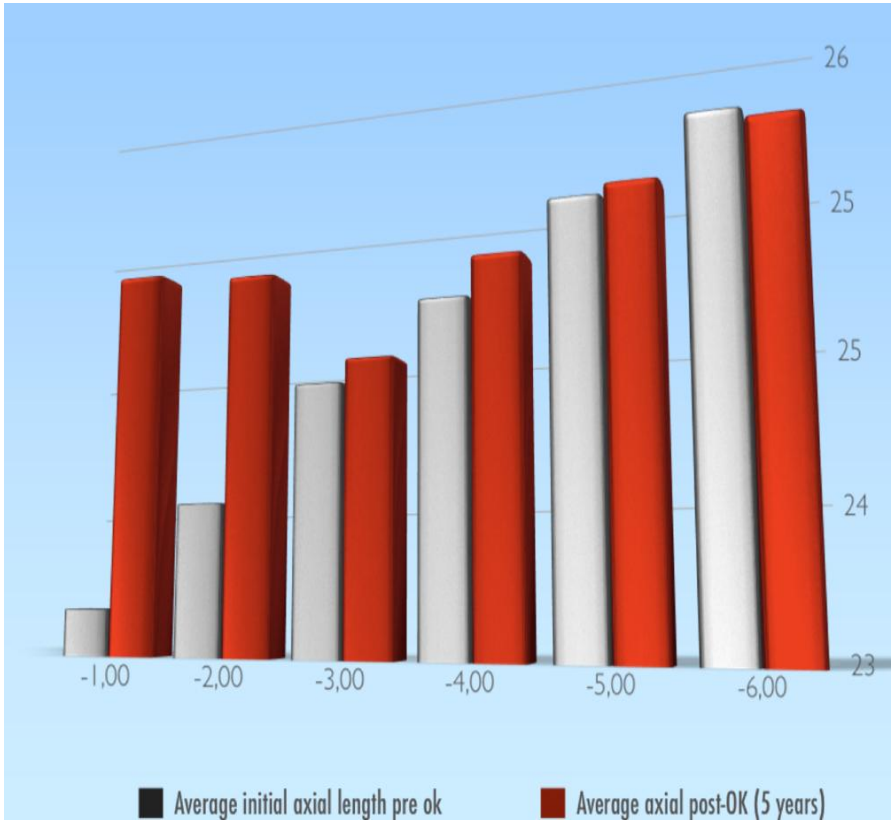
Vitreous Chamber Elongation

Two years follow-up - LORIC Study: Cho et al



Average Myopia Progression After 5 Years

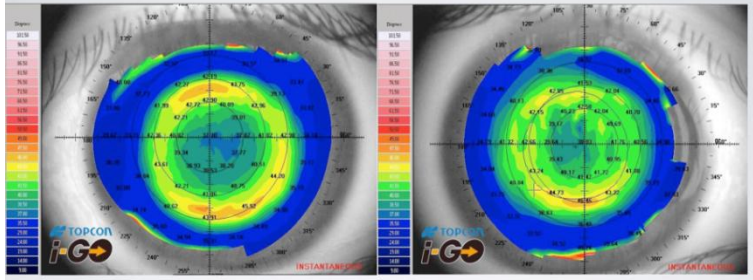
Chow 2010



How Can You Achieve The Proper Peripheral Defocus Without Over-Correction?

LOW MYOPIA

-1.00D



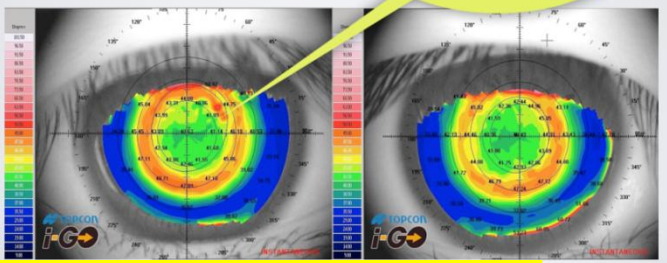
Central flattening & mid-peripheral steepening not enough

LOW MYOPIA

-1.00D

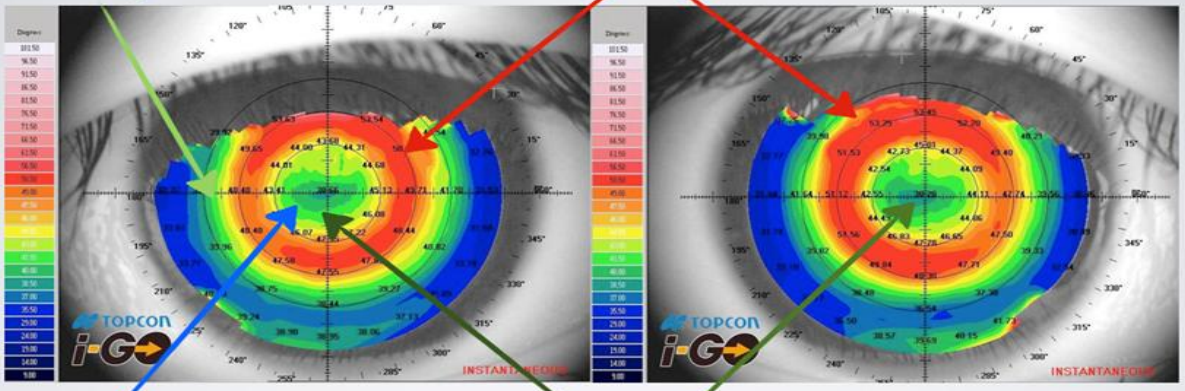
Double Reverse Curve

Improvement, but not enough treatment zone for desired myopia control



Mid-peripheral thickening of tissue

Gradual flattening due to flatter FC2

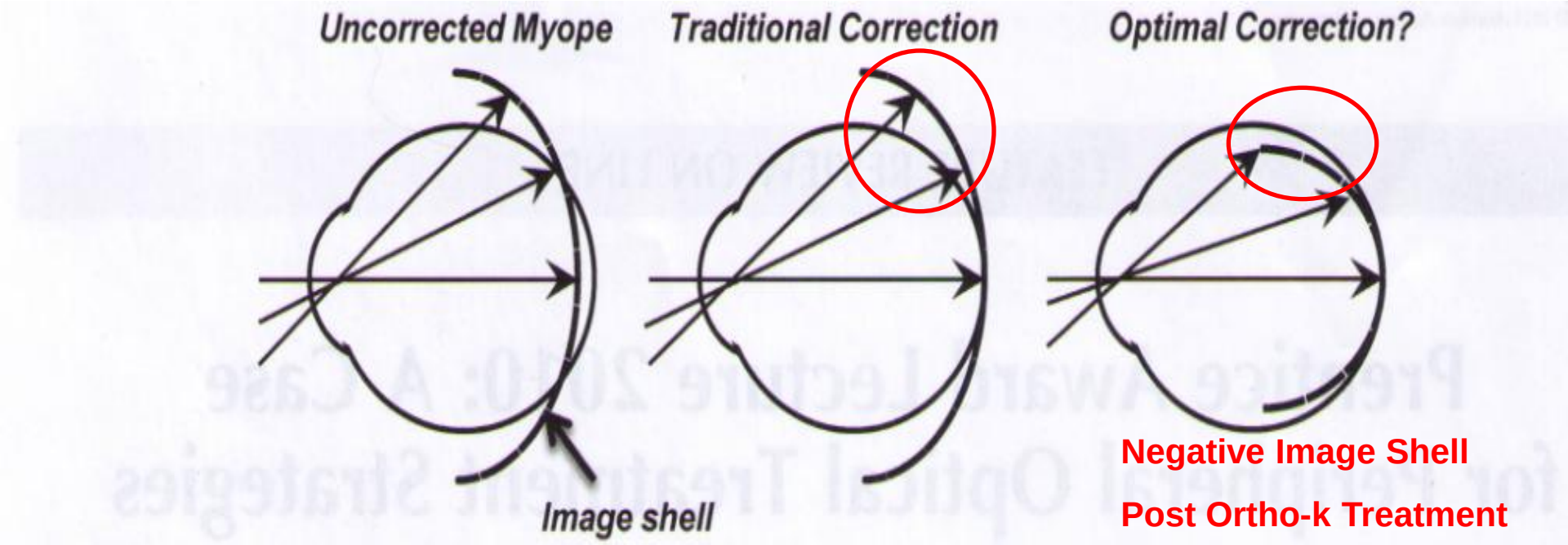


Transitional zone resulted from asphericity

Small area of central treatment zone

Desired Results

Basic Goal Of Peripheral Optical Treatment Strategy

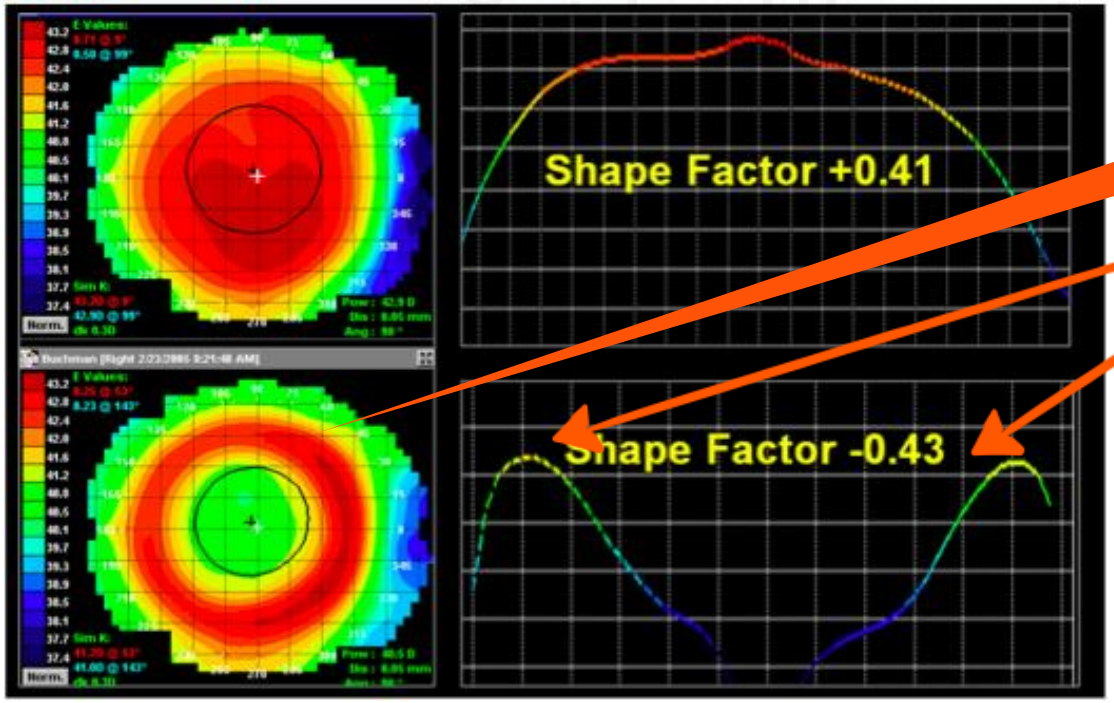


Development & Progression Of Myopia Linked With The Nature & Quality Of Both Central & Peripheral Retinal Images

Earl Smith: Peripheral Defocus Theory

Myopia Control Through Optical Intervention

Peripheral Hyperopia Defocus



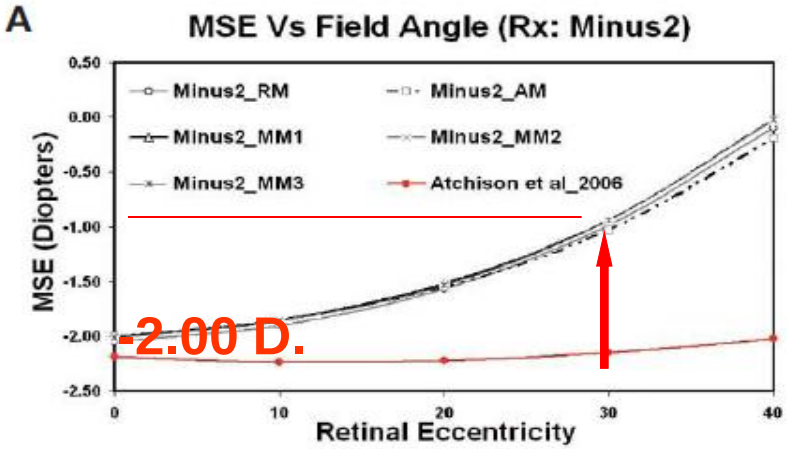
Steeper intermediate curves induce spherical aberration

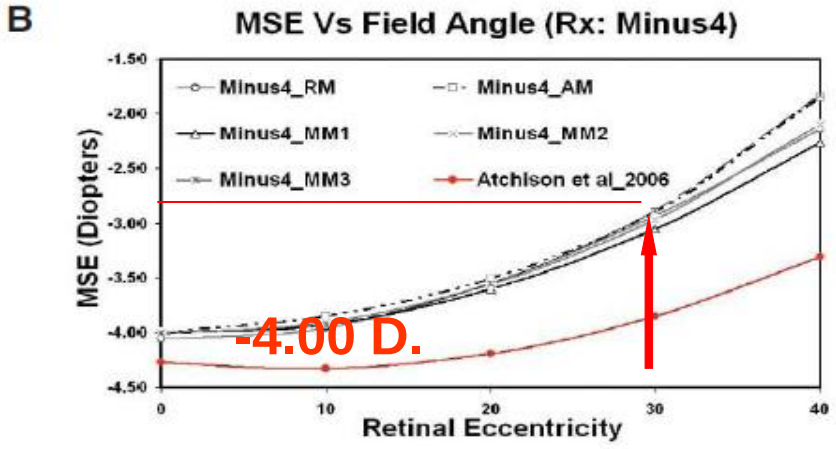
Created peripheral defocus manipulates potential source of blur from steep intermediate curve of cornea & central clear vision

Correcting the refractive error (no myopia centrally and hyperopia in the periphery) will prevent reaching that balance

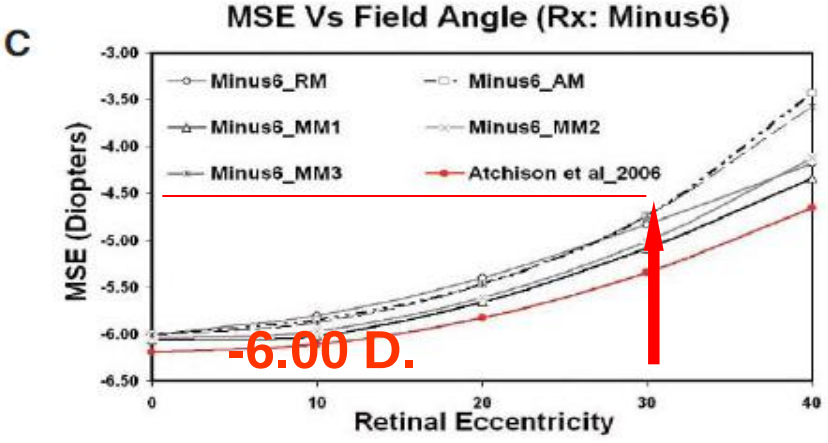
Do Peripheral Refraction and Aberration Profiles Vary with the Type of Myopia?

Ravi Bakaraju et al, The Journal of Optometry 2009
Ray Tracing



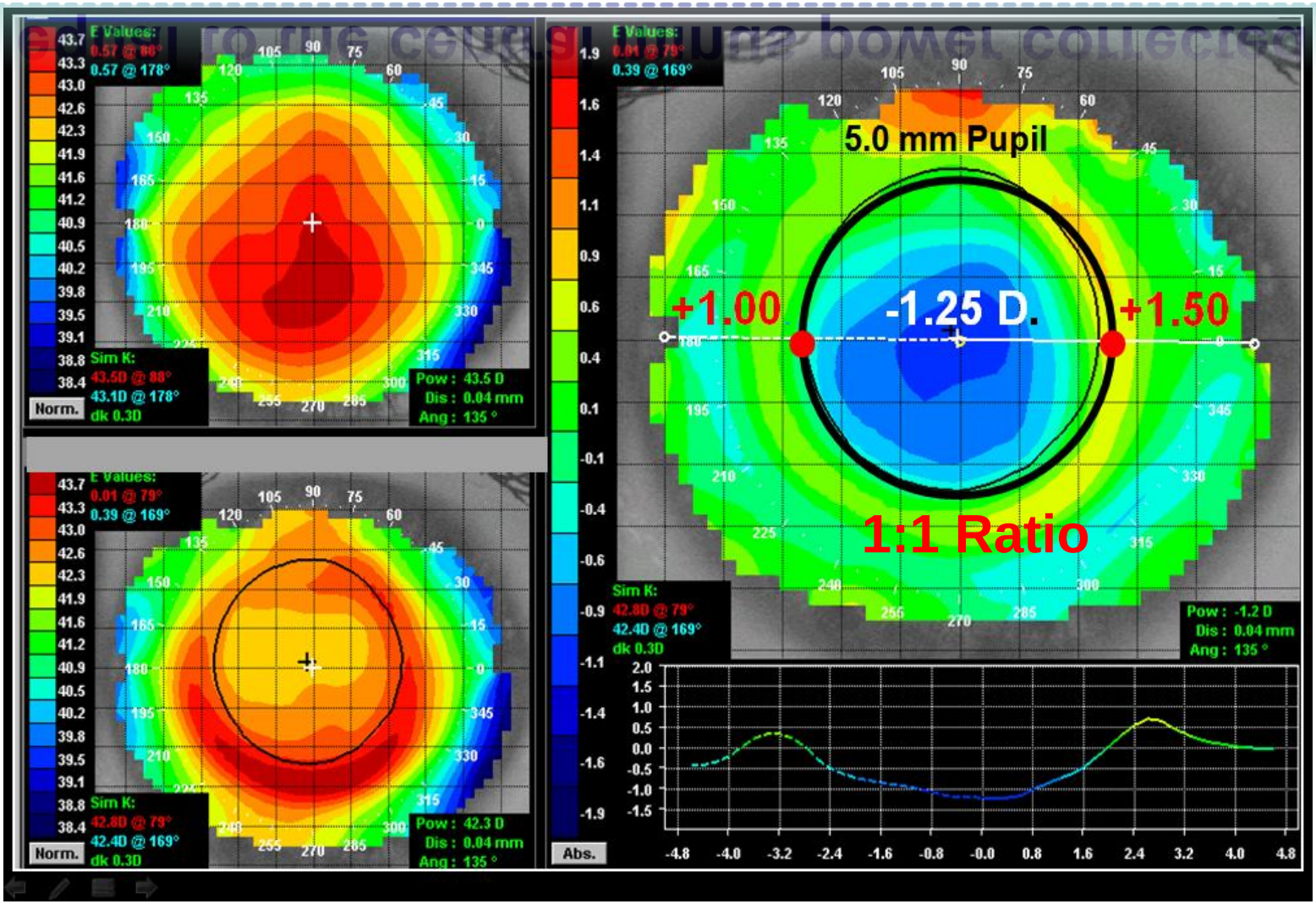


Average difference between the foval refraction and that 30 degrees away was between



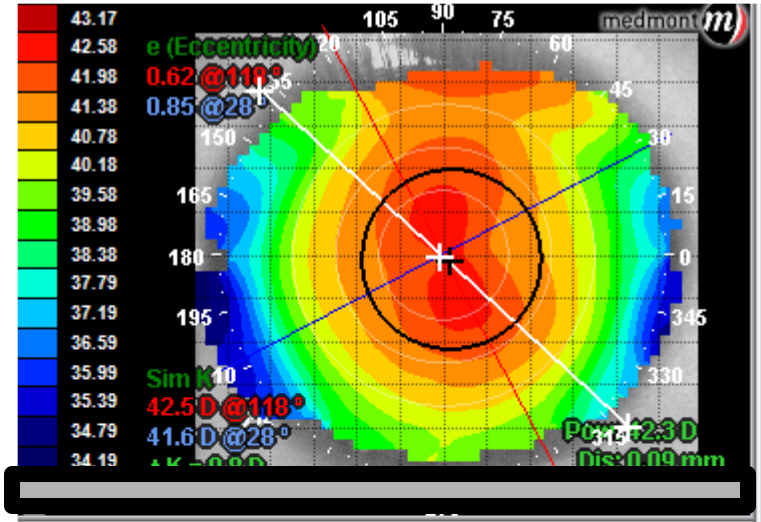
+1.00 D. and +1.50 D.

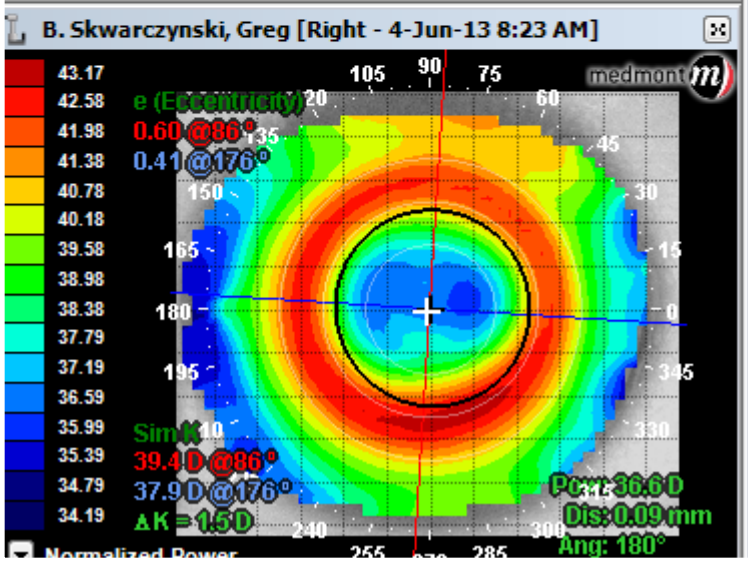
The amount of peripheral plus power at *5.0 mm* is equal to the central minus power corrected

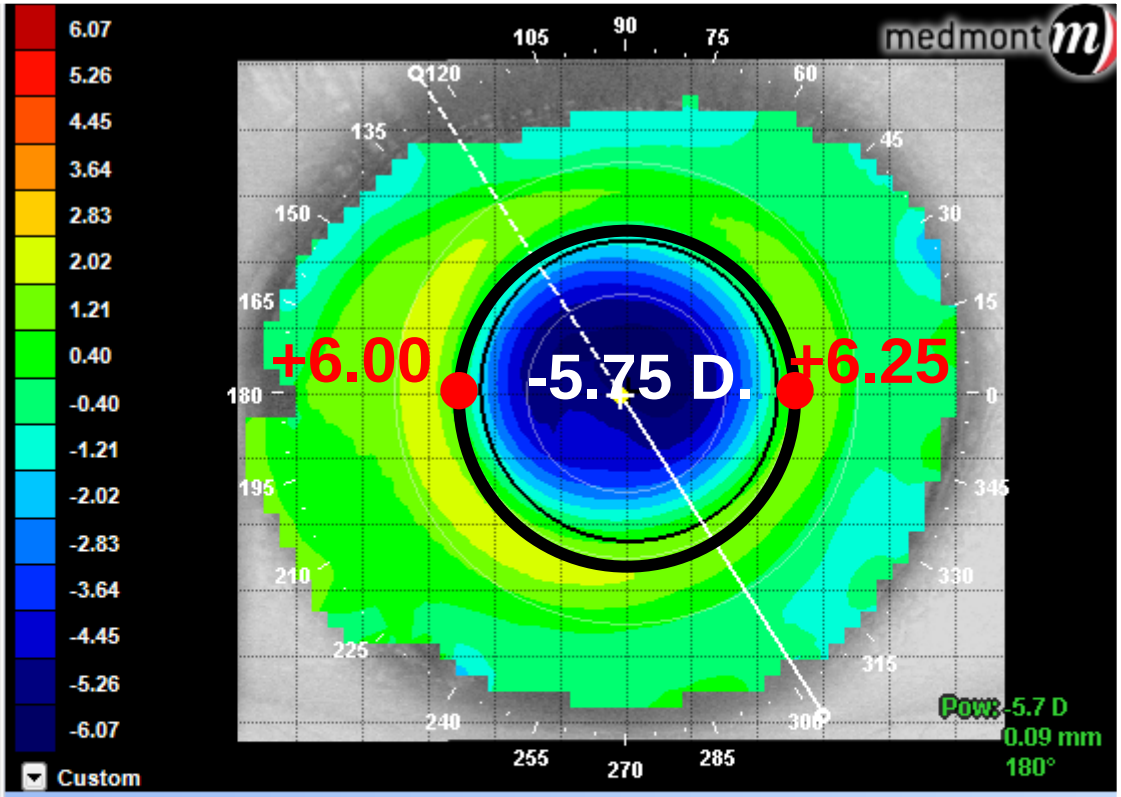


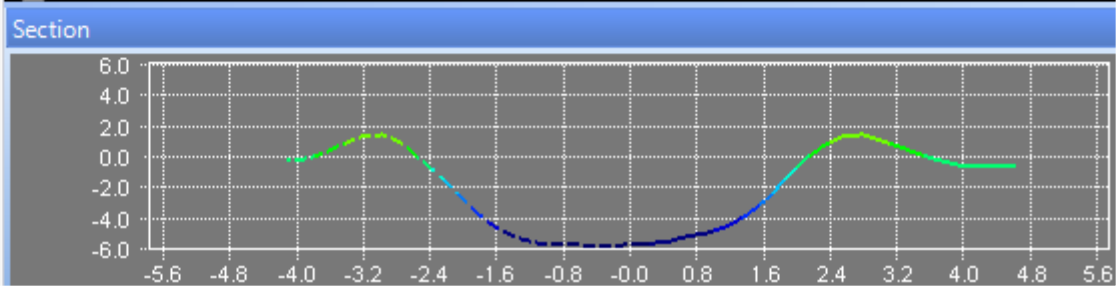
Pat Caroline, Pacific University

-5.75 D. Correction

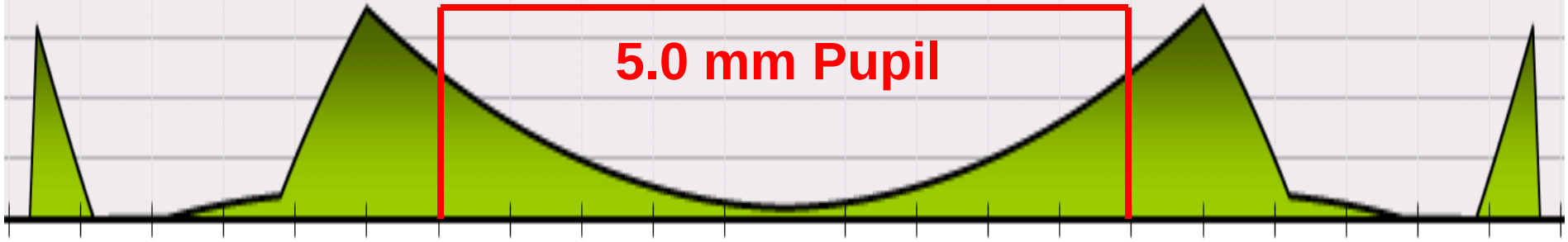




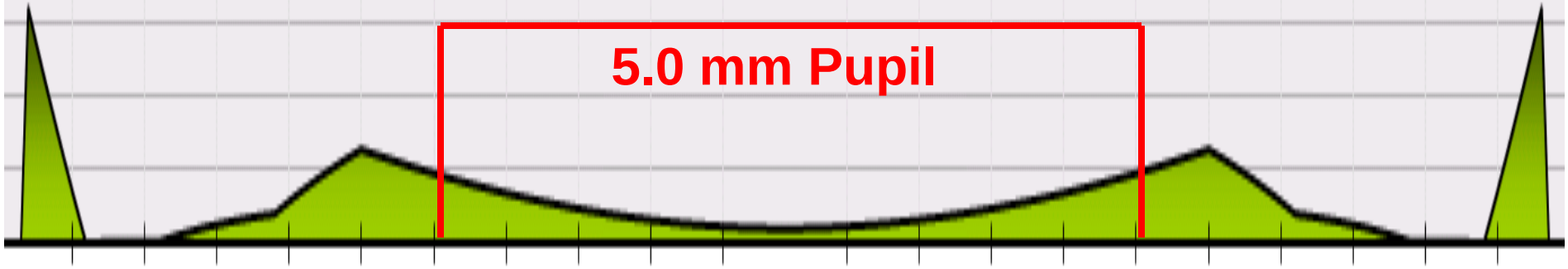




Tear Profile of a -5.00 D Correcting OK Lens

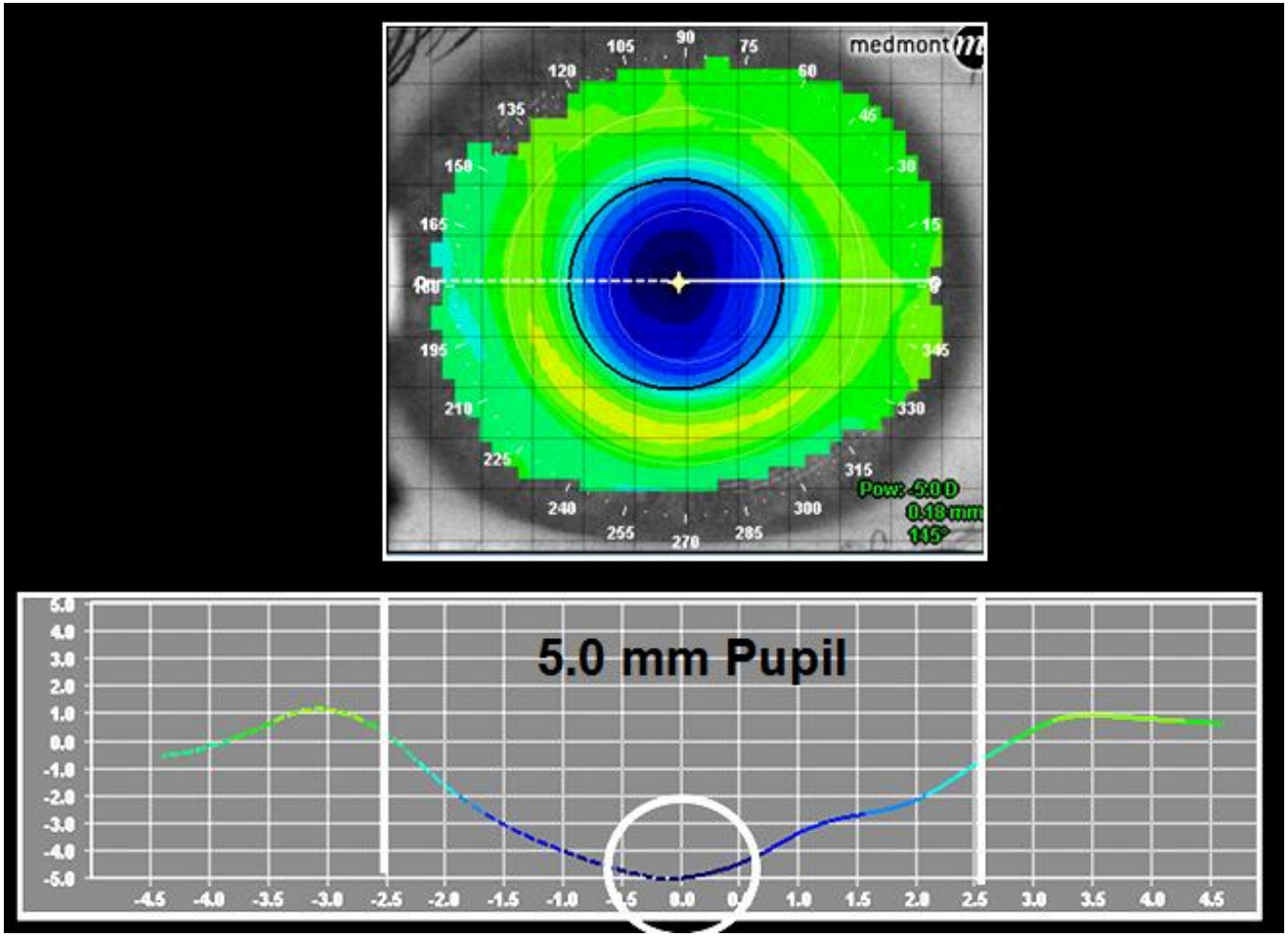


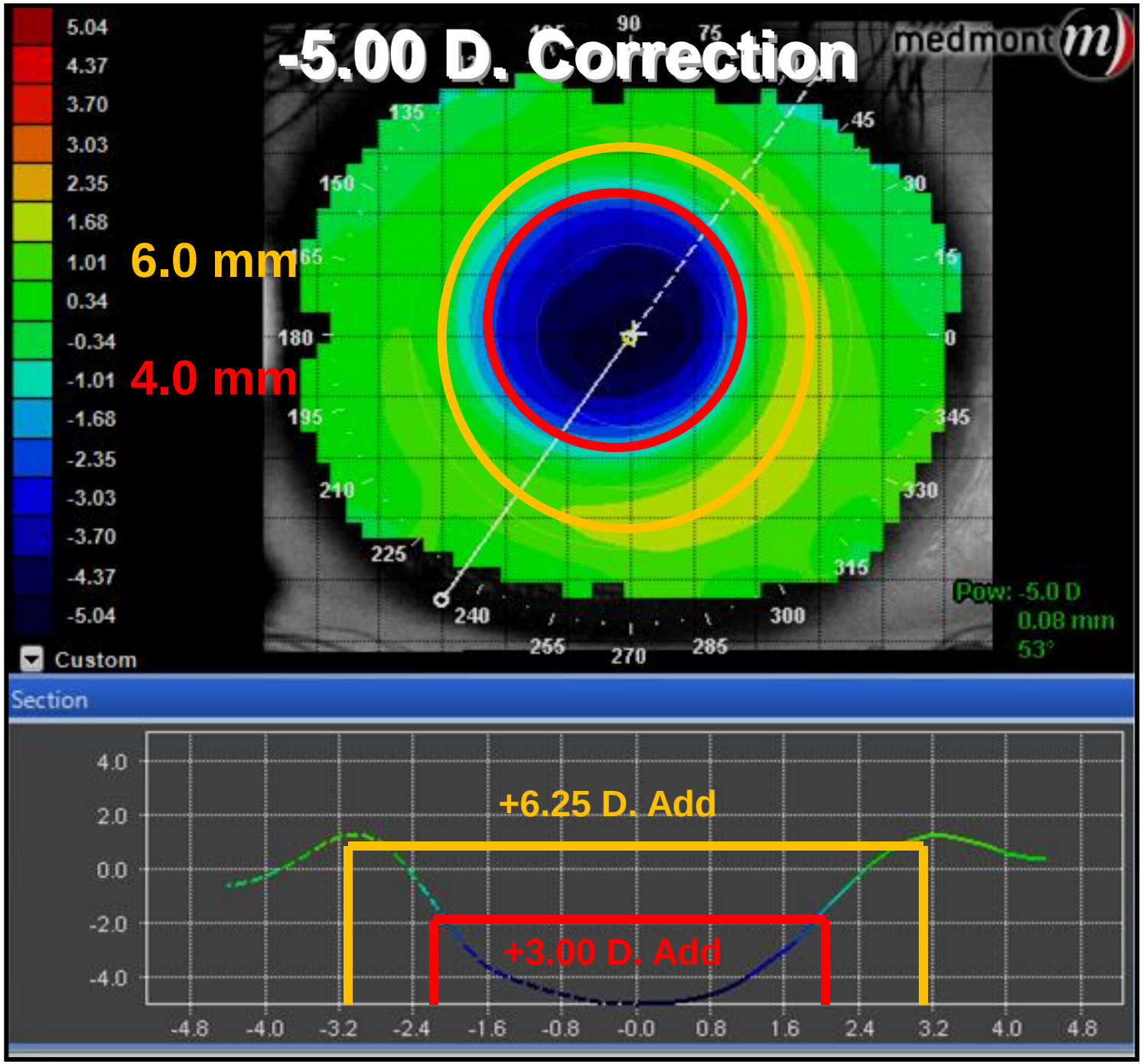
Tear Profile of a -1.00 D Correcting OK Lens

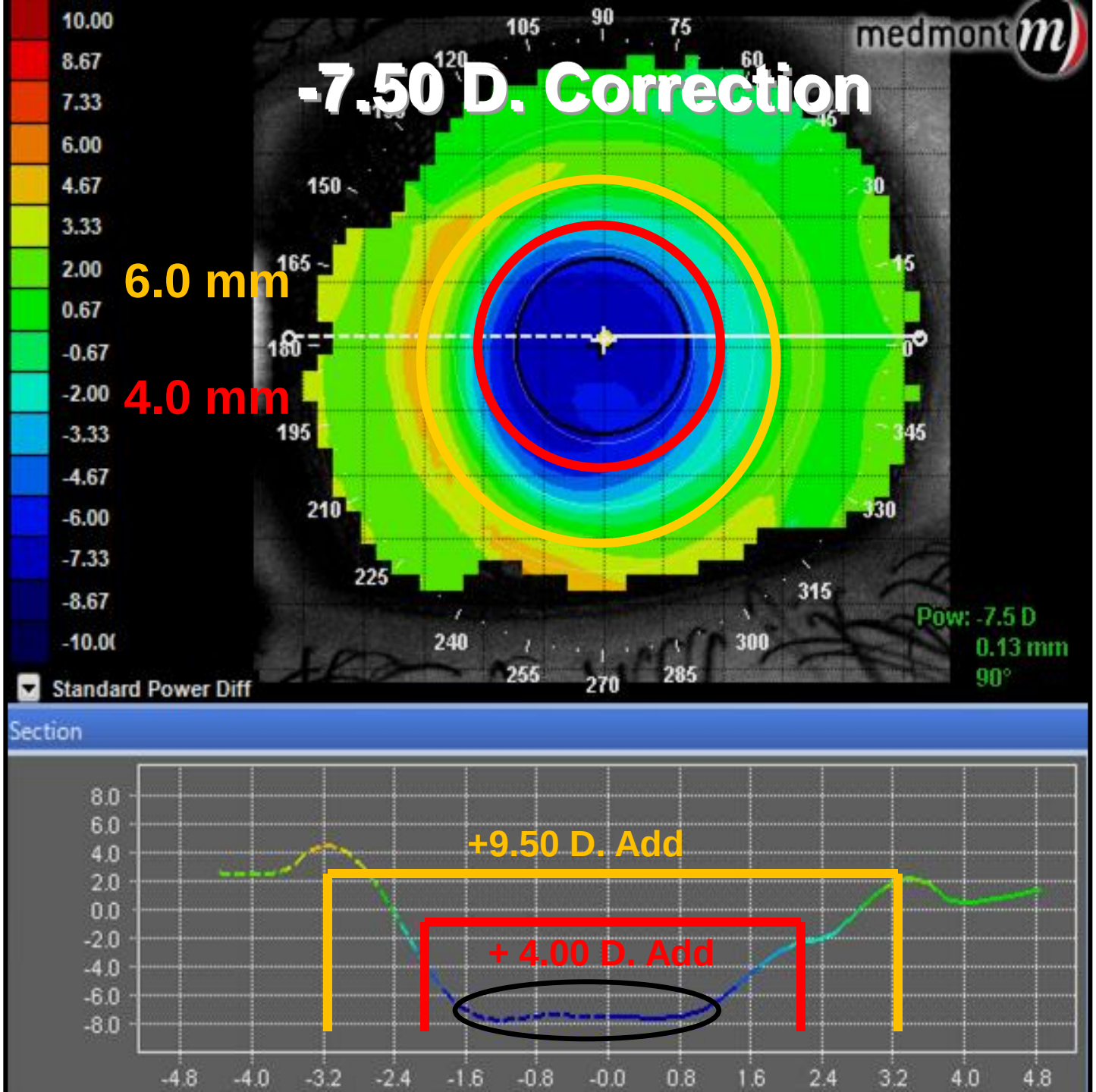


THE OPTICS of OK

The foveal treatment zone in OK is approximately <u>1.5 to 2.5 mm in diameter</u> (How & Why?)




-5.00 D. Correction
medmont
5.04
4.37
3.70
3.03
2.35
1.68
1.01
0.34
-0.34
-1.01
-1.68
-2.35
-3.03
-3.70
-4.37
-5.04
6.0 mm
4.0 mm
Custom
90
75
135
45
150
30
165
15
180
0
195
345
210
330
225
315
240
300
255
270
285
Pow: -5.0 D
0.08 mm
53°
Section
4.0
2.0
0.0
-2.0
-4.0
+6.25 D. Add
+3.00 D. Add
-4.8
-4.0
-3.2
-2.4
-1.6
-0.8
-0.0
0.8
1.6
2.4
3.2
4.0
4.8

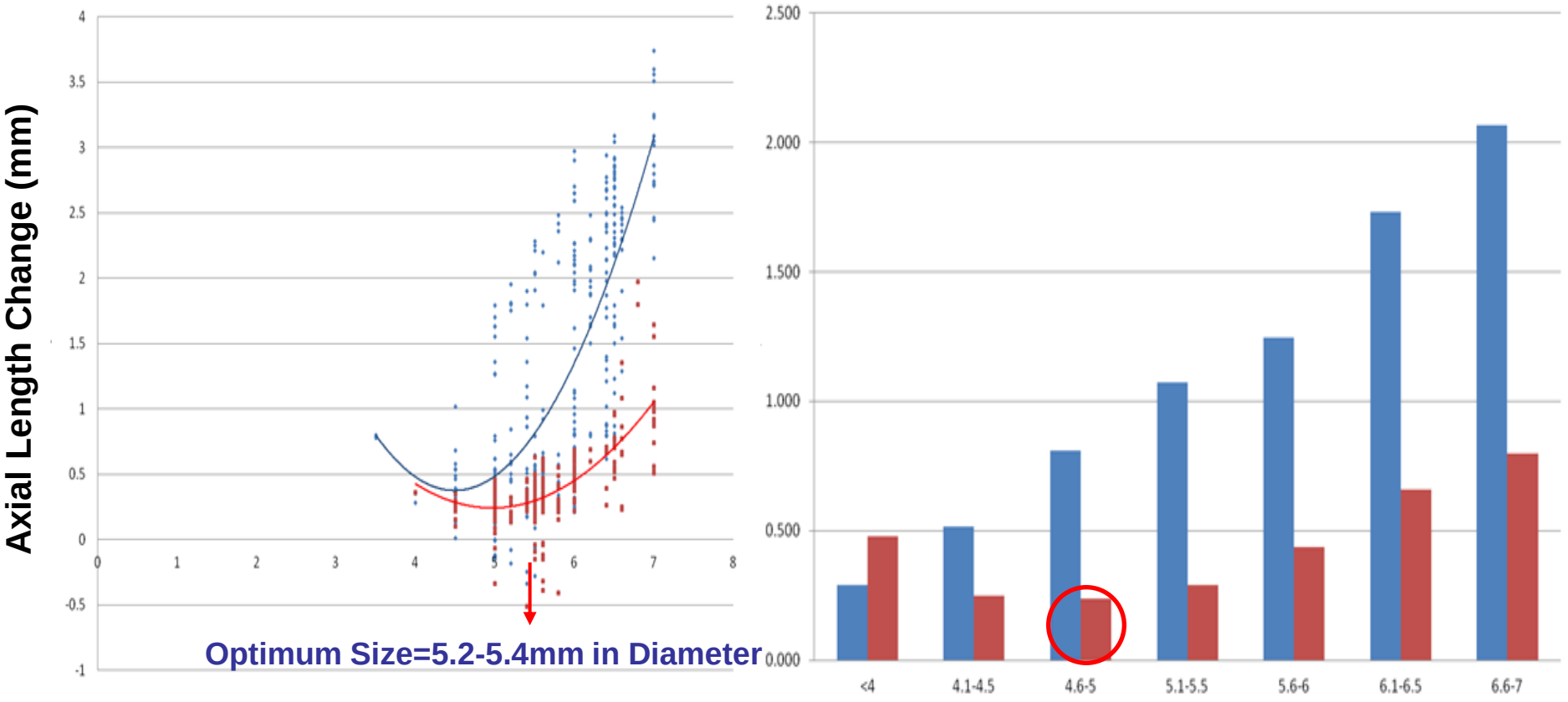

-7.50 D. Correction
medmont
6.0 mm
4.0 mm
10.00
8.67
7.33
6.00
4.67
3.33
2.00
0.67
-0.67
-2.00
-3.33
-4.67
-6.00
-7.33
-8.67
-10.0(
Standard Power Diff
Pow: -7.5 D
0.13 mm
90°
Section
+9.50 D. Add
+ 4.00 D. Add
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-4.8
-4.0
-3.2
-2.4
-1.6
-0.8
-0.0
0.8
1.6
2.4
3.2
4.0
4.8

Axial Length Change as the Function of Pupil Size, Chow 2013

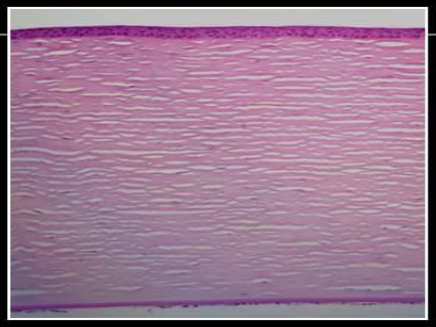
- Project 1 With 4-5 Curves
- Project 2 With Double Reverse Curves (6 Curves)

(N=296)

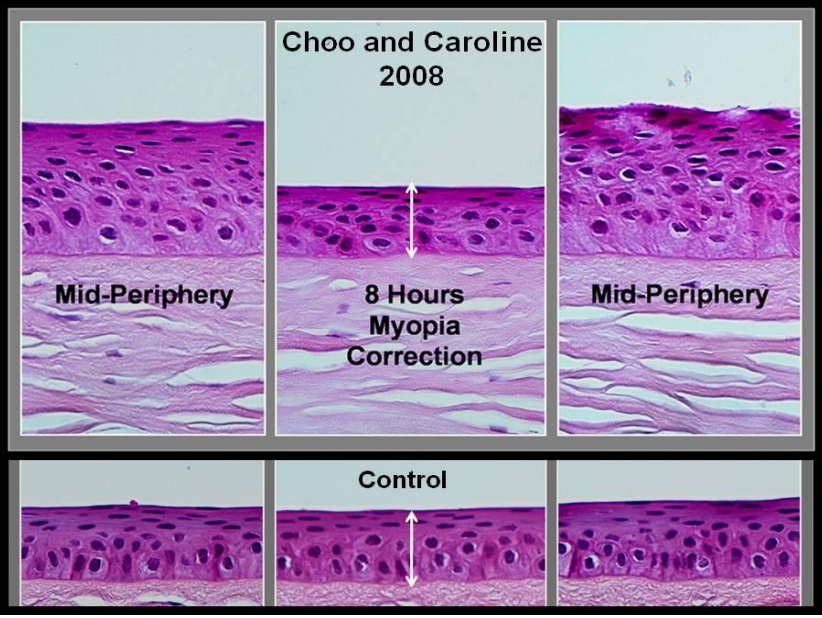
Pupil Size

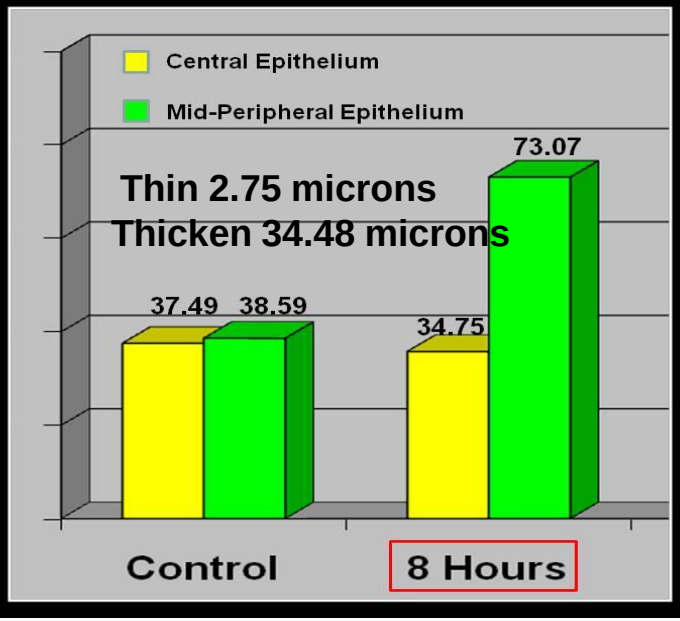


Layer	Approx. Thickness at Central Cornea
Epithelium	50 microns
Bowmans Layer	10 microns
Stroma	465 microns
Descemets Membrane	10 microns
Endothelium	5 microns
Appro. Total Thickness	540 microns .54 mm









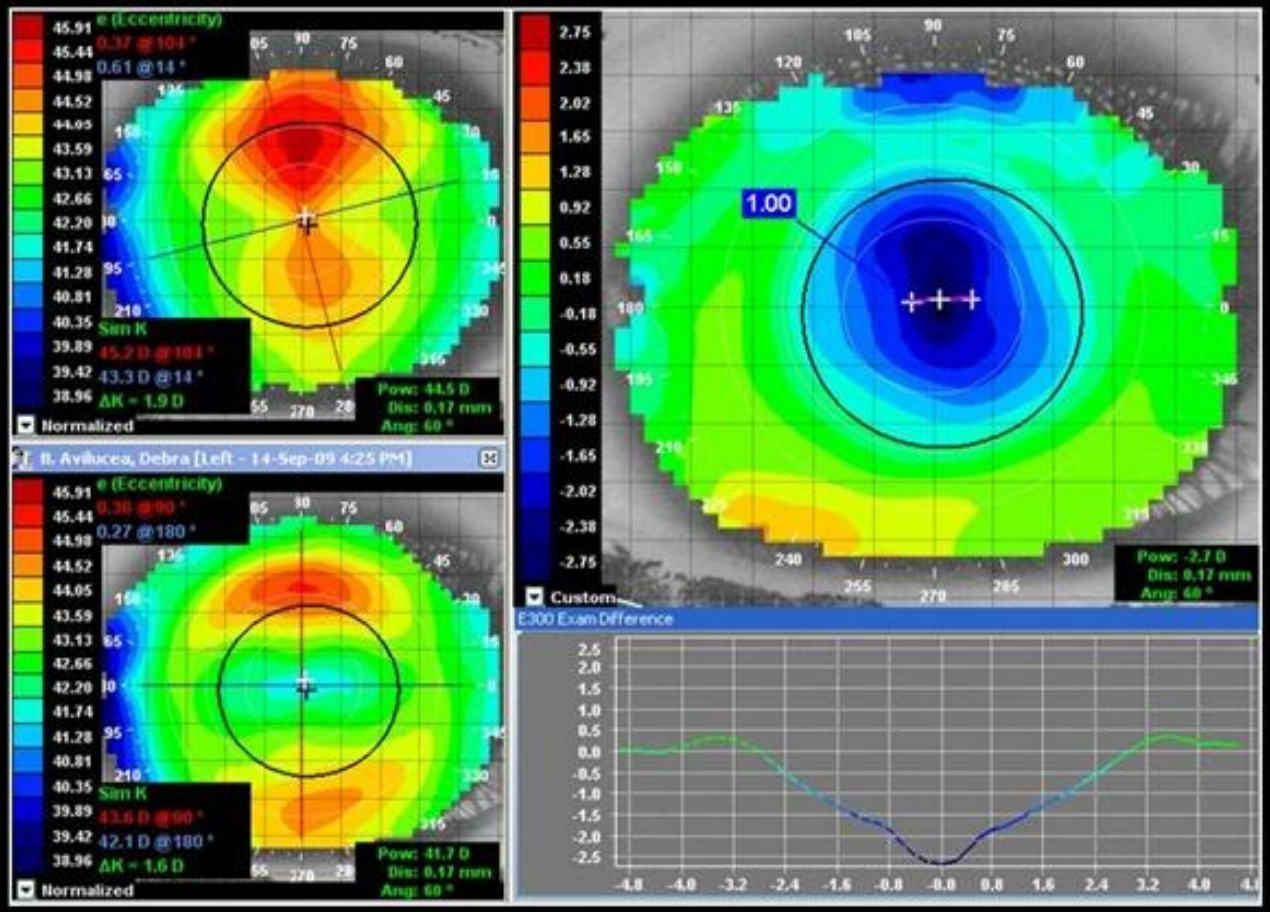
Munnerlyn Formula

Depth of the Treatment Zone Equals

$$\frac{\text{Optical Zone Diameter}^2 \times \text{Refractive Error}}{3}$$

Treatment Zone Diameter =	**5.0 mm**
OZ Squared 5.0 x 5.0 =	**25**
Times the Refractive Error =	**-3.00 D.**
Divided by 3 =	**75**
Tissue Displacement =	***25 microns***

Axial Display 1.0 mm Treatment



Munnerlyn's Formula

-3.00 Correction

Treatment Zone	*Amount of Tissue Displacement*
1.0 mm	1 microns
2.0 mm	4 microns
3.0 mm	9 microns
4.0 mm	16 microns
5.0 mm	25 microns
6.0 mm	36 microns

Force Concept

PUSH/PULL CONCEPT



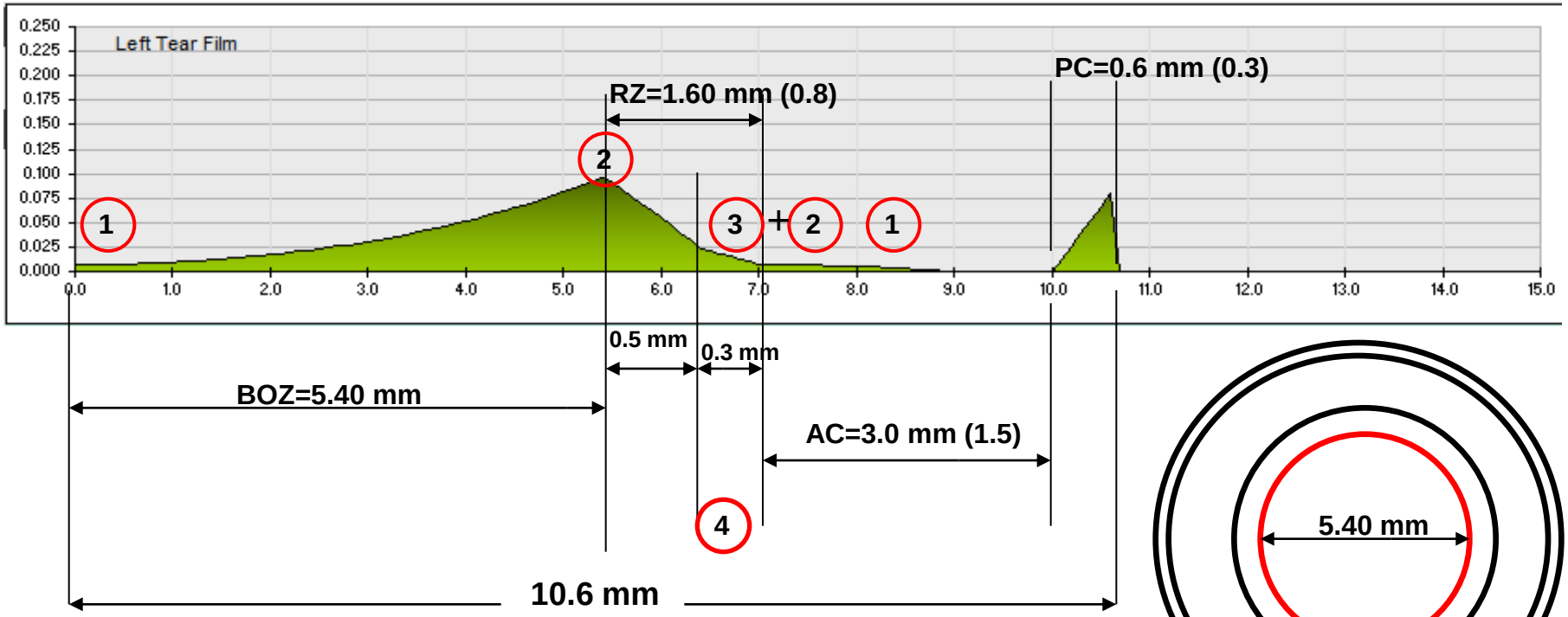
The reverse zone does not just connect the treatment zone and alignment zone

- **Force=lid force (+ve) + squeeze film force (-ve)**
- **RGL work by applying both compressive and tension forces at different sites across the corneal surface**
- **Push-Pull balance**
  1. **<u>Pull-On</u> of the AZ towards RZ**
  2. **<u>Push-Off</u> of the TZ (BC flatter than K)**
- **Optimum balanced lens design brings those opposing forces into proper equilibrium**

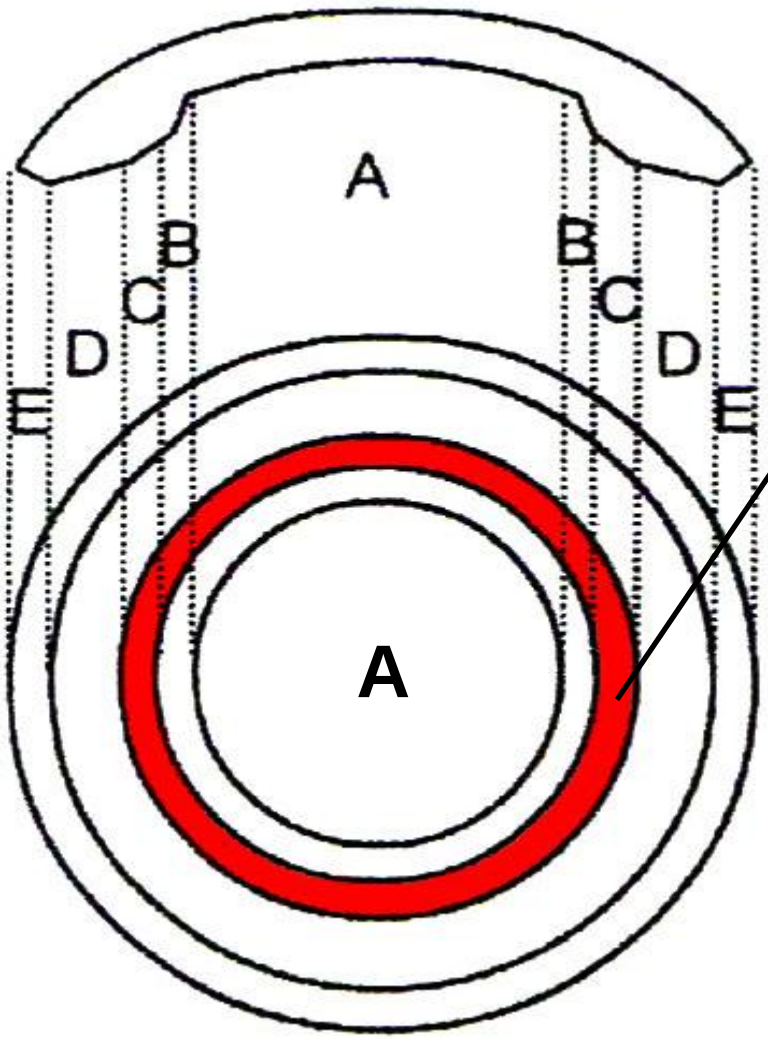
Tear Film Analysis Chart

(Cross-Section of Lens)

Total Diameter=10.6 mm, BOZ Diameter=5.40 mm



1. Compression & tear layer fluid force
2. Squeeze film force
3. Small capillary force
4. Relief/Enhancement zone



A. Central Optical Zone

B. Reverse Zone

C. Facilitation/Relief/Enhancement Zone

D. Alignment Zone(S)

E. Periphery Zone

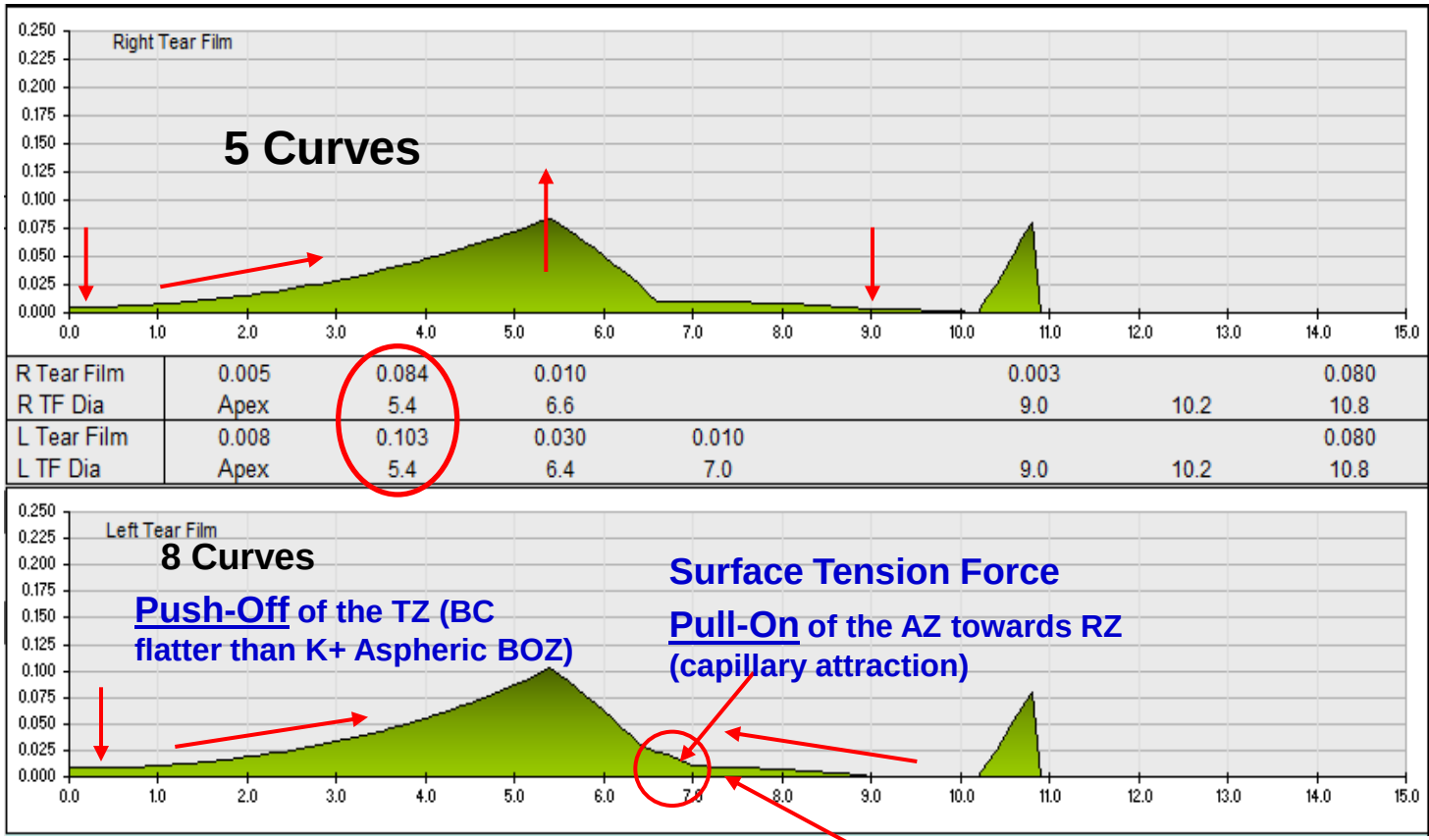
Double Reverse Curves (B+C): Most powerful for successful Ortho-K practice

Central optical zone can be spherical or aspherical

Force Concept

Represents True Tear Volume & Force Applied at Various Points of Interest

H K Reading	43.00	43.00
V K Reading	44.00	44.00
V K Axis	100	100
Eccentricity	0.50	0.50
HVID	11.5	11.5
Sphere	-5.00	-5.00
Cylinder		
Axis		
Vertex	12	12
Add Power		
Lens Rx	**Right**	**Left**
Flat Base	9.05	9.05
Steep Base		
Base Ecc.		
Flat Power	1.00	1.00
Steep Power		
Front Ecc		
Add Power		
Diameter	10.6	10.6
1st Curve	6.64	6.63
1st Width	0.60	0.40
2nd Curve	8.01	7.45
2nd Width	0.80	0.40
3rd Curve	8.14	8.01
3rd Width	0.50	0.80
4th Curve	10.08	8.14
4th Width	0.40	0.50
5th Curve		10.07
5th Width		0.40
6th Curve		
6th Width		
Start Curve	CC Chow 1	CC Chow 1
		0.4/0.4/70%



R Tear Film	0.005	0.084	0.010		0.003		0.080
R TF Dia	Apex	5.4	6.6		9.0	10.2	10.8
L Tear Film	0.008	0.103	0.030	0.010			0.080
L TF Dia	Apex	5.4	6.4	7.0	9.0	10.2	10.8

Negative Force: Pull

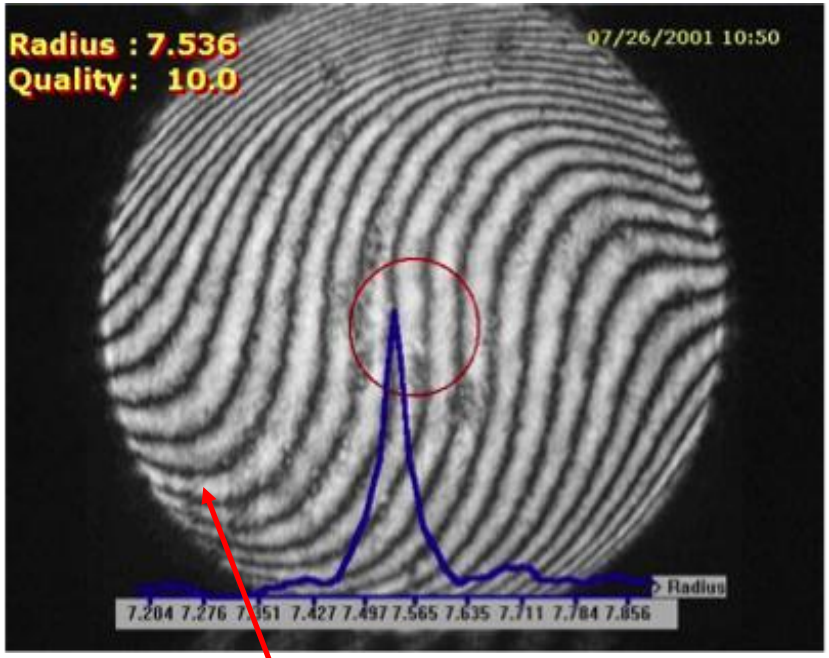
Positive Force: Push

Small Capillary Force

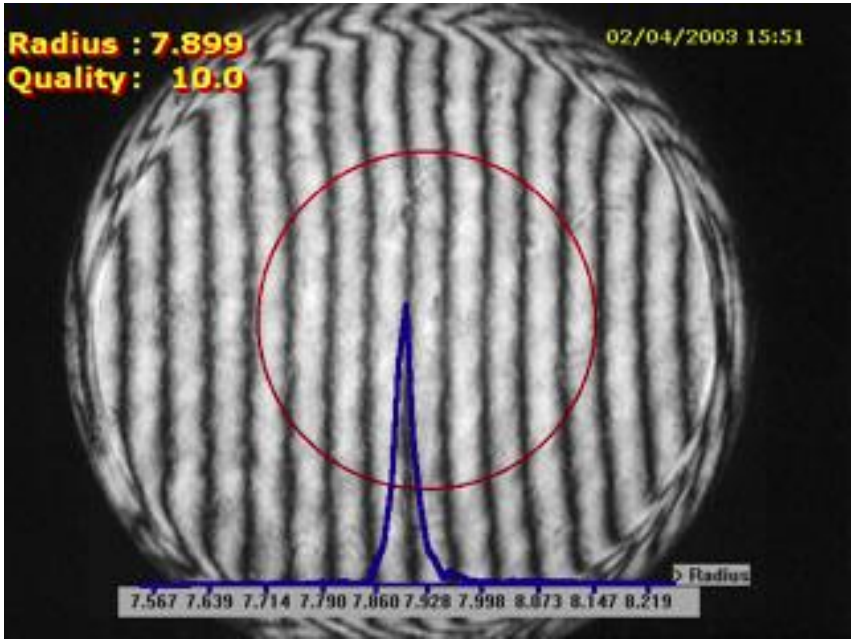
Optimum balanced design brings those opposing forces into proper equilibrium

Progressive Aspheric

E= 0.5 to > 1.60



Sphere E=0



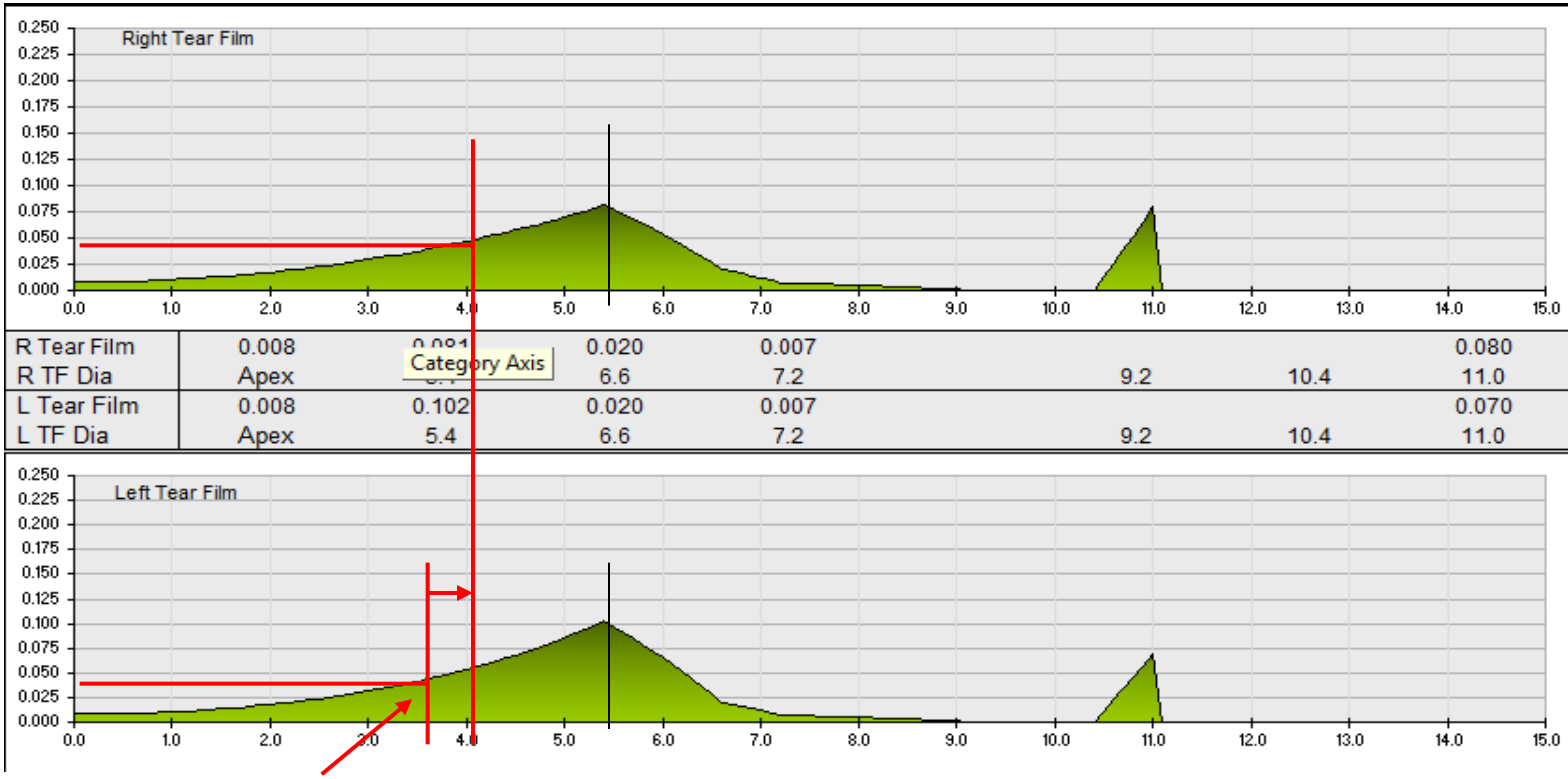
Aspheric curve flattens towards periphery

Creating extra add in mid-periphery

Spherical vs Aspheric

Same OZD

43.00	43.00
44.00	44.00
90	90
0.25	0.25
11.5	11.5
-5.00	-5.00
12	12
Right	Left
9.20	9.20
	1.50
2.50	2.50
	+0.50
11.0	11.0
6.58	6.28
0.60	0.60
7.38	7.38
0.30	0.30
7.85	7.85
1.00	1.00
7.94	7.94
0.60	0.60
9.91	9.57
0.30	0.30
5.4	5.4
7.0	7.0
0.19	0.21
0.14	0.14



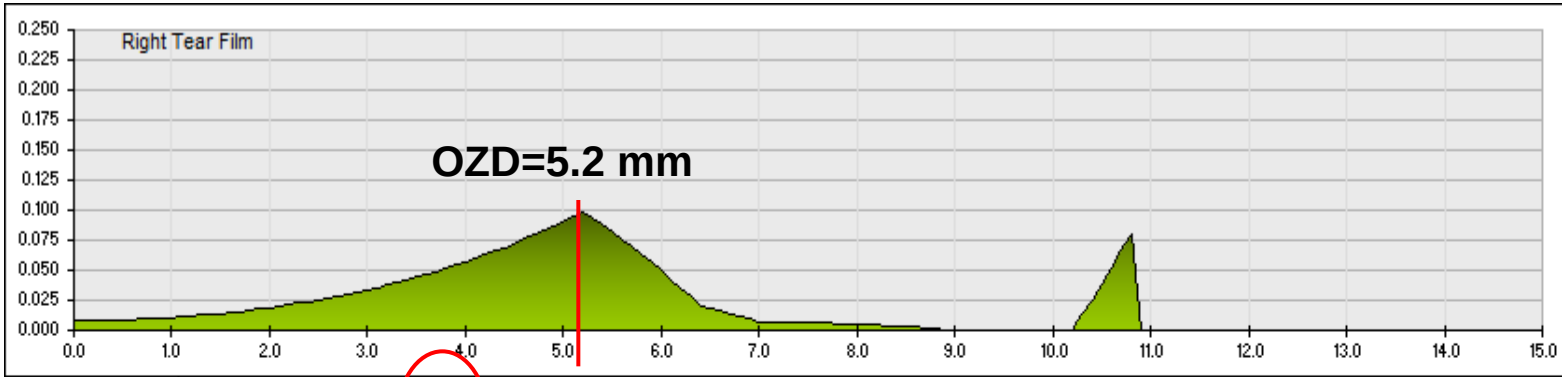
BC Flatten Faster creating extra force at RZ

Aspheric BOZ As Function Of Treatment Zone

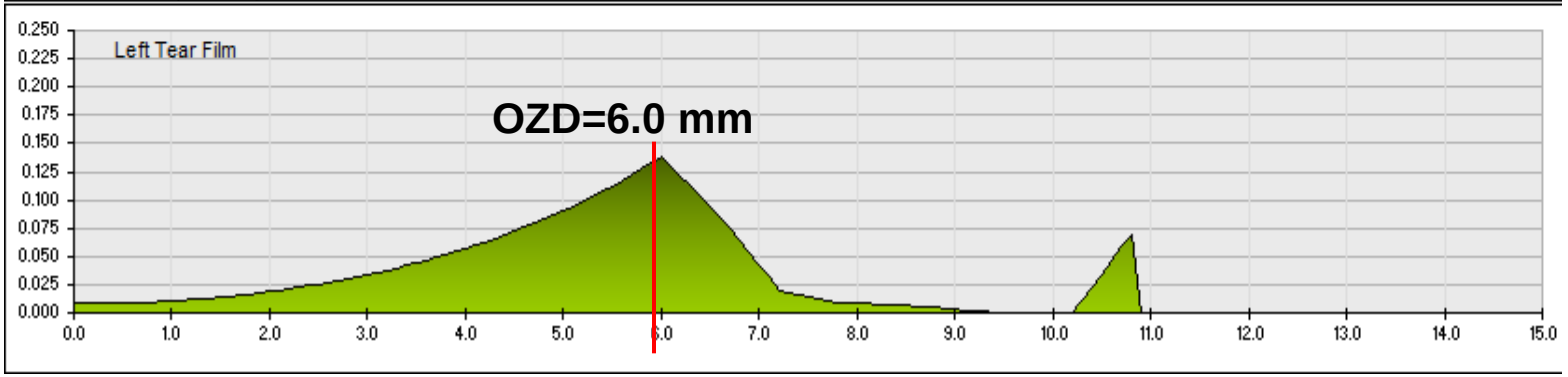
(Back Optical Zone)

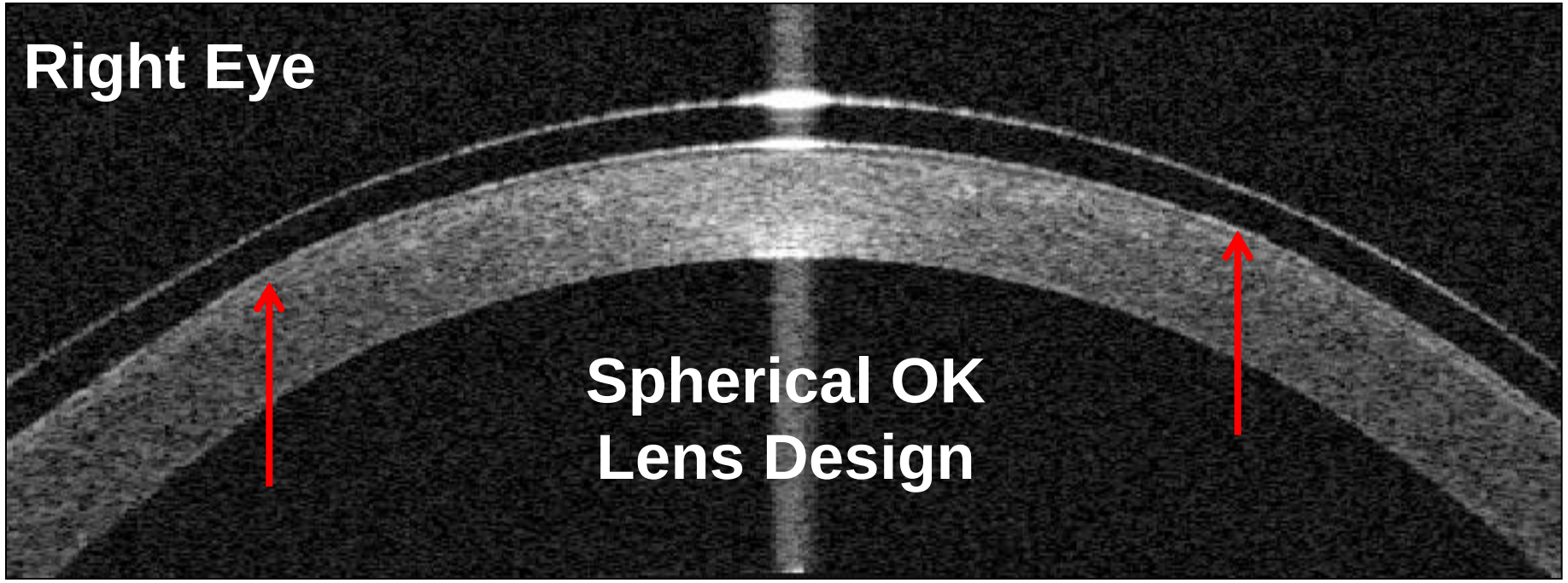
BC Radius Flatten Faster Towards Edge Of BOZ

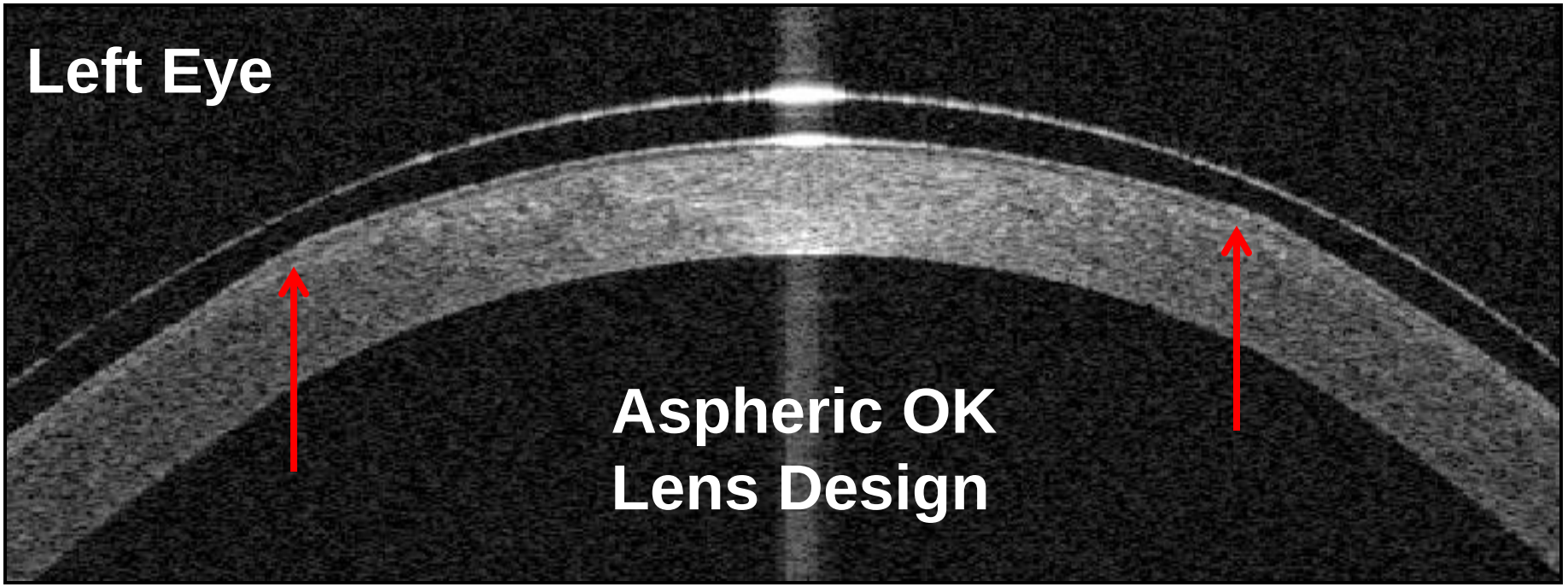
43.00	43.00
44.00	44.00
90	90
0.45	0.45
11.5	11.5
-5.00	-5.00
12	12
Right	Left
9.40	9.40
1.60	1.60
2.50	2.50
+0.50	+0.75
10.8	10.8
6.26	6.06
0.60	0.60
7.43	7.62
0.30	0.30
7.99	7.99
1.00	0.80
8.14	8.15
0.60	0.40
10.64	10.19
0.30	0.30
5.2	6.0
7.0	7.0
0.21	0.23
0.14	0.14



R Tear Film	0.008	0.099	0.020	0.007			0.080
R TF Dia	Apex	5.2	6.4	7.0	9.0	10.2	10.8
L Tear Film	0.008	0.138	0.020	0.009			0.070
L TF Dia	Apex	6.0	7.2	7.8	9.4	10.2	10.8

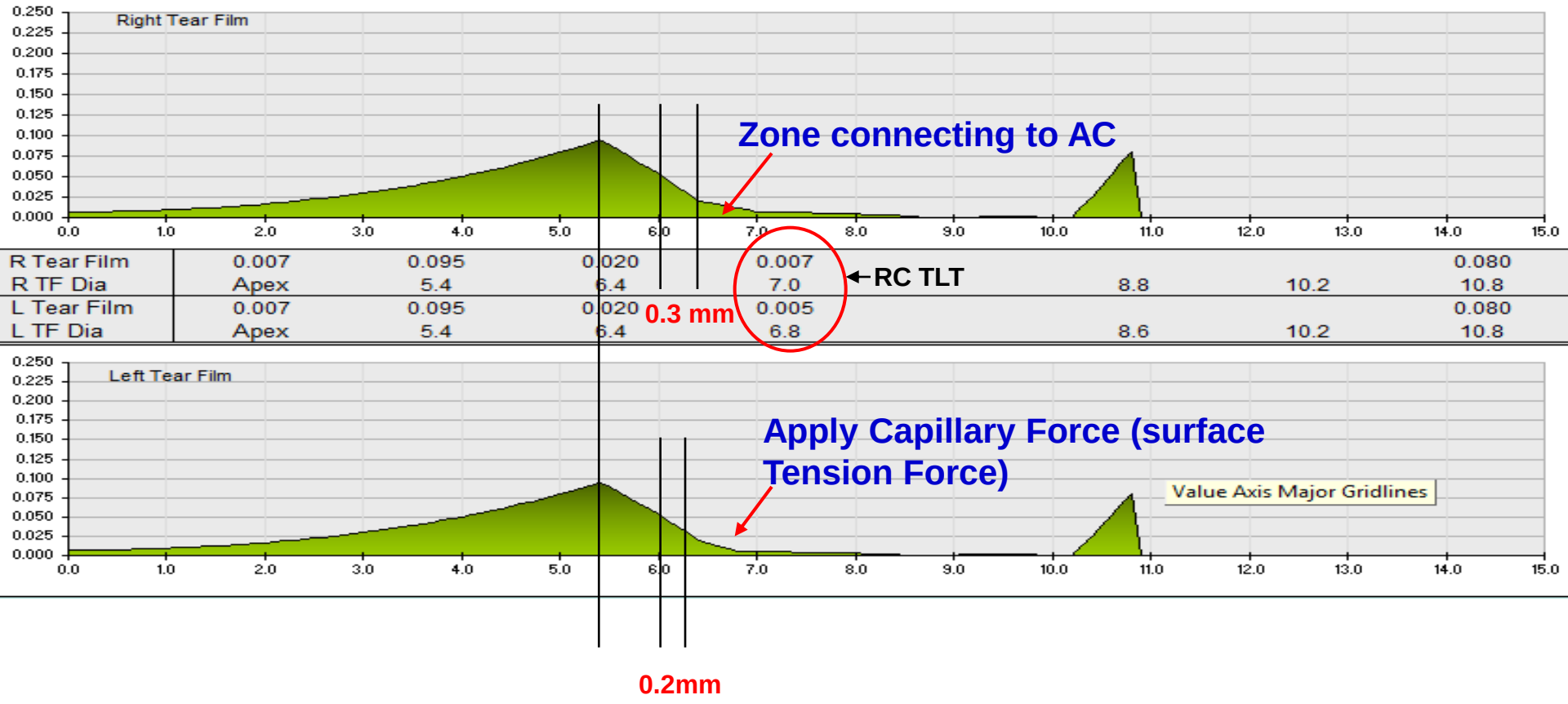



Right Eye
Spherical OK
Lens Design


Left Eye
Aspheric OK
Lens Design

Fitting/Reverse Curves

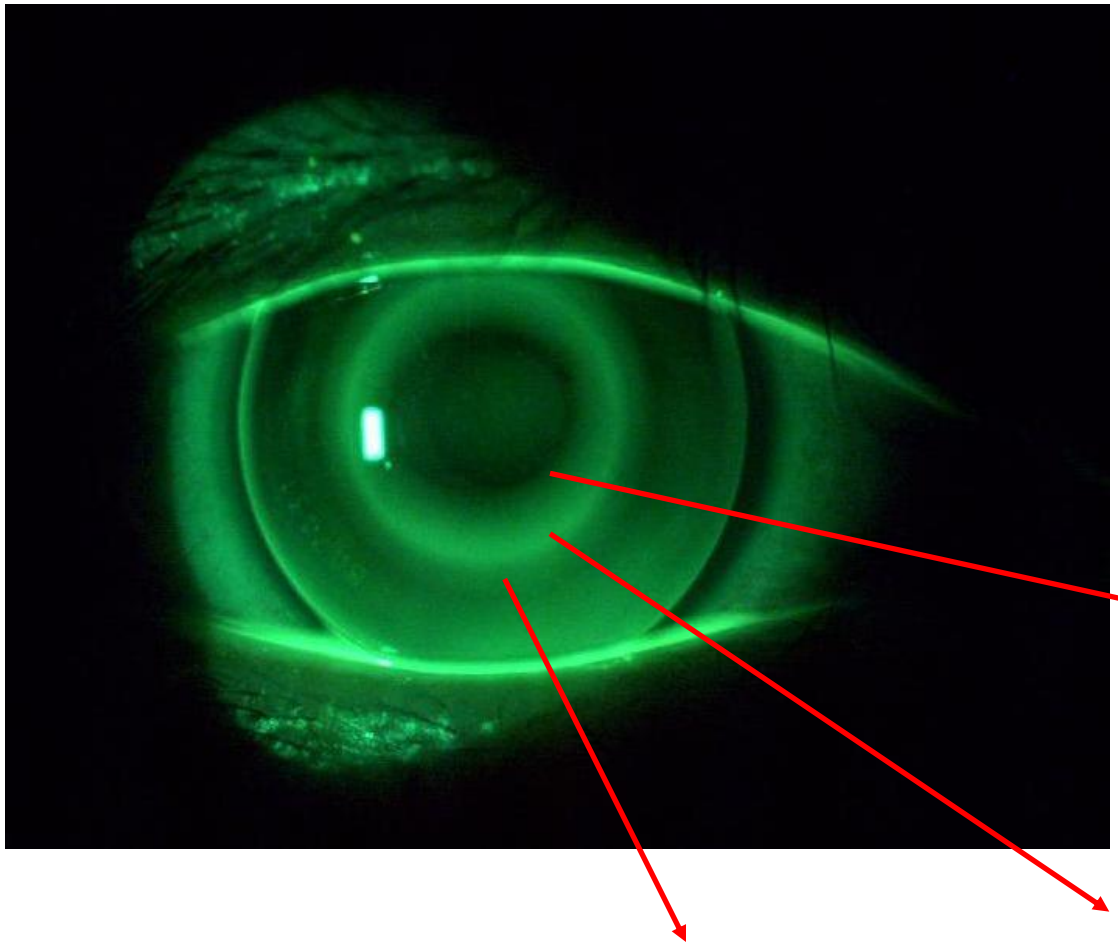
- RC divided into 2 zones to achieve tear equilibrium (apply to Pull-on/Push-off forces created by AZ & TZ)
- RC2 (Relieve Curve-1a) used to enhance the building-up mid-peripheral tissue (steepen) for OK effect (enhancement by surface tension)



RC2 used to balance pressure between RC1 & AC1(same function as pressure pot)

Picture showing design with double reverse curves

Aspheric back OZ



- Small treatment zone
- Small reverse curves
- Larger width of Alignment curves

Flattening towards a steeper FC1

Steeper FC1 radius

Flatter FC2 radius

Viscosity and Damping

Corneal Hysteresis: Result of Viscous Damping in Corneal Tissue



Viscosity: **Resistance of a fluid to a change in shape, or movement of neighboring portions relative to one another. The more viscous a fluid is, the more it resists flow.**

Honey, for example, has a greater viscosity than water.

Resistance to an applied force depends primarily on the SPEED at which the force is applied.



Damping: **The ability of tissue to absorb and dissipate energy.**

e.g. mechanical oscillations

Low CH = Soft Corneas, Average 11.19 mm Hg (Luce & Taylor)

Elasticity



<u>Elasticity:</u> The property of a substance that enables it to change its length, volume, or shape in <u>direct</u> response to a force, and to recover its original form upon the removal of the force.

Strain (deformation) is directly proportional to stress (applied force), independent of the length of time or the rate at which the force is applied. Greater Speed = Greater Resistance

Corneal Resistance Factor (CRF)

Mathematically Similar to CH, Provides More Information About Elastic Properties



Visco-Elastic System

An Automotive "Strut" Assembly
- Coil Spring: Static Resistance (Elasticity)
- Shock Absorber: Viscous Resistance (Damping)

The Cornea is a Visco-Elastic System

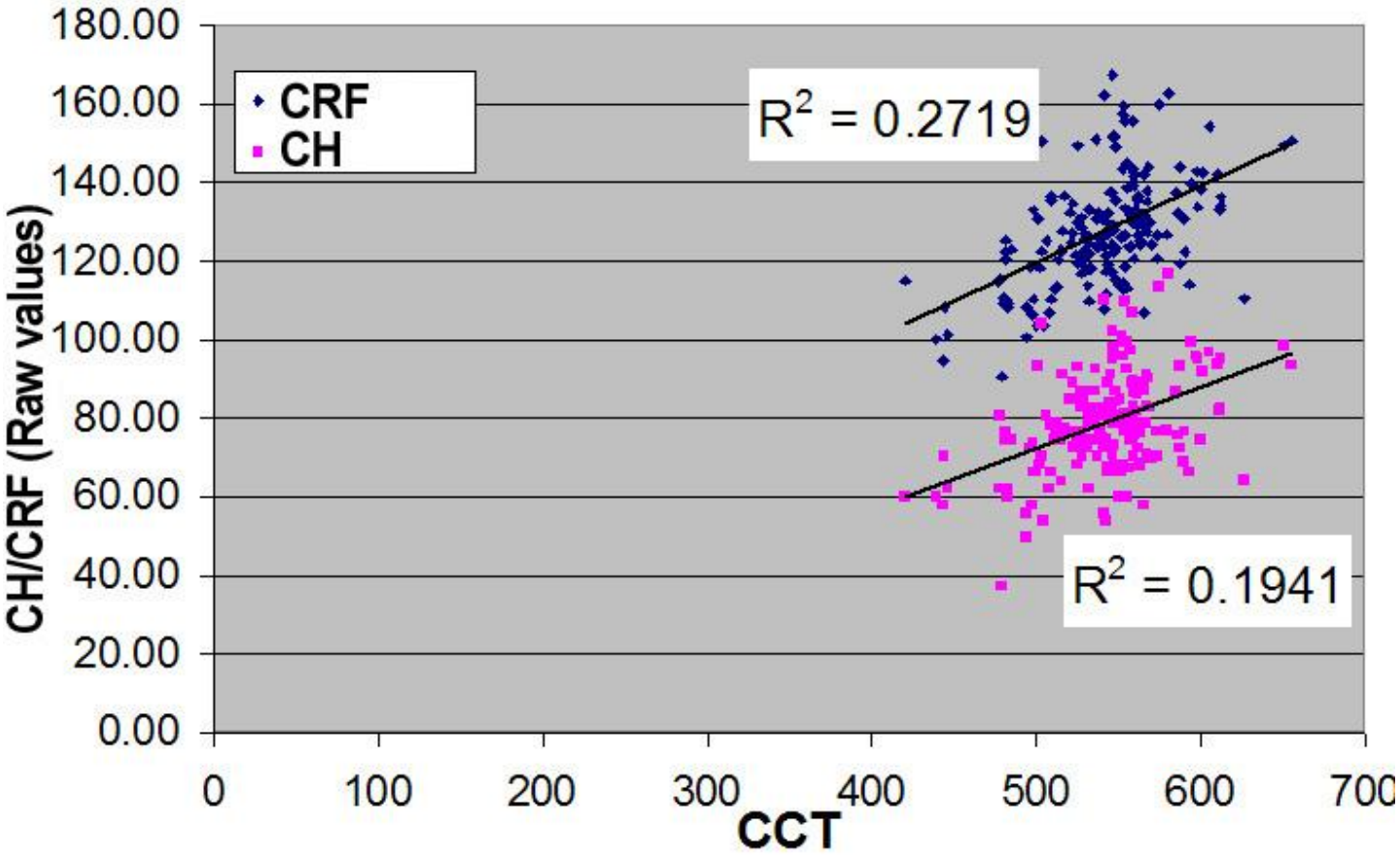
An indicator of the overall "resistance" of the cornea, including both the viscous and elastic properties. It is significantly correlated with Central Corneal Thickness (CCT) and GAT.



CRF: Average normal values 10.46 mm Hg (Luce & Taylor)

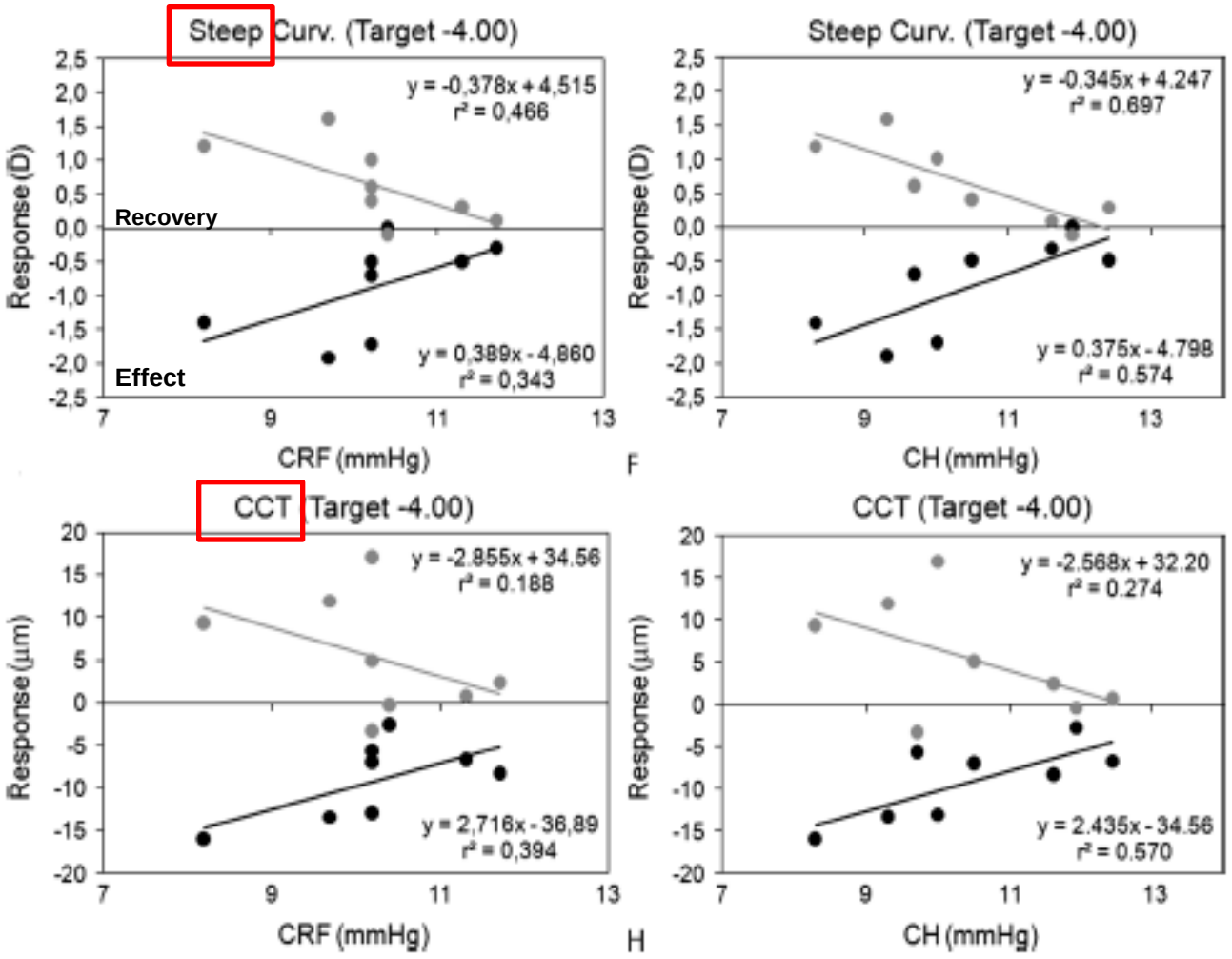
Correlation of CH and CRF vs. CCT

n=339 Normal Eyes



Courtesy: Reitcher Technologies

CH/CRF Relationship to Ortho-K (CRT) Response



Conclusions: corneal flattening response to myopic Ortho-K and recovery of the effect occur more rapidly in eyes with lower CRF and CH within normal ranges, at least in the short term

Gonzalez-Meijome, et al. Pilot Study on the Influence of Corneal Biomechnical Properties Over the Short Term in Response to Corneal Refractive Therapy for Myopia. Cornea, 2008

Influence of Biomechanical Properties in Response to Corneal Refractive Therapy for Myopia: Age Related

Older lens wearers showed a reduced or delayed response to reverse-geometry lens wear in the short term, suggesting a reduced corneal epithelial response to interventions with increasing age

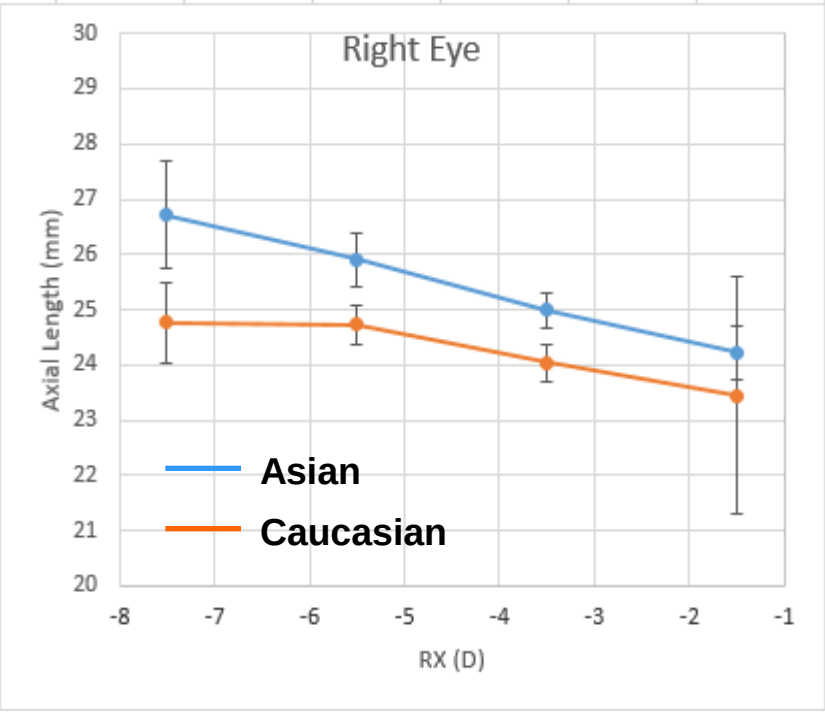
Jayakumar J, et al. The effect of age on short-term orthokeratology, Optom VisSci, 2005

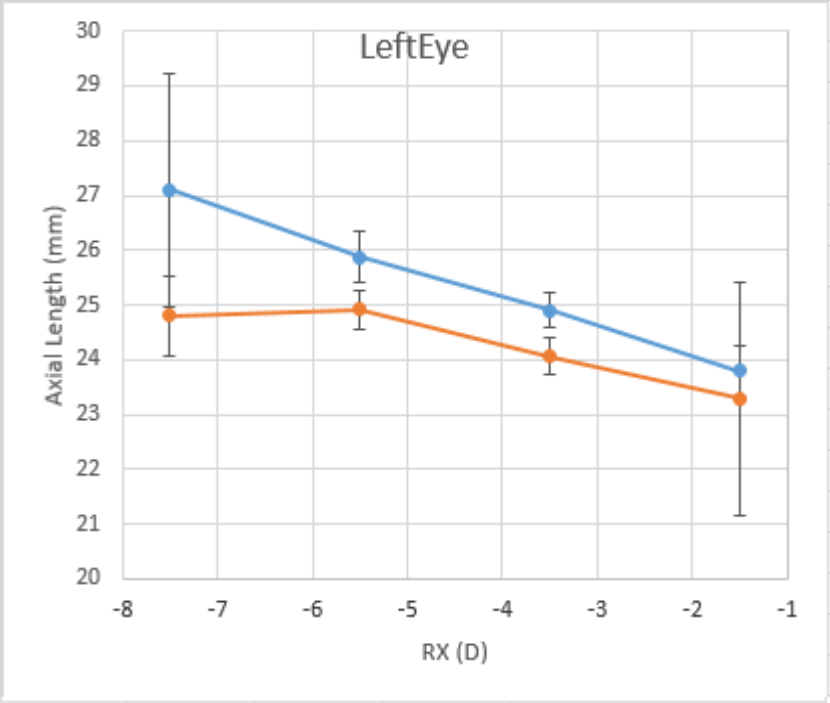
Older corneas shown to change their Biomechnical Properties, displaying high rigidity

Pallikaris IG et al. Ocular rigidity in living human eyes. Invest Ophthalmol Vis Sci, 2005

Biomechanical Properties of cornea help in understanding the inter-individual response to ortho-k

Comparison Between Races & Axial Length for Myopic Children, n=30 Chow, 2015





Two-way ANOVA was used to compare Asians and Caucasians across levels of Rx. Asians had significantly longer axial lengths (F=24.1, p<.001; F=19.7, p<.001 for right and left eyes respectively)

***This may account for TIGHTER LIDS for Asian children**