Spectum of Customized Laser Vision Correction Options

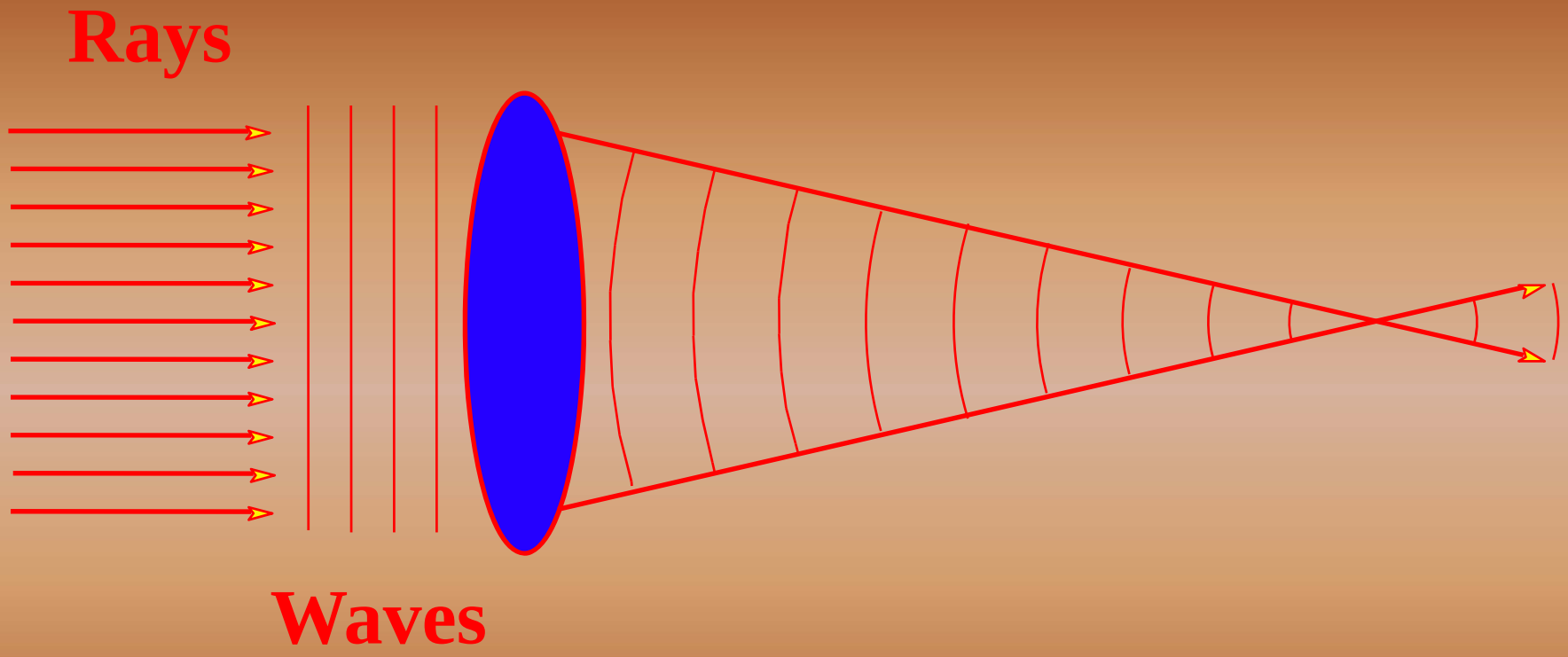
From Wavefront to Topography Guided Surgery

Cole Eye Institute
Cleveland Clinic

Ronald R. Krueger, MD

I am a Consultant for Alcon

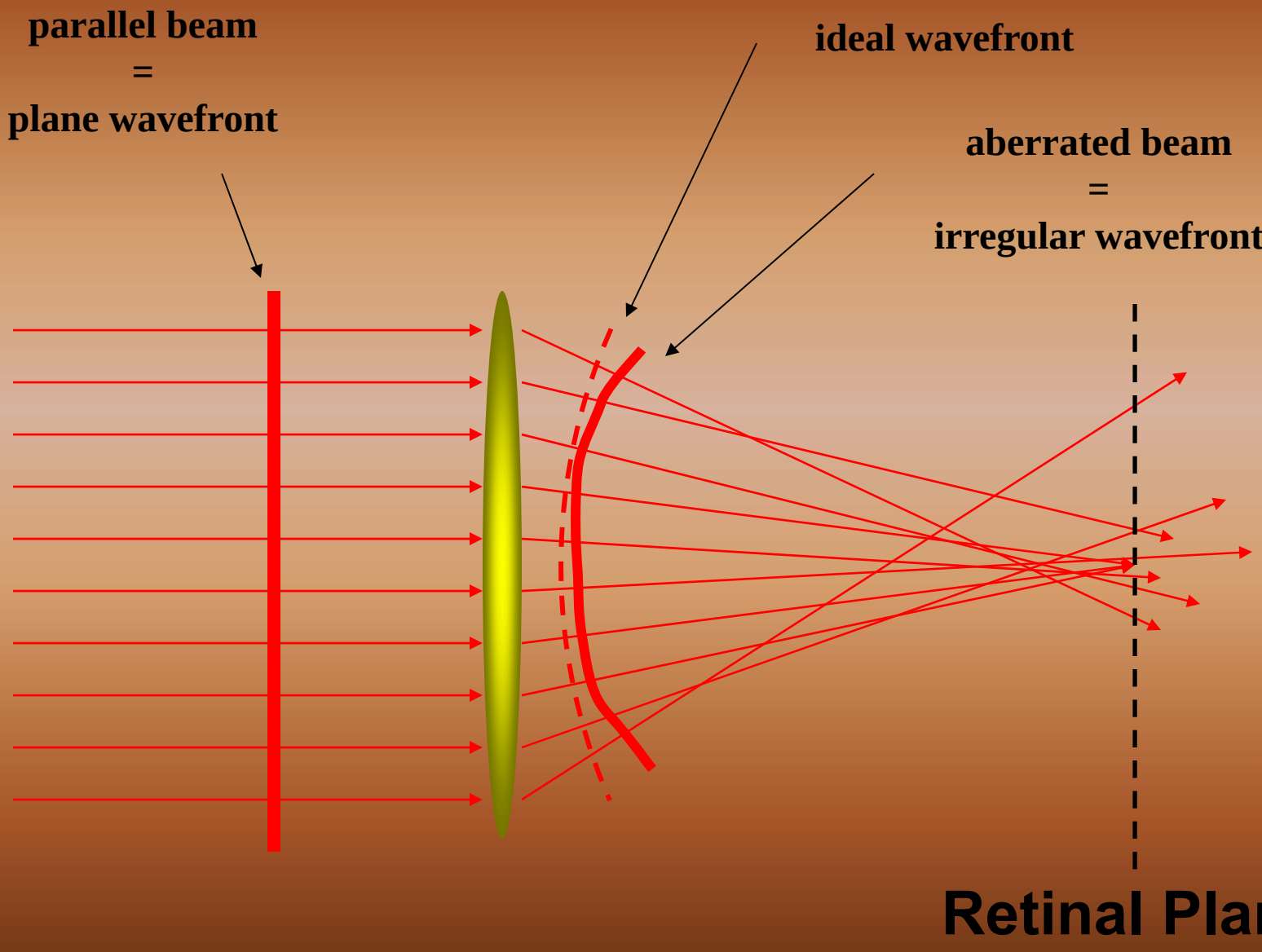
What is Wavefront Sensing?

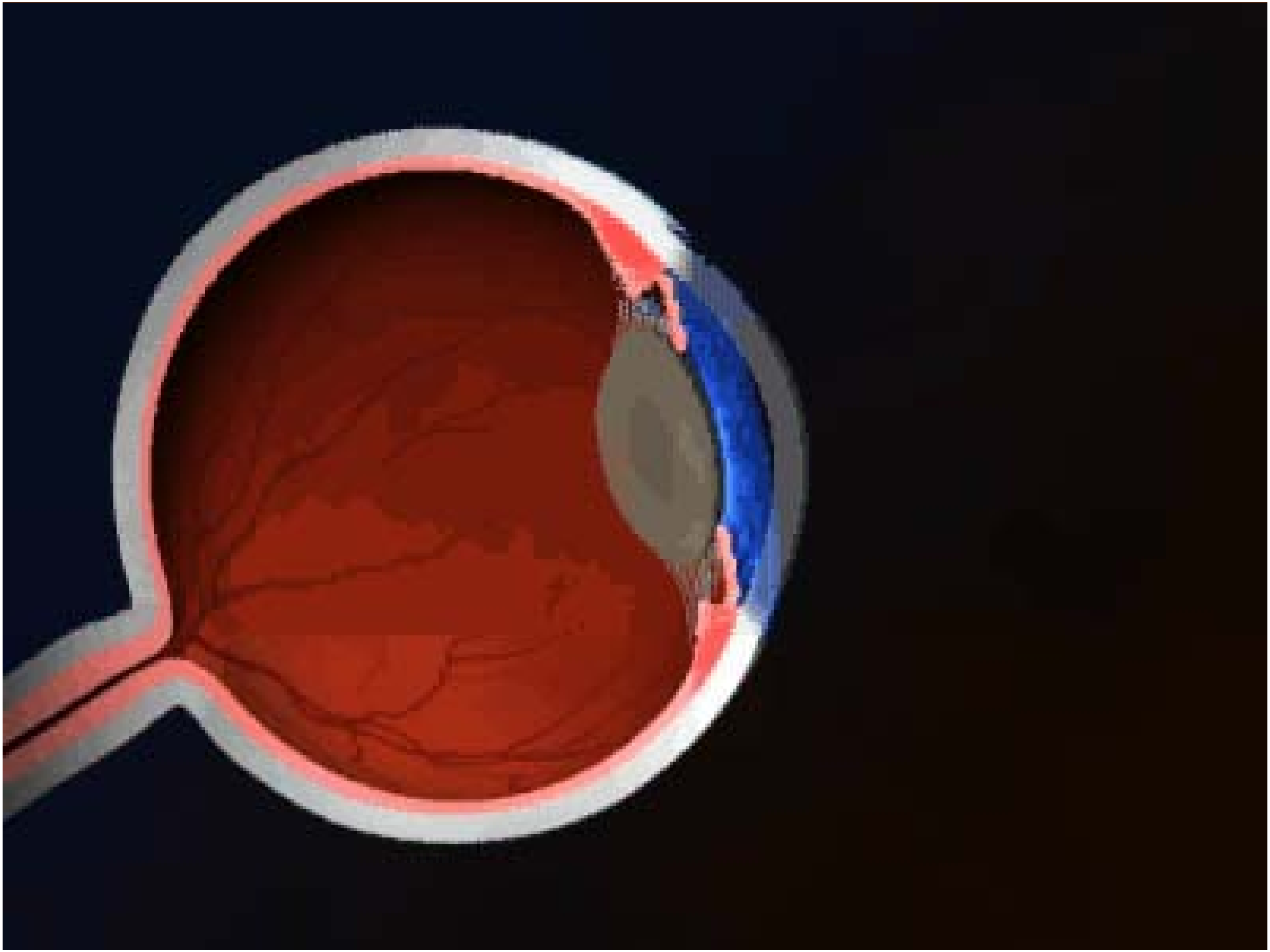


- **Method for Mapping the Refractive and Aberration Profile of the Eye**

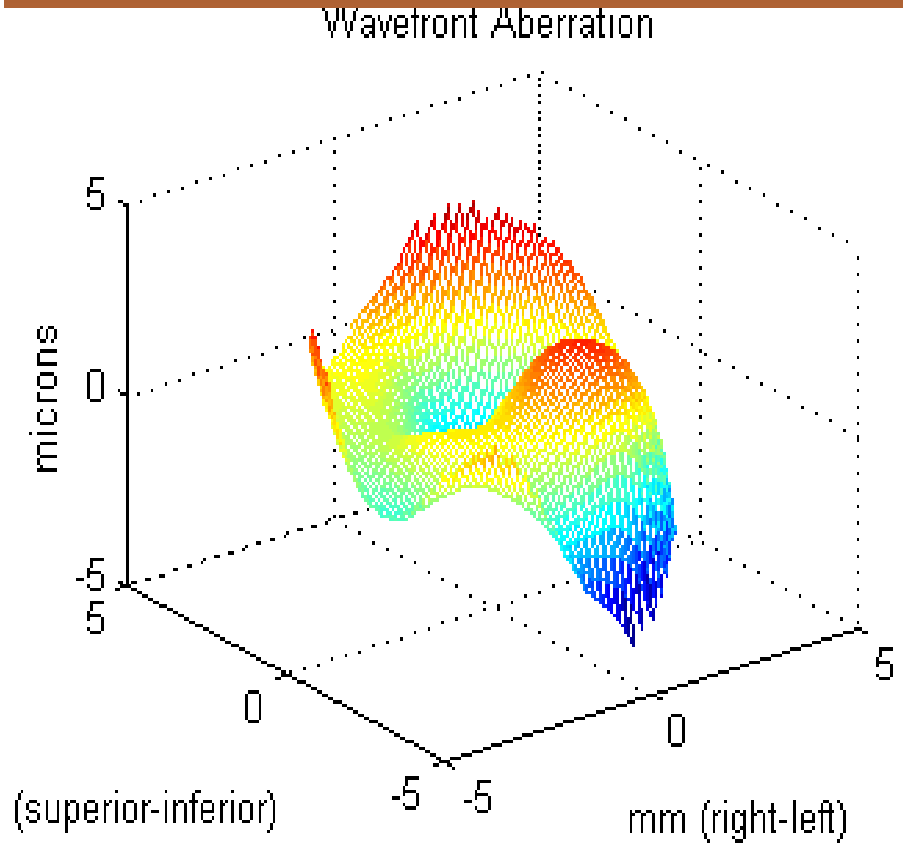
Slide courtesy of Ray Applegate, OD,PhD

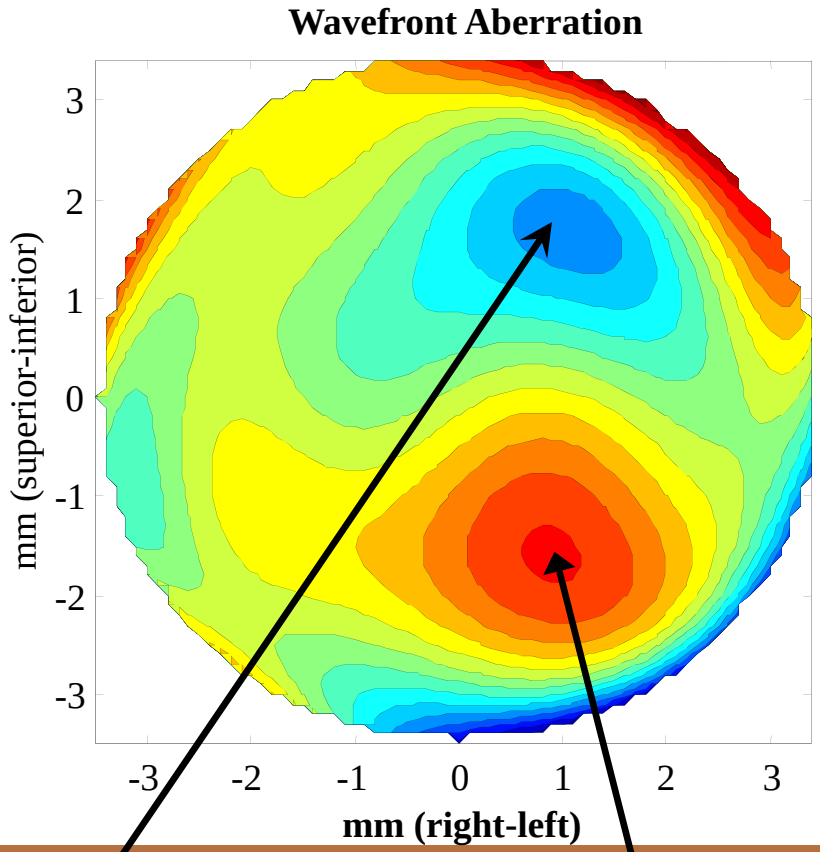
Aberrations at Retinal Plane





Wavefront Error as a Refractive Map





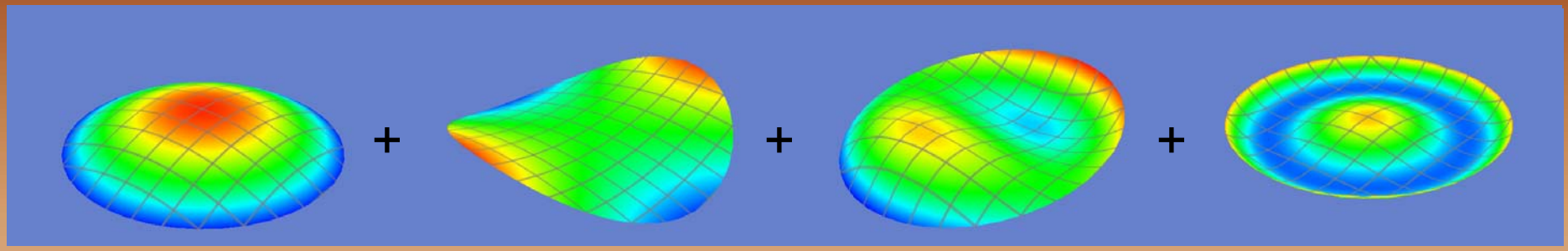
3-D Map

2-D Map

Myopic

Hyperopic

Wavefront Components



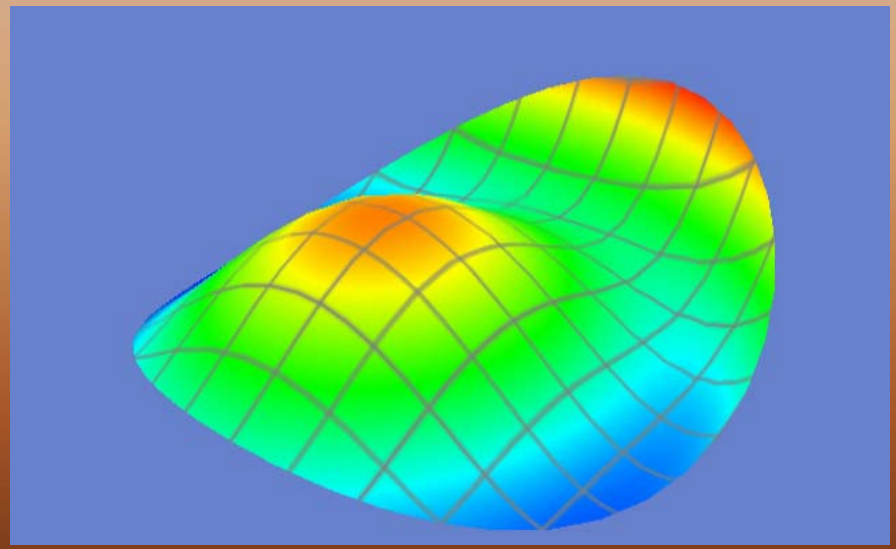
-0.27 μm
Defocus

+0.25 μm
Astigmatism

+0.24 μm
Coma

+0.13 μm
Spherical Aberration

Complete
Wavefront



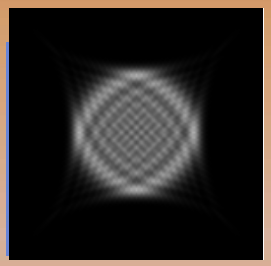
Total RMS Error
0.46 μm

Zernike Aberrations

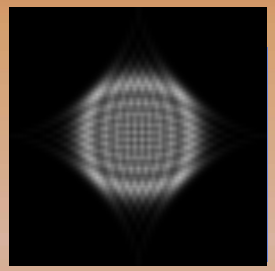
Pupillary Plane to Retinal Plane

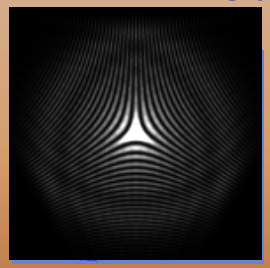
Zernike Point Spread Functions

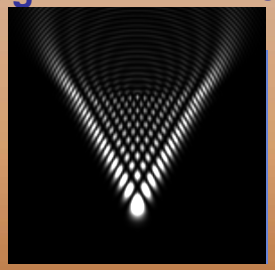
Zernike OPD Maps

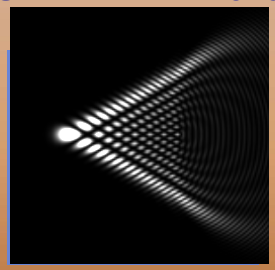

Obl Astig

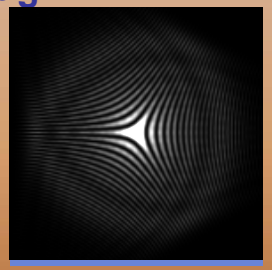

Defocus

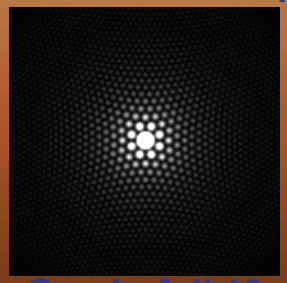

Card Astig

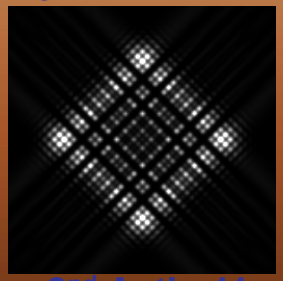

Trifoil 6


Coma 7

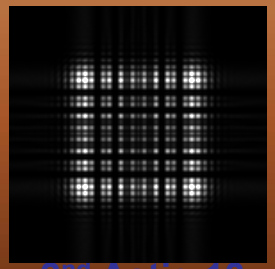

Coma 8

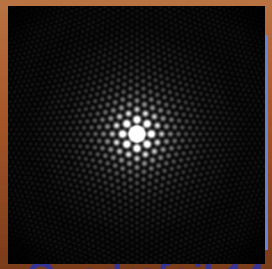

Trifoil 9


Quadrafoil 10


2nd Astig 11

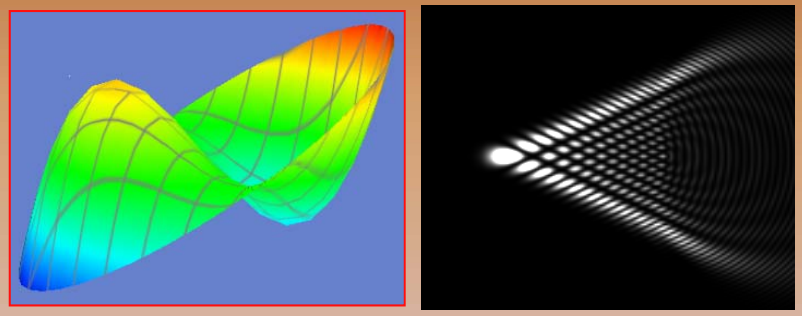

Sph Ab 12


2nd Astig 13


Quadrafoil 14

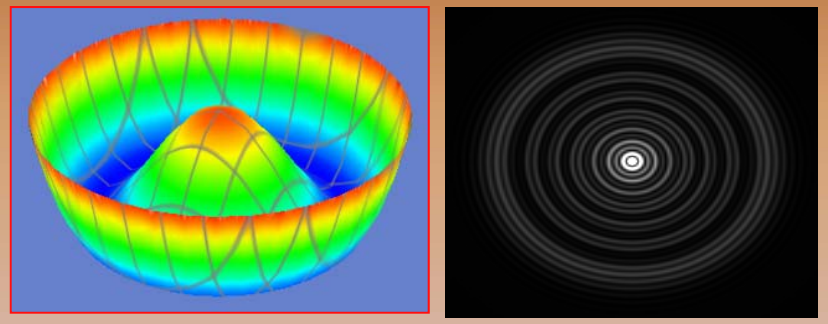
Clinical Symptoms Correlate with Convolved Aberrations?

Coma



Double (Shadow) Vision

Spherical Ab

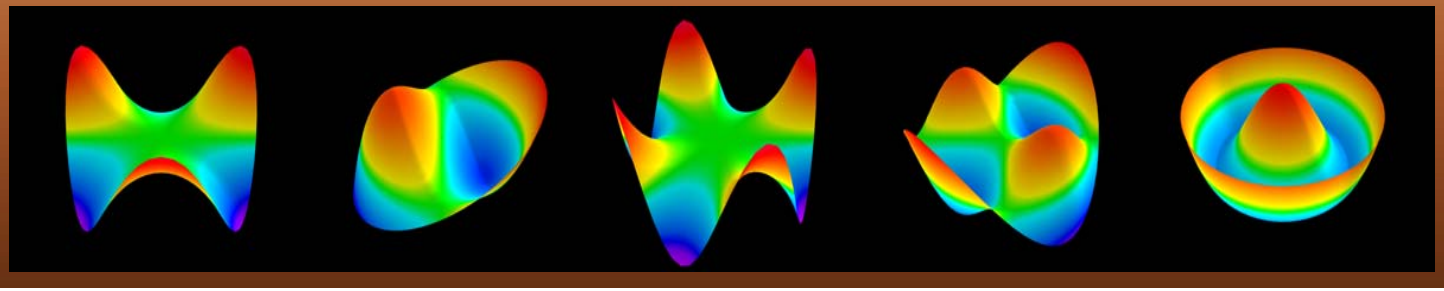


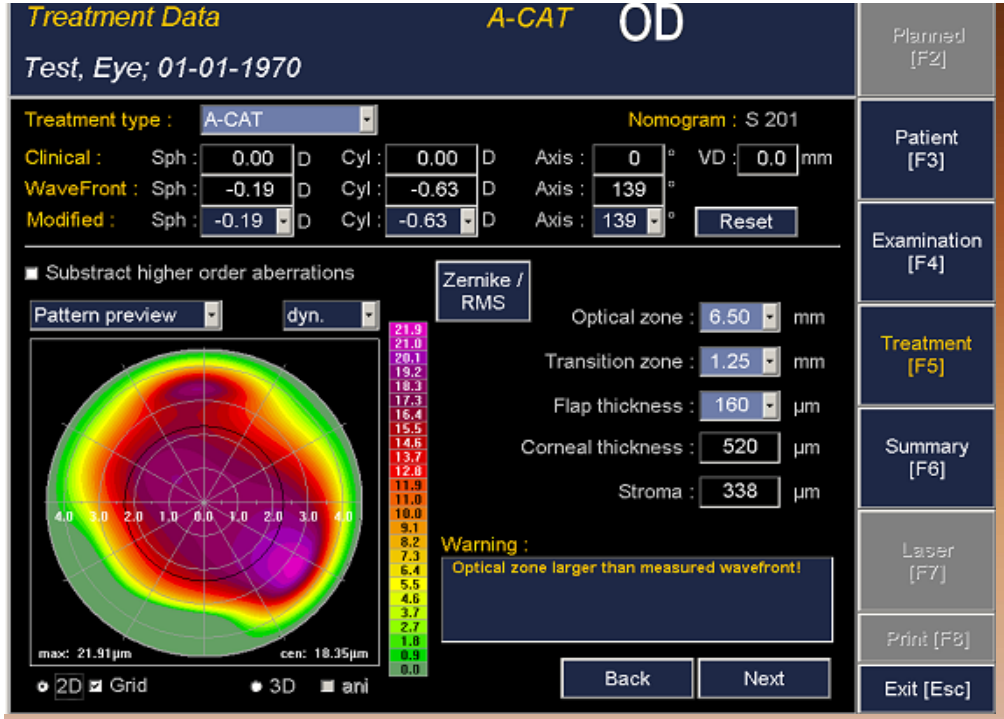
Halo/Glare/Starburst

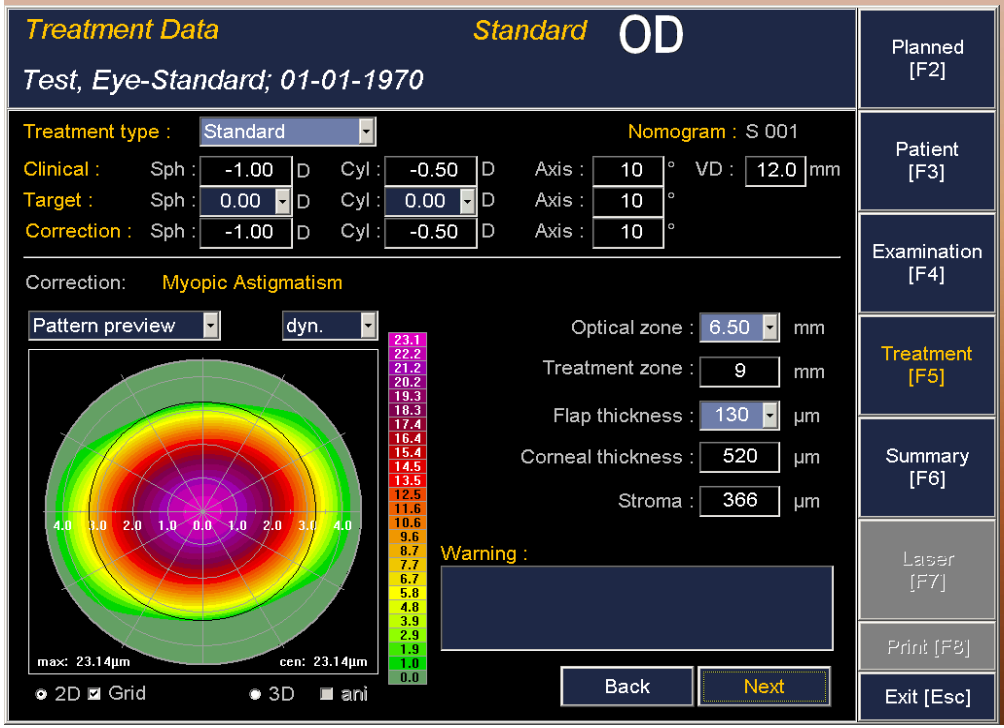
Wavefront-Guided Laser Systems

- WaveLight and Alcon were first to begin WFG LASIK in 1999 (First FDA approval in 2002).
- Visx, B&L followed with their wavefront-guided treatments.
- WaveLight soon realized that most of the advantage was from not inducing aberrations

Caused them to largely abandon Wavefront-Guided treatments for "Wavefront Optimized".







Definitions

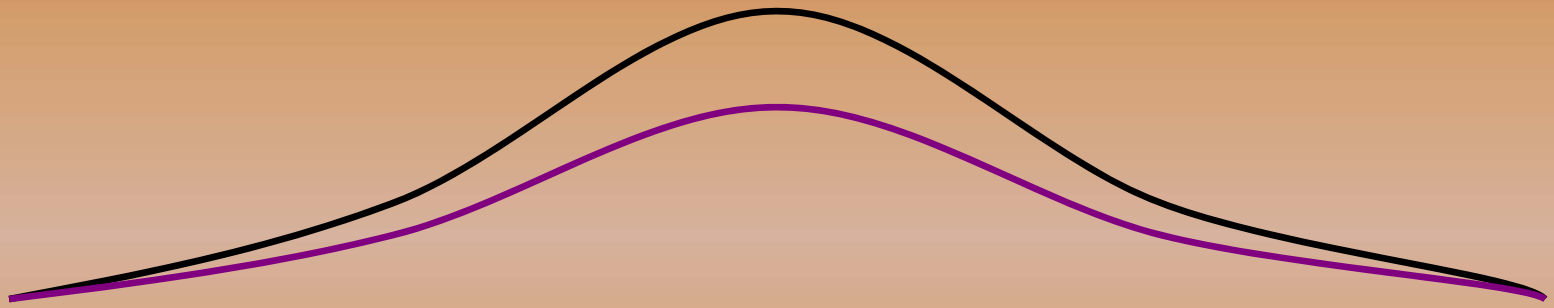
Wavefront Guided

- Refractive + Higher-Order aberrations such as coma, spherical aberration, etc.

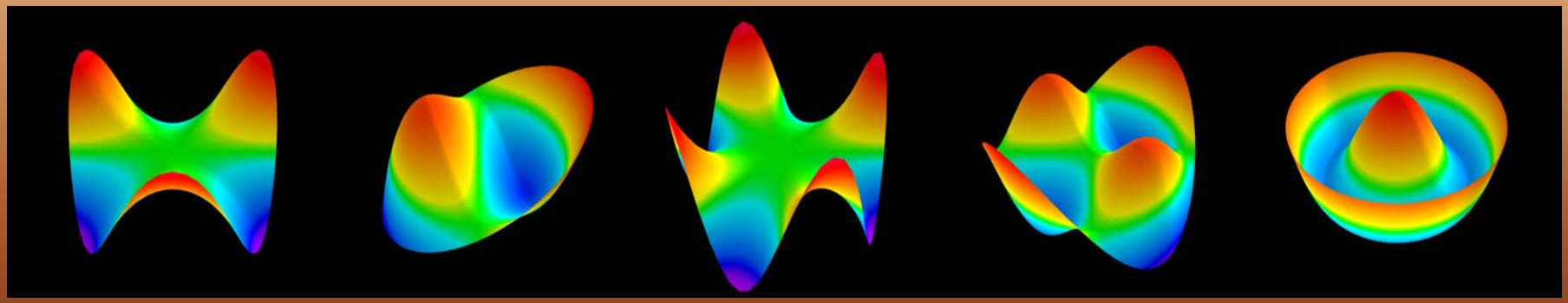
Wavefront Optimized

- Treatment is based on phoropter refraction
- "Pure Refractive Treatment" – has no effect on higher order aberrations
- Maintains the "prolate" corneal shape

Why Consider WFO Ablation Instead of WFG in Myopic Femto-LASIK Eyes?



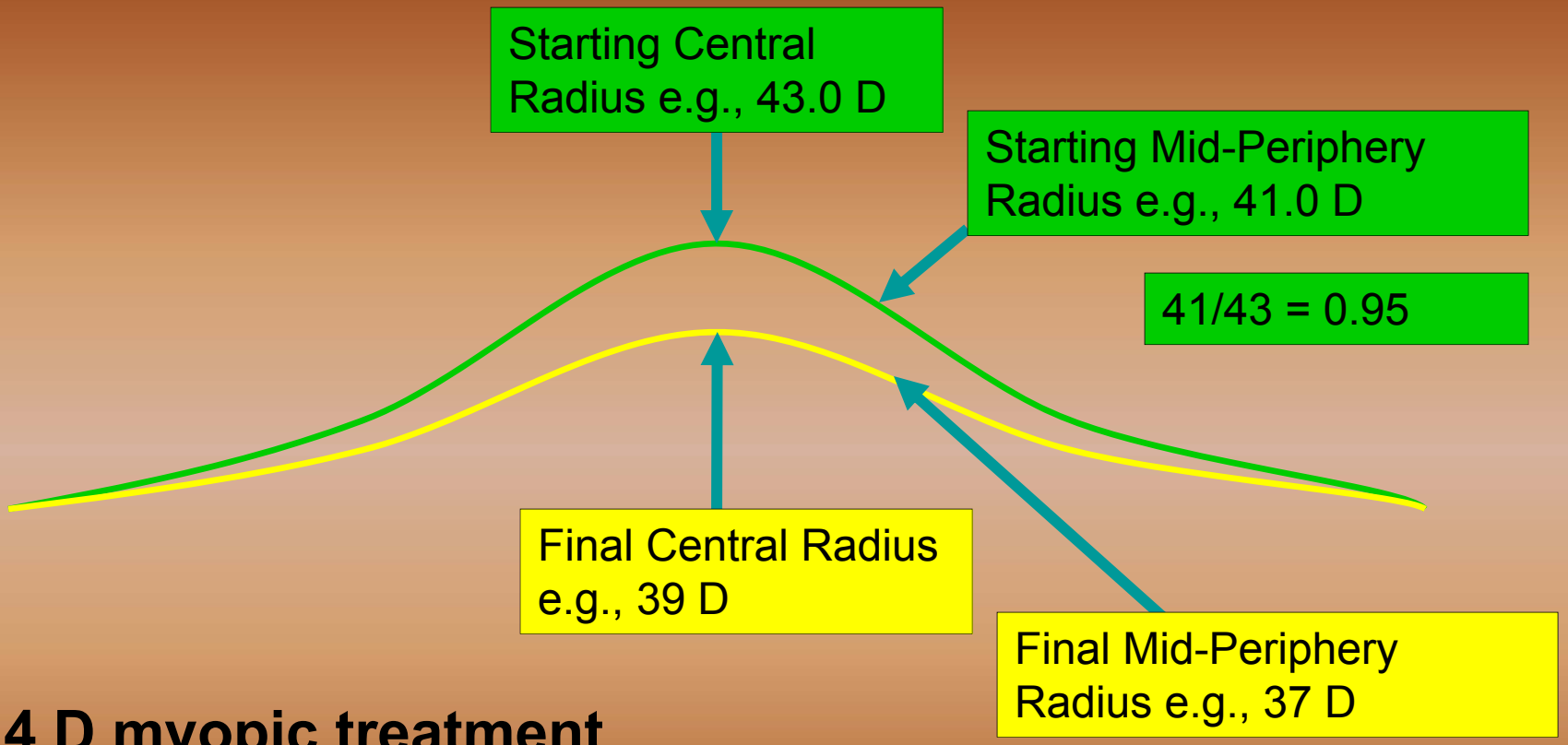
vs.



WF Guided Potential Limitations

- **WF Guided** = Treatment of the spherico-cylindrical refractive error + the pre-existing higher order wavefront error
  - **Optimal laser beam (size, shape)**
  - **High repetition rate**
  - **Reliable wavefront measurement**
  - **Perfect centration !!!**
  - **Performance Eye tracker !!**

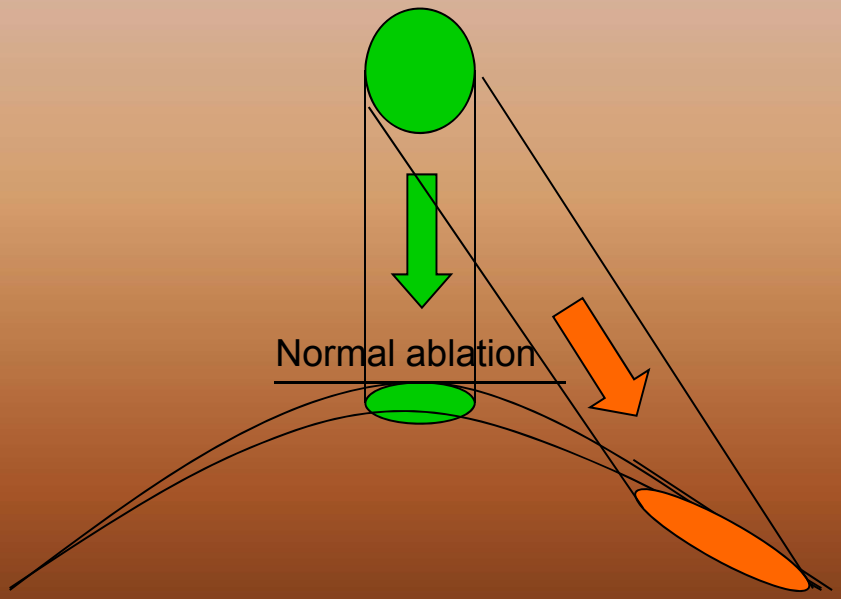
"Wavefront-Optimized"



- **4 D myopic treatment**
- **Goal is to maintain the same ratio of the central and mid-peripheral radii**

WF Optimized Potential Benefit

- **WF Optimized** = Designed to minimize the induction of spherical aberration by:
  - Pre-compensating for the induction of SA
  - **Maintaining the corneal asphericity**



WFO compensates for the loss of laser ablation efficiency in the mid-periphery (**cosine effect**)

Results analysis

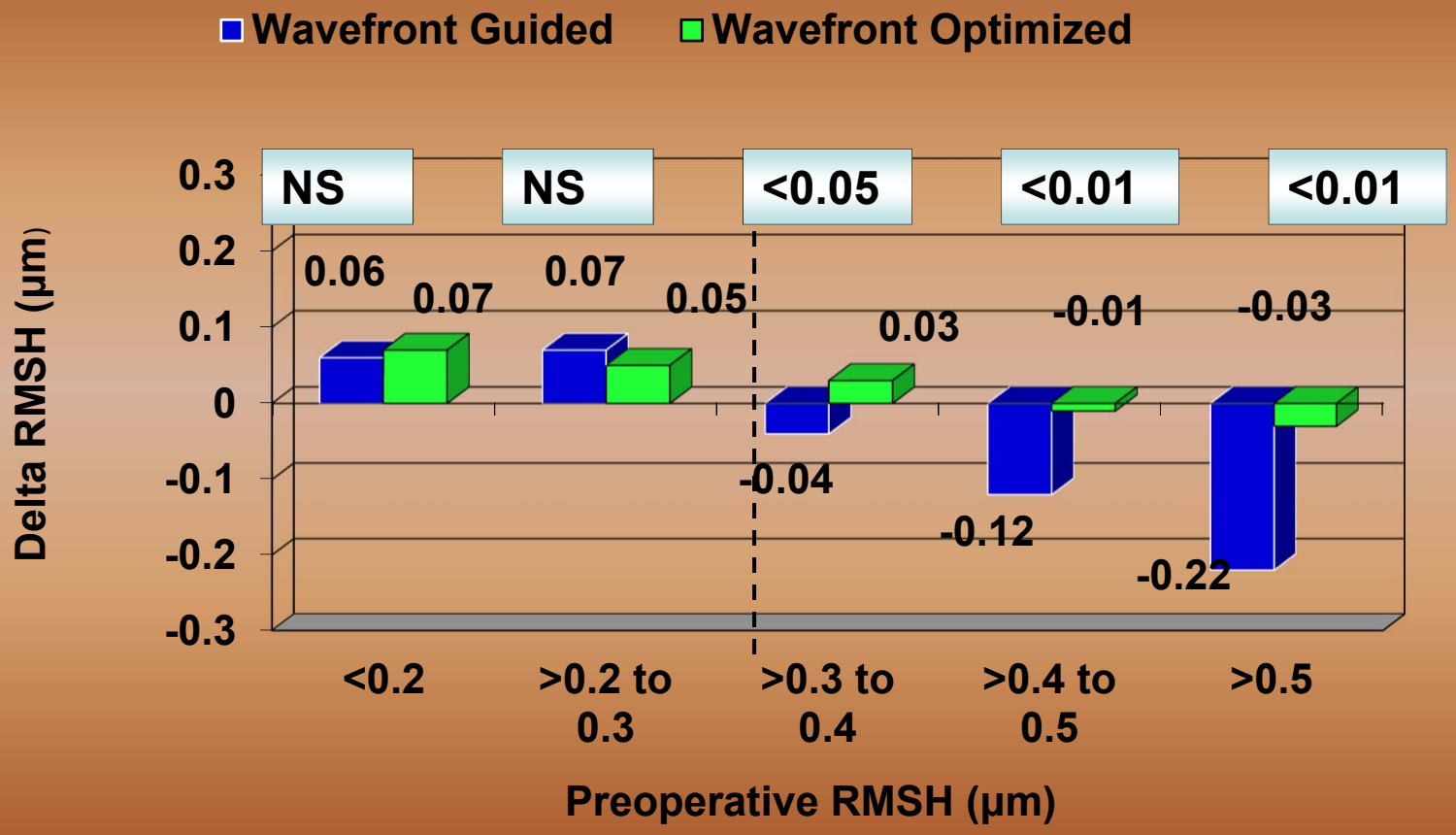
Wavefront-optimized Versus Wavefront-guided LASIK for Myopic Astigmatism With the ALLEGRETTO WAVE: Three-month Results of a Prospective FDA Trial

Karl G. Stonecipher, MD; Guy M. Kezirian, MD, FACS

J Refract Surg. 2008;24: S424-S430

- In 83% of eyes with **< 0.3 µm preop RMS HOAs:**
  - **No difference** in post operative WF errors
- In eyes with **> 0.3 µm preop RMS HOAs:**
  - WFG showed **less post op RMS HOAs** than WFO

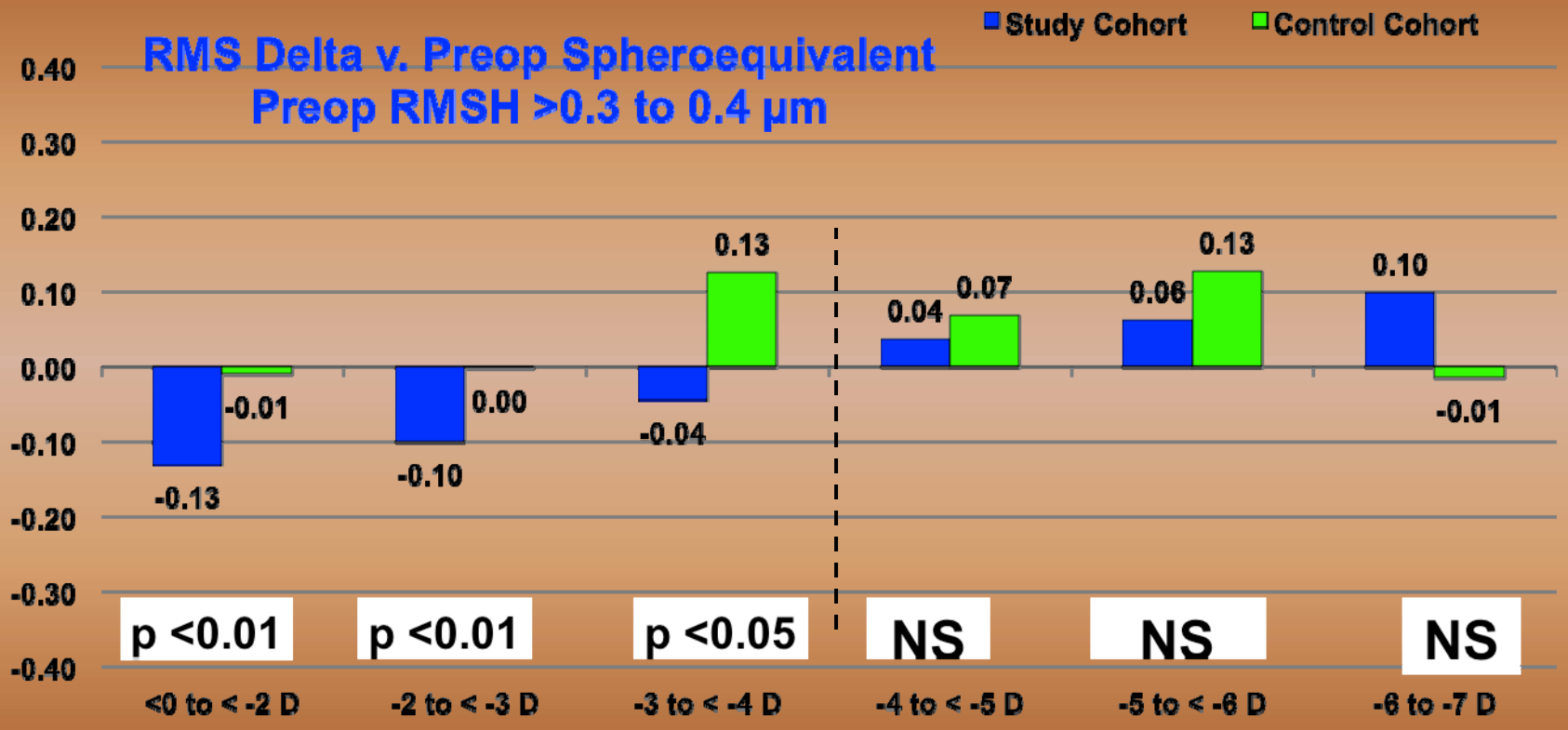
Change in Higher Order Aberrations (HOAs) - 6.00 mm Pupil



> 0.3 um HOAs: WFG BETTER than WFO

Up to 0.3 um HOAs: WFO = WFG

Change in Higher Order Aberrations (HOAs) - 6.00 mm Pupil



Less than -4.00 D: WFG BETTER than WFO

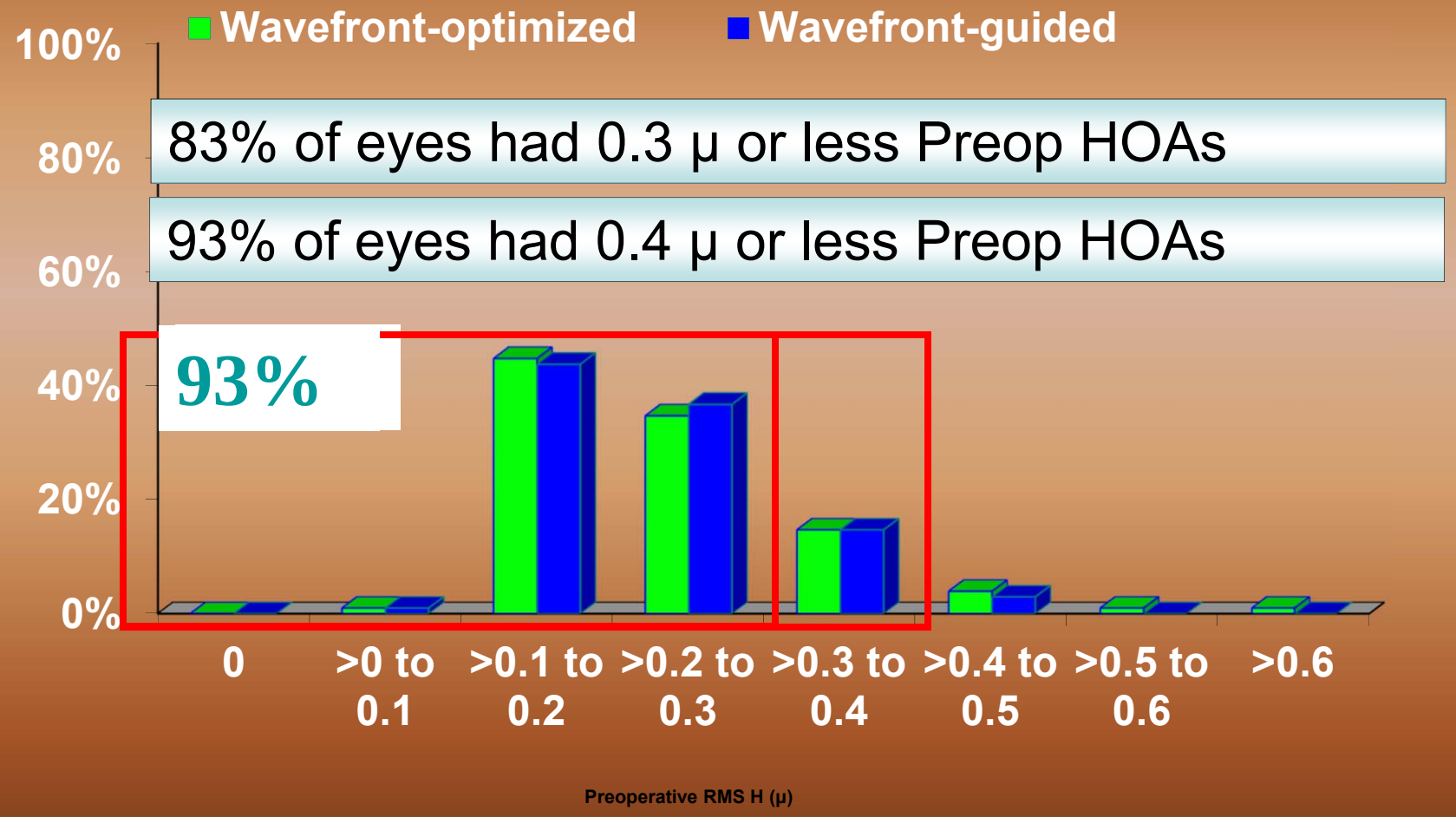
-4.00 D and Above: WFO = WFG

Patient Selection based on PreOp Higher Order Aberrations (HOAs)

Preop RMS_H	-1 to < -2	-2 to < -3	-3 to < -4	-4 to < -5	-5 to < -6	-6 to < -7
<=0_2 µ	WO	WO	WO	WO	WO	WO
>0_2 to 0_3 µ	WO	WO	WO	WO	WO	WO
>0_3 to 0_4 µ	WG	WG	WG	WO	WO	WO
>0_4 µ	WG	WG	WG	WG	WG	WG

Spheroequivalent Treatment Range (D)

Preop Higher Order Aberration (HOAs) Distribution - 6.00 mm Pupil



Results analysis

Meta-Analysis of WFG vs WFO LASIK for myopia

Optom Vis Sci, Sept 2011

Feng J, Yu J, Wang Q

7 studies & 930 Eyes

- **No difference in UCDVA, BSCVA, MRSE**
- **Post operative induction of HOAs :**

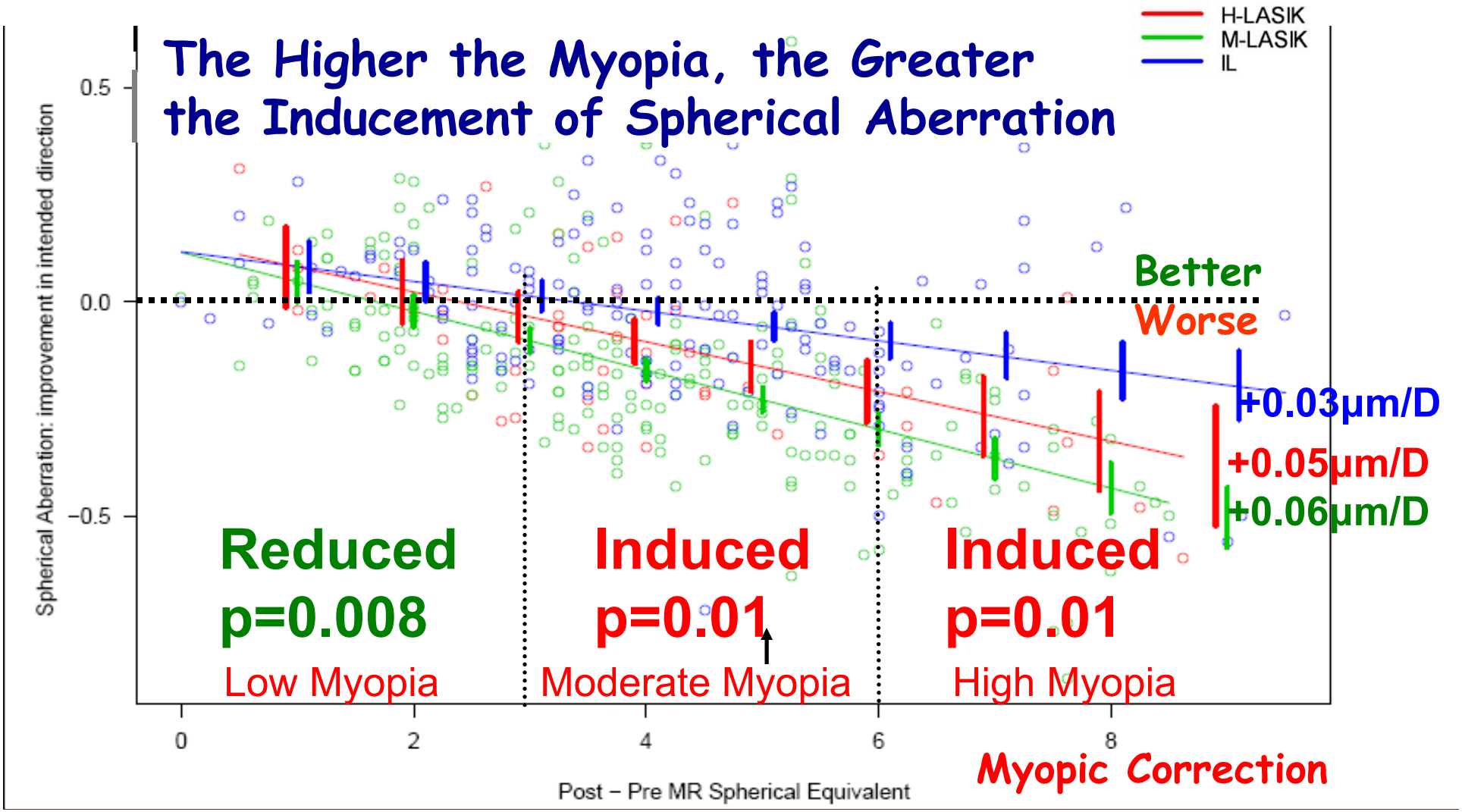
No difference in eyes with preoperative **RMS HOA < 0.3 µm**

WFG has significantly less post operative HOAs than WFO in eyes with preop **RMS HOAs >0.3 µm**

HOA & Spherical Aberration Change

Wavefront Guided LASIK with Custom Cornea

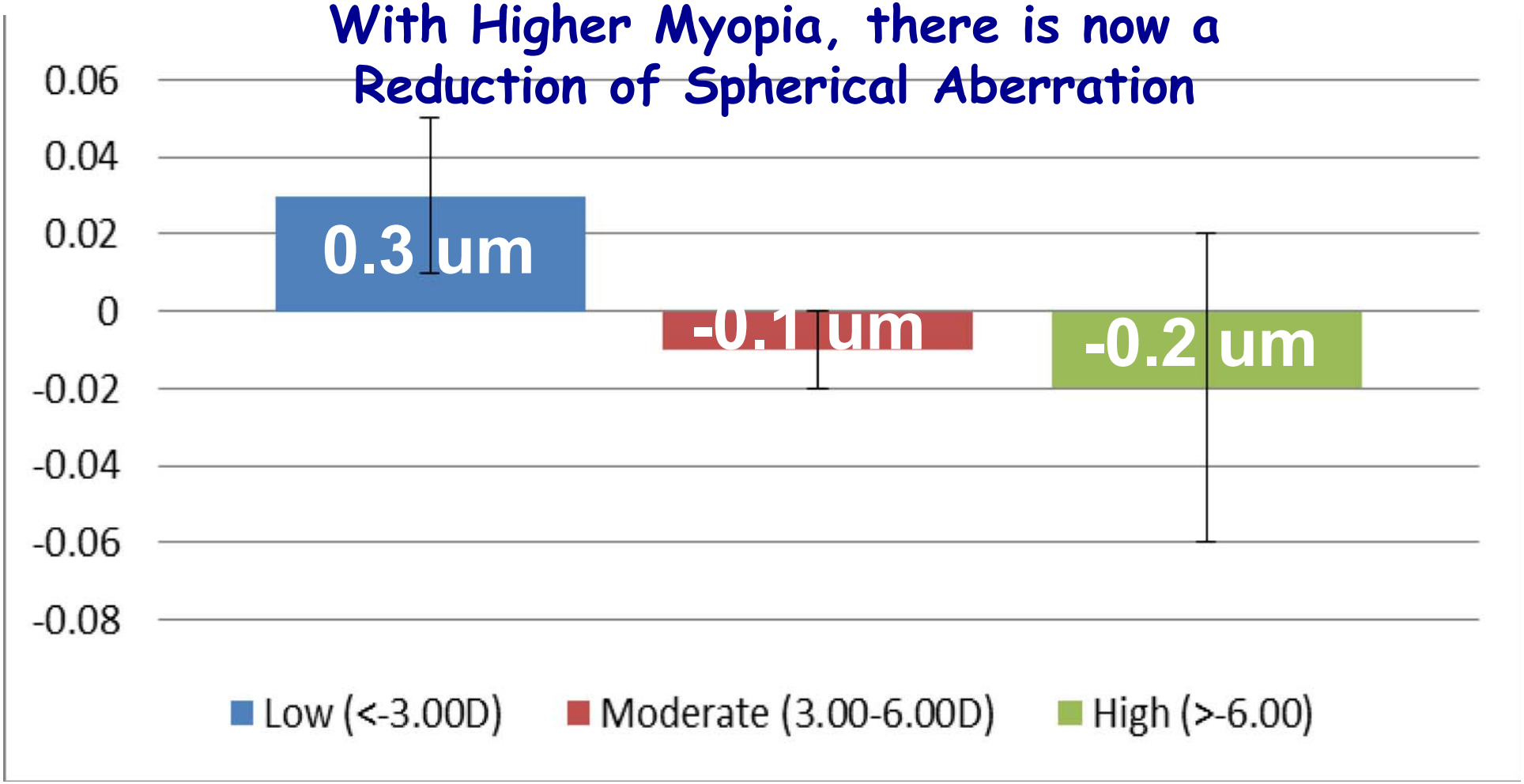
Medeiros FW, et al. ***J Refract Surg.*** **2007** November;23(9):880-887.



Spherical Aberration Change

Wavefront Optimized LASIK with WL Allegretto

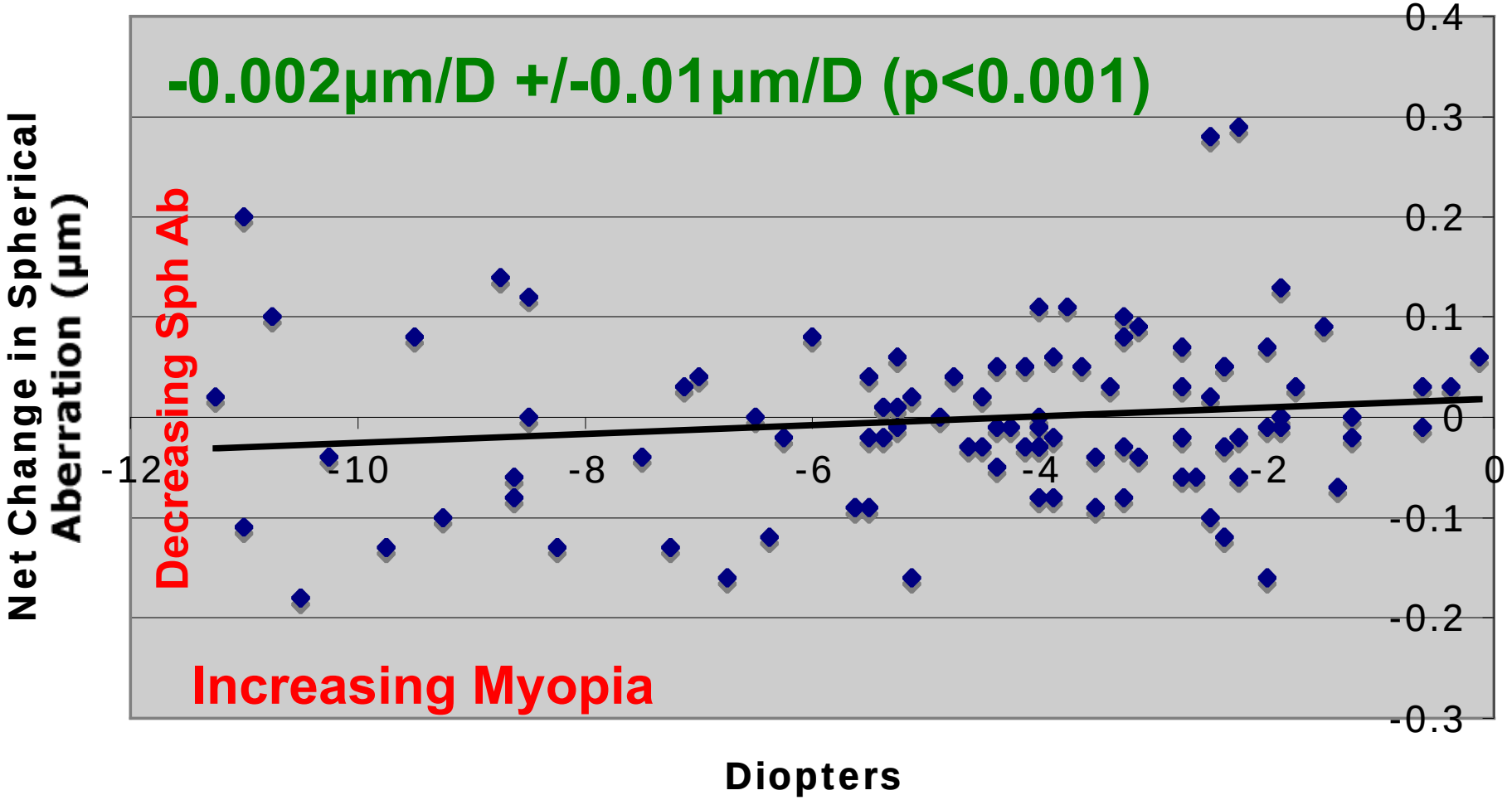
Au JD, Krueger RR. ***J Refract Surg*. 2012** Nov;28(11 Suppl): S821-5.



Spherical Aberration Change

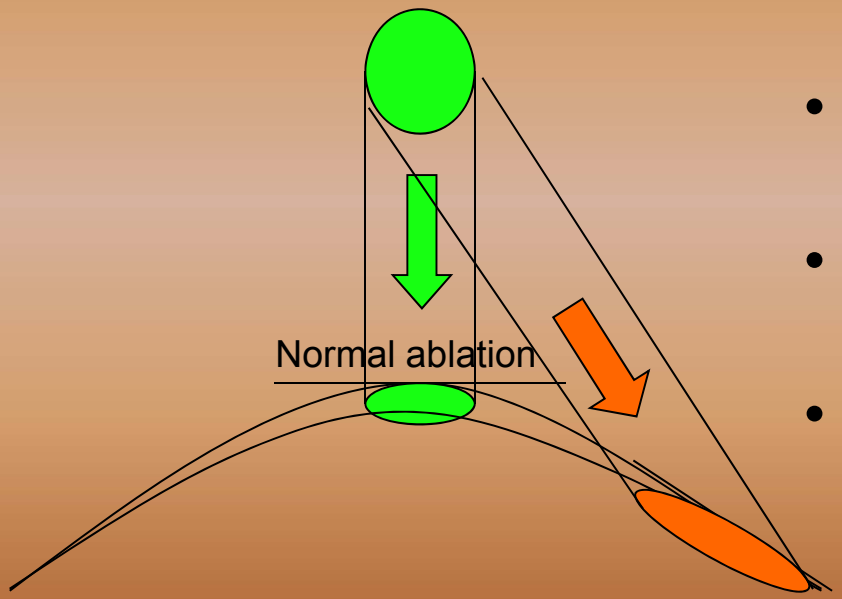
Myopic Correction Versus Net Postoperative Change in Spherical Aberration

Au JD, Krueger RR. ***J Refract Surg*. 2012** Nov;28(11 Suppl): S821-5.



Wavefront Optimized Compensates for Peripheral Pulse Reduction

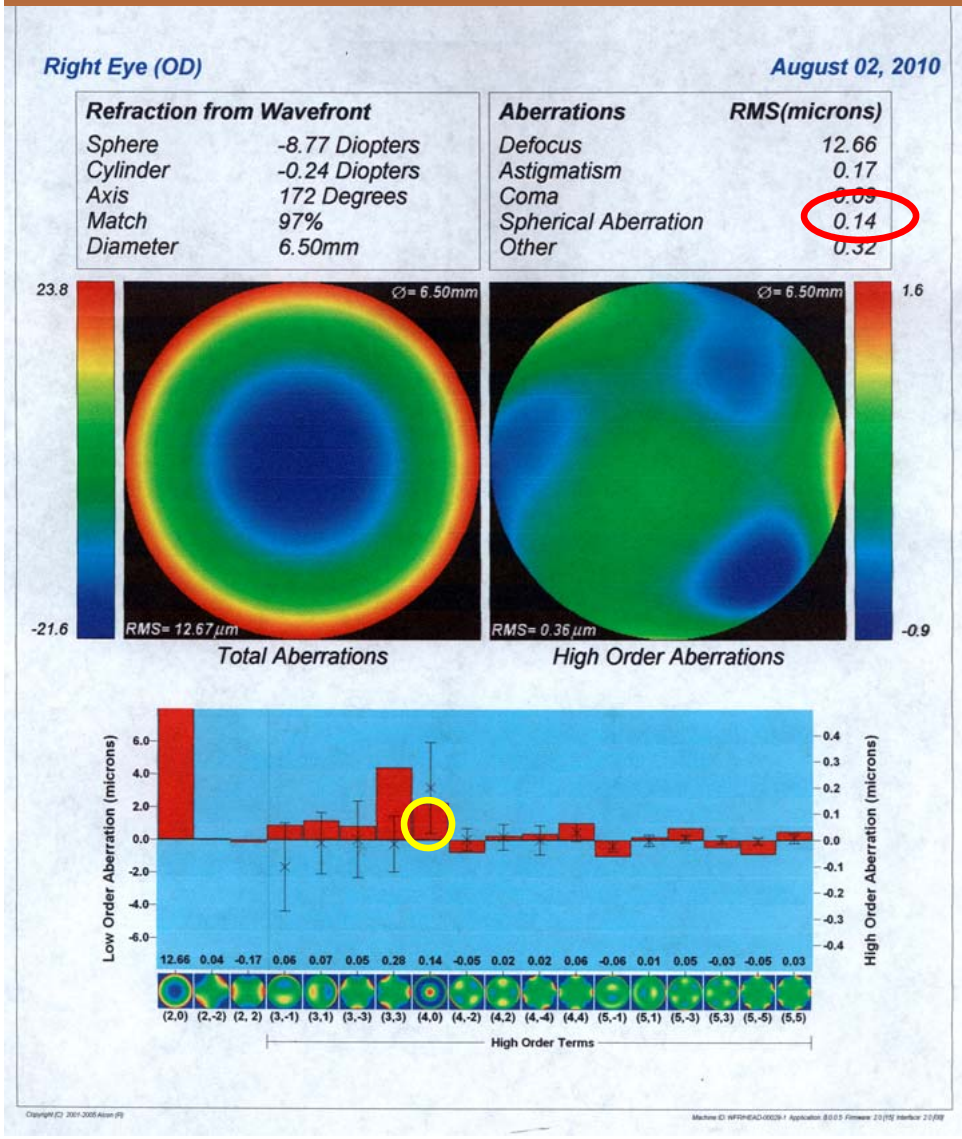
- In the periphery, laser pulses strike the cornea at an angle and the ablation energy is reduced due to:

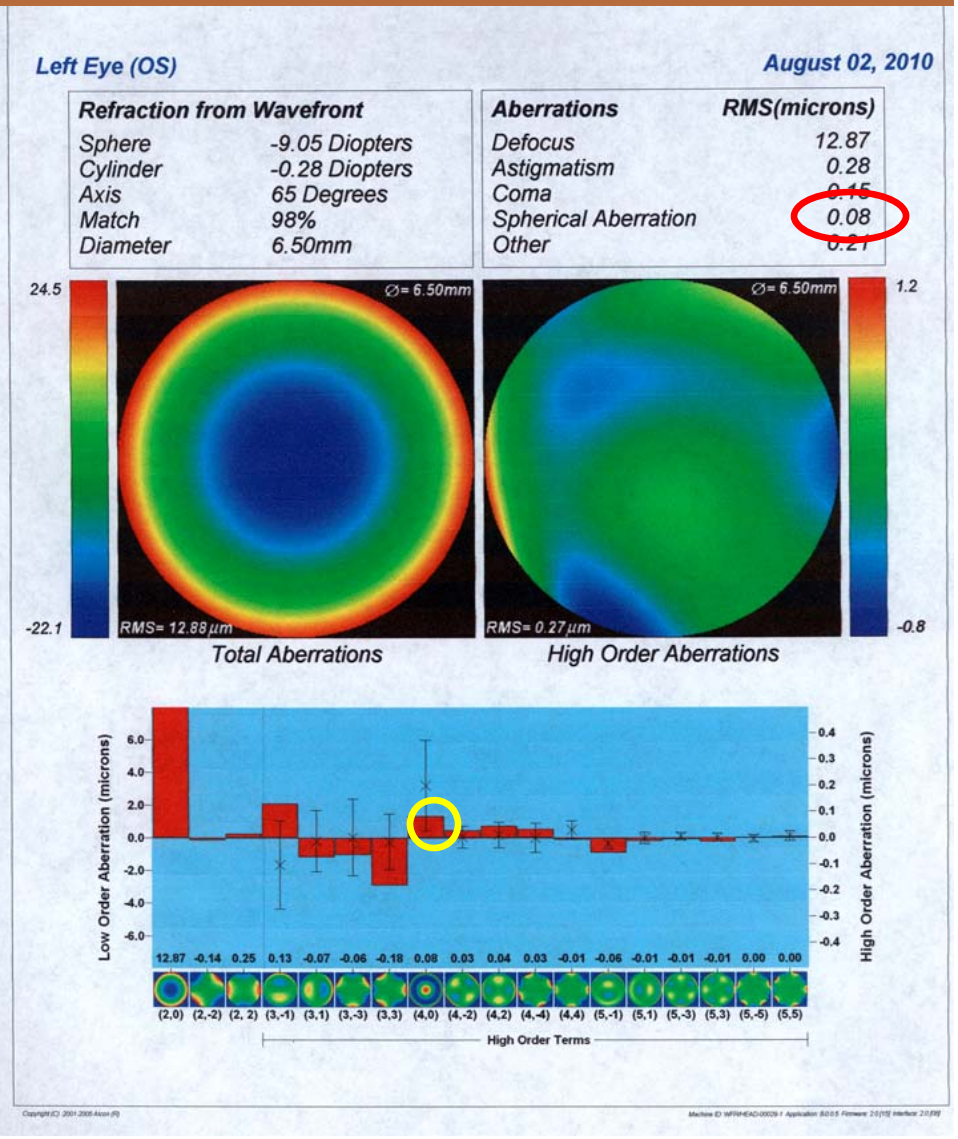


- The cosine effect
  (Results in Beam Ovation)
- The angle of incidence
  (Reflects Laser Energy)
- Increased plume interference

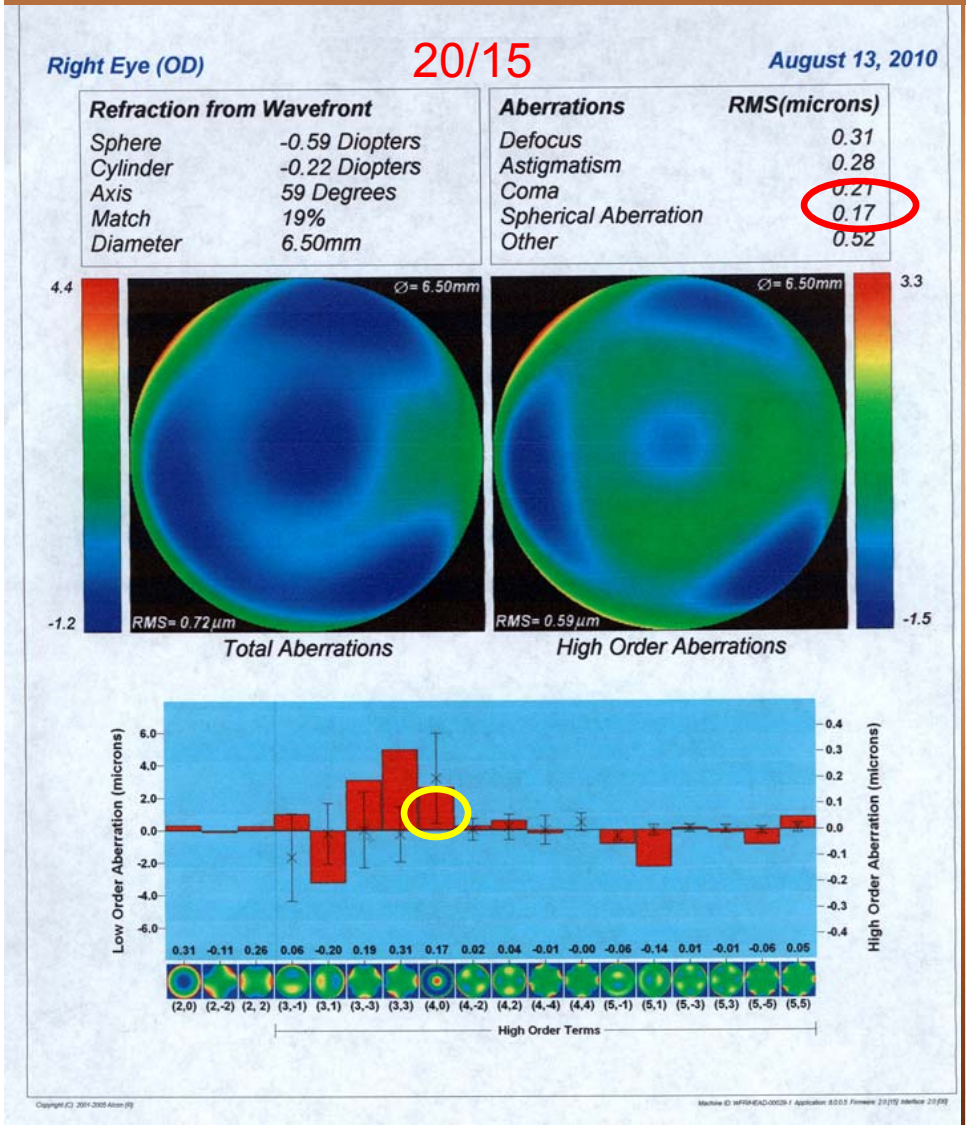
WFO compensates by delivering extra pulses in the periphery for little/no induced spherical aberration

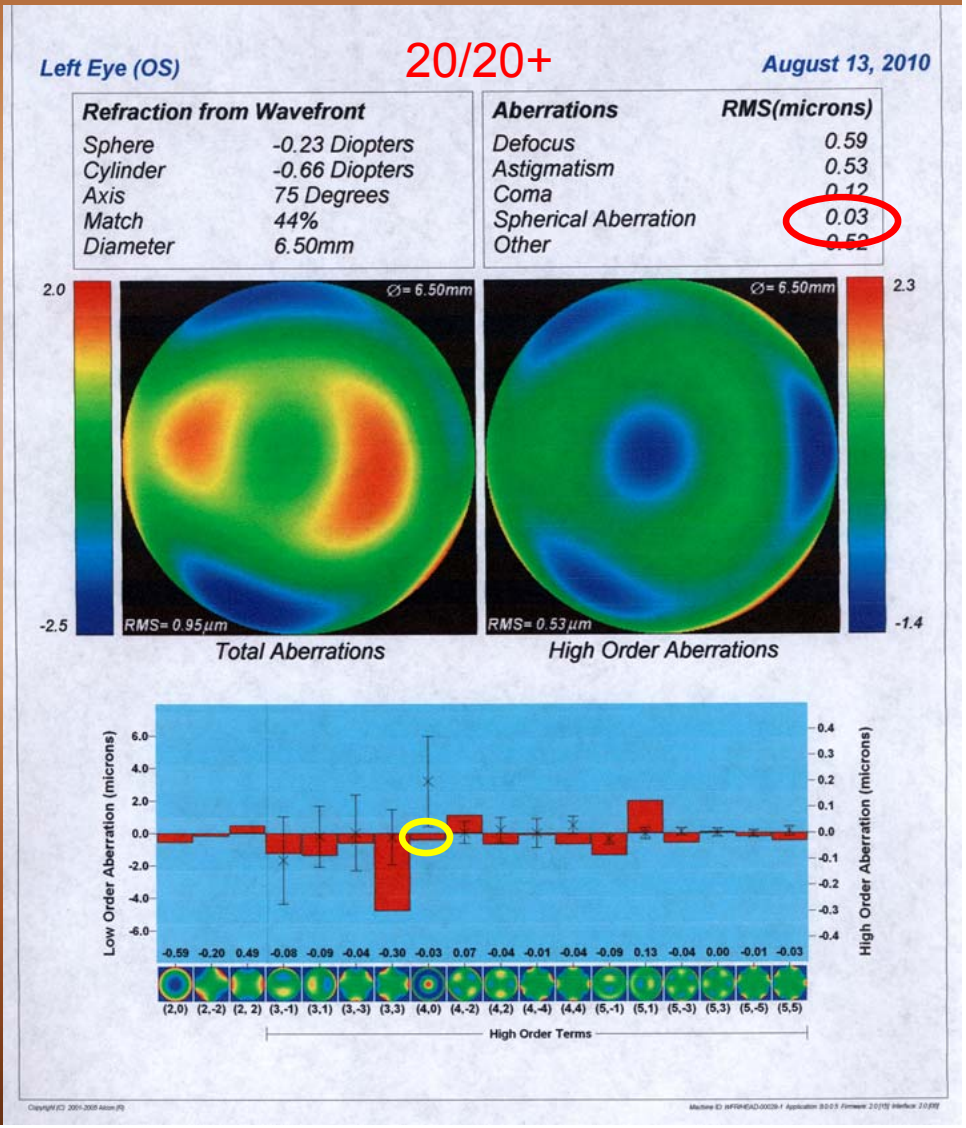
High Myopic LASIK Among Ophtho Residents at Cleveland Clinic



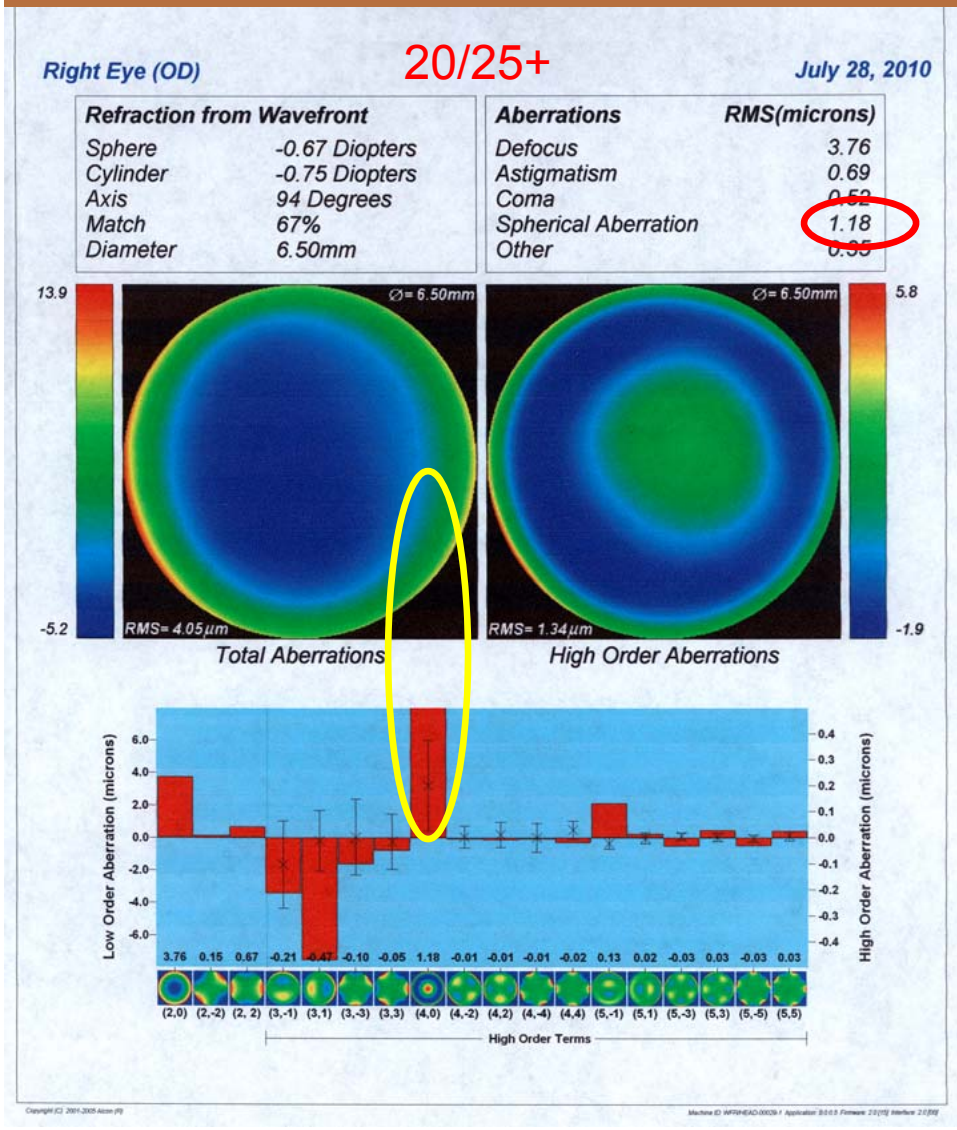


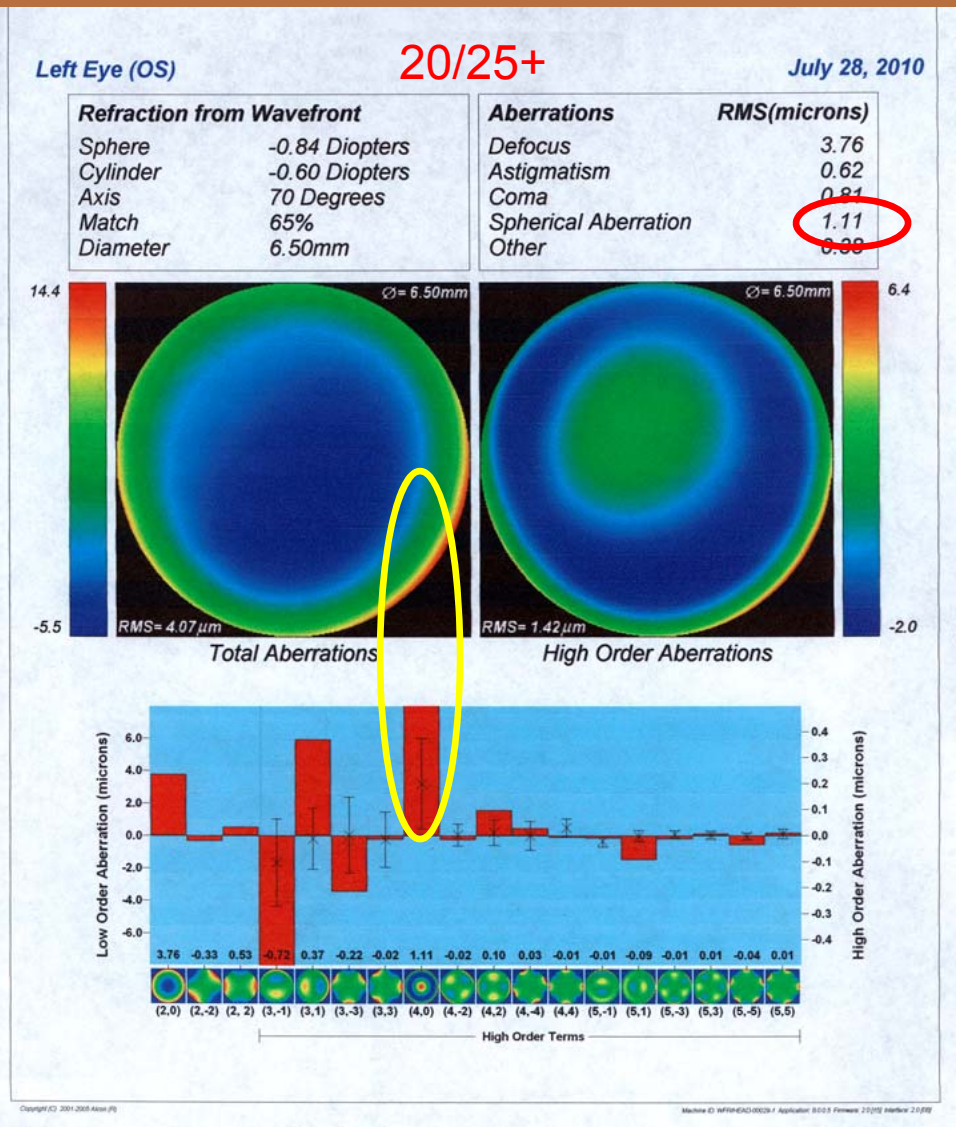
Cleveland Clinic Ophtho Resident Treated with Allegretto Wave 400Hz





Cleveland Clinic Ophtho Resident Treated with VISX Wavescan





Summary

- WFG has **No Benefit** for Myopic Eyes with **HOAs < 0.3 um**.
- **83 %** of Eyes have **HOA <0.3 um**.
- Reasons for the Lack of Benefit are:
  - Small Decentrations and Cyclorotations.
  - Failure of Iris Recognition and Tracking.
  - HOAs <0.3 um not significant with Adaptive Optics.
  - For Ideal Visual Performance, HOAs should be Optimized, rather than Minimized.
  - Treating Higher Myopia Induce Spherical Aberration, especially when profile in not WF Optimized.

Evolution of LASIK

- First LASIK procedure – 1990
- First LASIK U.S. FDA approval – 1997
- First Customized LASIK procedure – 1999
- Femto-LASIK enters the U.S. – 2002
- Wavefront LASIK FDA approval – 2003
- Optimized LASIK FDA approval – 2005
- Topo-guided LASIK FDA approval – 2013
- First Commercial Topo LASIK – 2015

Topographic Guided LASIK

U.S. FDA Approved in 2013

ALLEGRO Topolyzer

ALLEGRETTO WAVE® Eye-Q

Study Device:
Laser Notebook + T-CAT Software

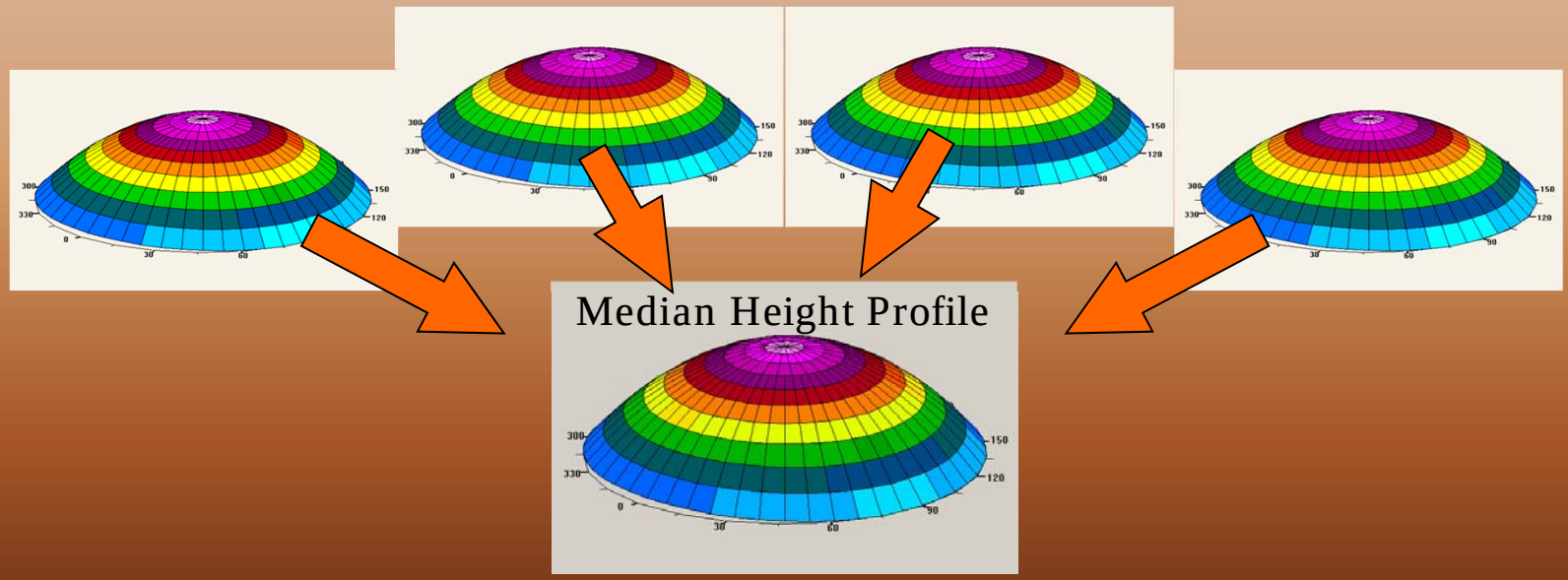
Alcon/WaveLight U.S. T-CAT Study

The WaveLight Range of LASIK FDA Approvals

- WFO Range
  - Myopia up to -12 D and astigmatism up to -6 D
  - Hyperopia up to +6 D and astigmatism up to 5 D, MRSE of +6 D
  - Mixed astigmatism of up to 6 D
- WFG Range
  - Myopia up to -7 D MRSE, up to -7 D sphere and up to 3 D astigmatism
- T-CAT Range
  - Myopia up to -9 D MRSE, up to -8 D sphere and up to -3 D astigmatism

T-CAT Software

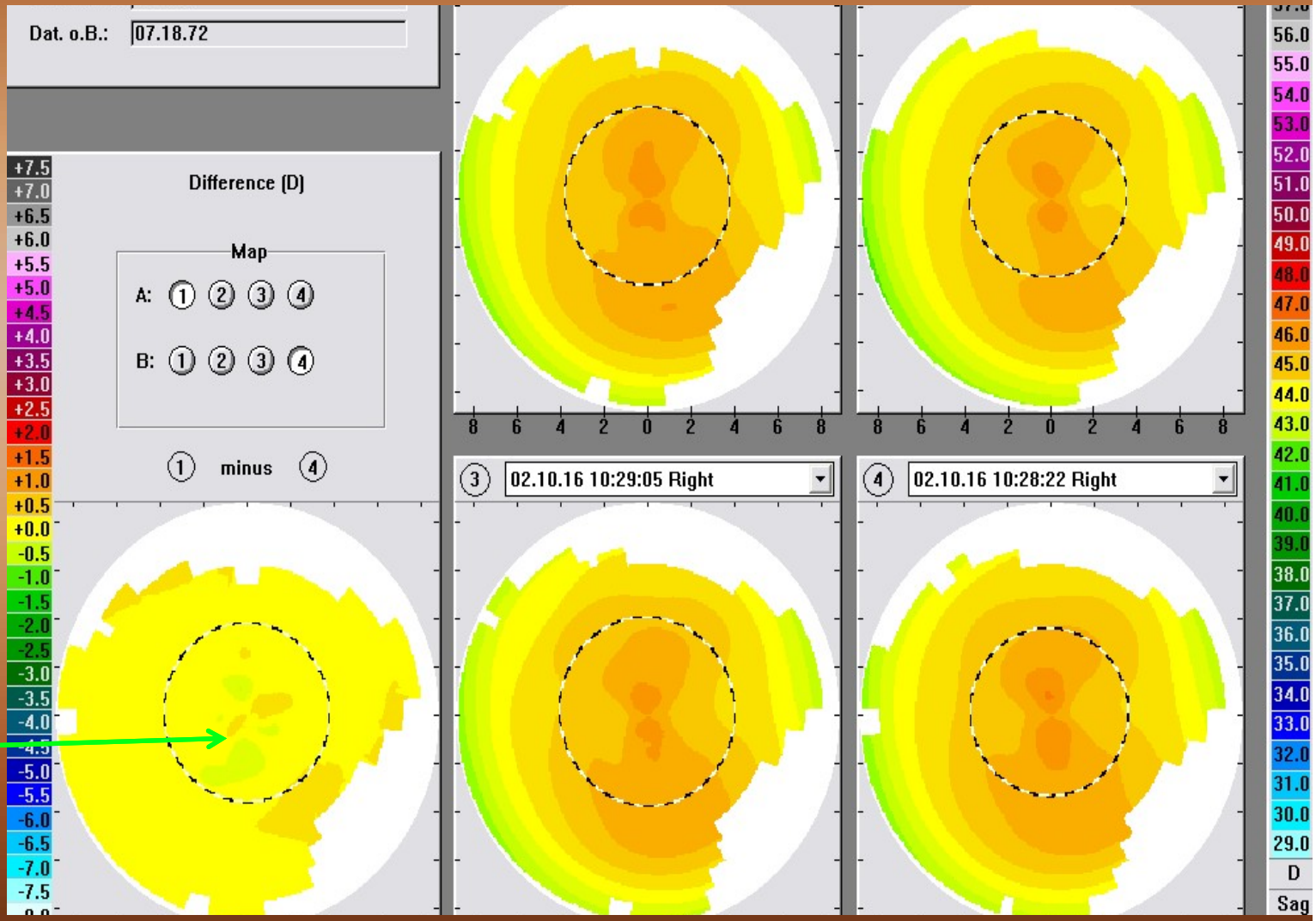
- Calculates treatment plan by combining manifest refraction data and corneal irregular shape data from topographer
- Four to eight images preferred
- Selection of single or median (averaged) image



Best 4 Maps Compared to Assure Consistency

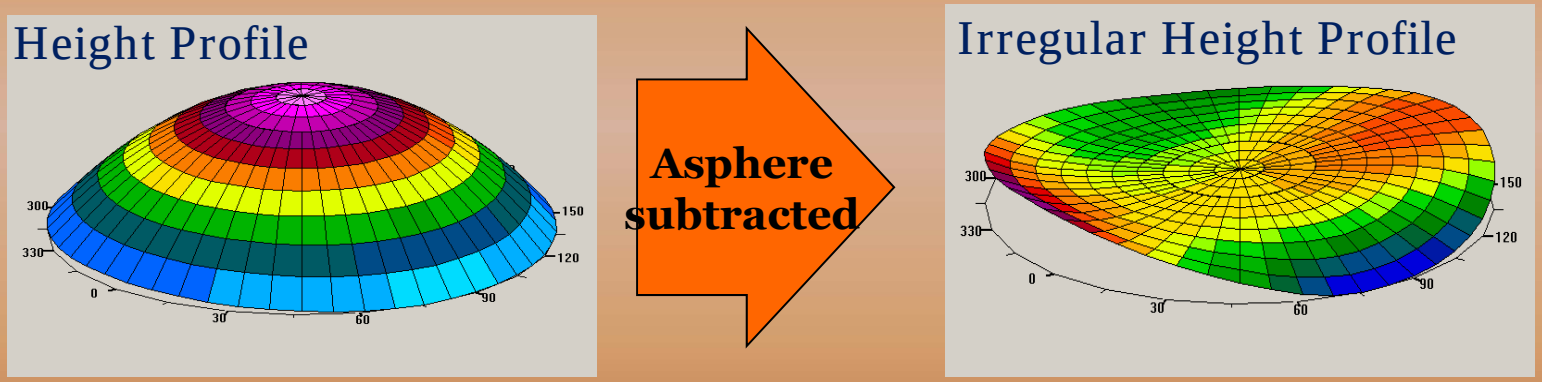
4 closest maps form a composite

Difference map used to make sure there are no central areas of more than 0.50 D difference.



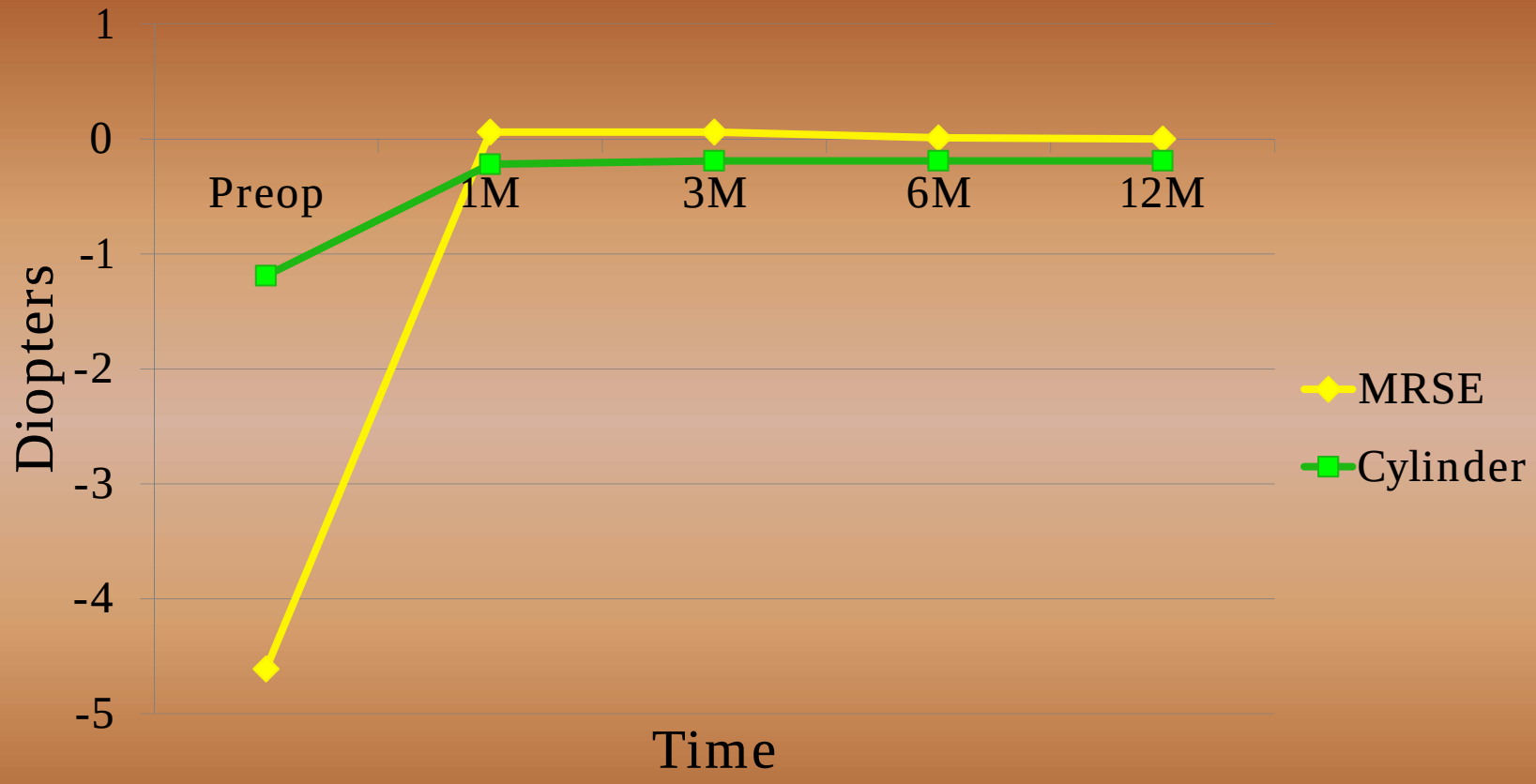
T-CAT Software

- Best fitting asphere (least square fit) subtracted from median height profile



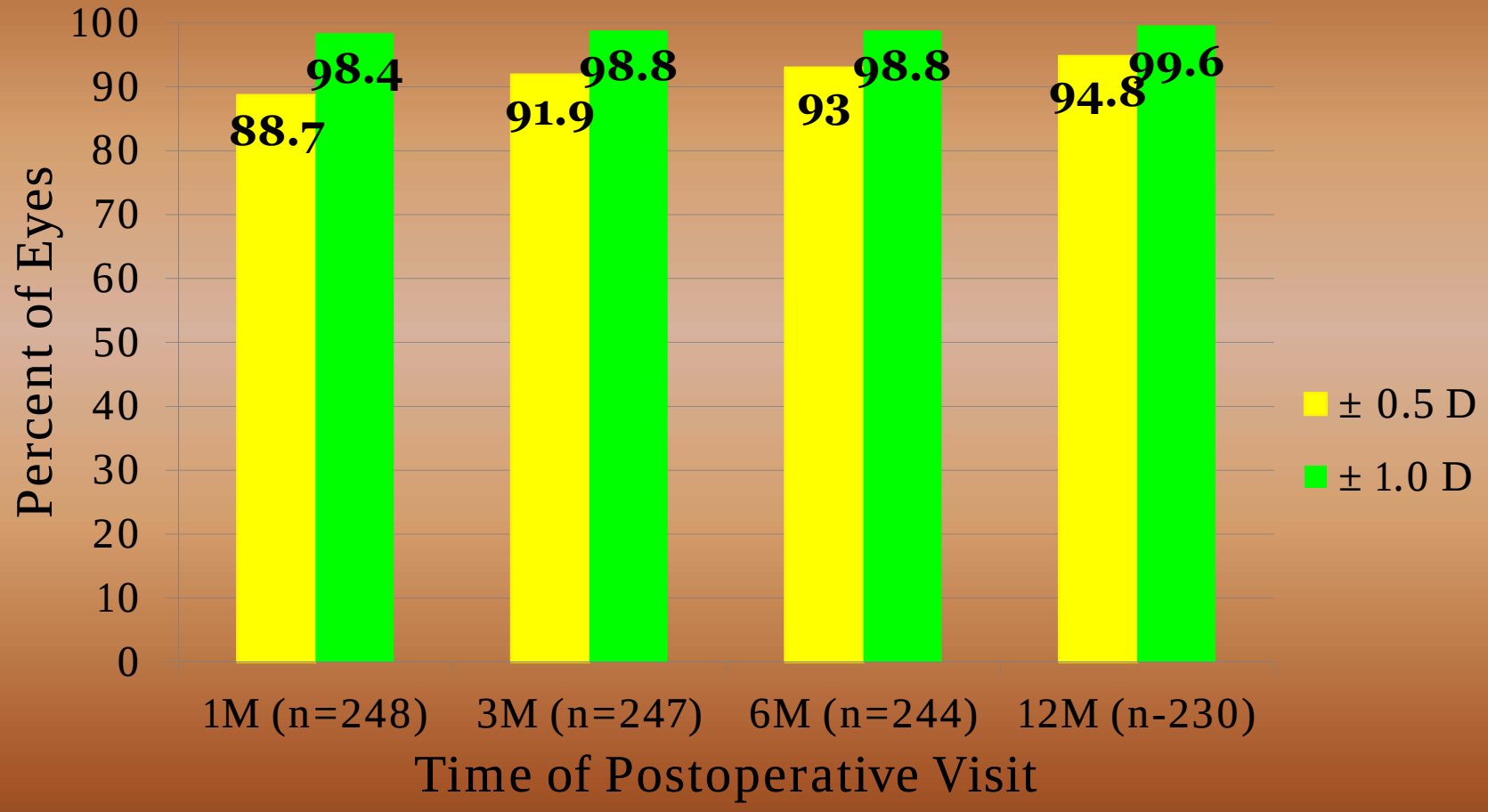
- Zernike fit into resulting profile
- Modification of cylinder/axis Zernike terms based on MR

Refractive Outcomes – Mean Values

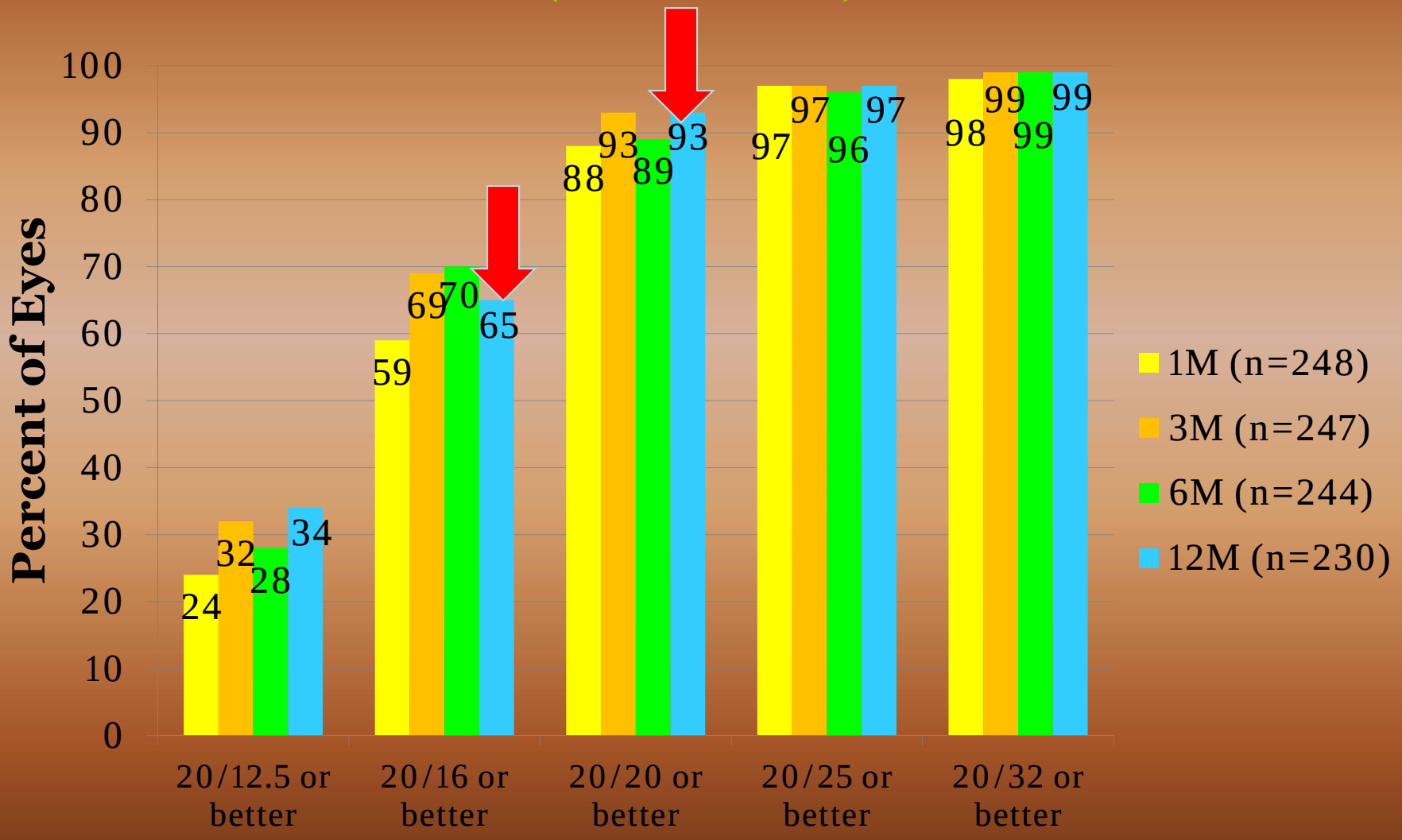


	Pre, n=249	1M, n=248	3M, n=247	6M, n=244	12M n=230
MRSE (D)	-4.61	0.06	0.06	0.01	0.00
Std Dev(D)	2.43	0.36	0.33	0.35	0.27

Refractive Outcomes within Intended Target (MRSE)

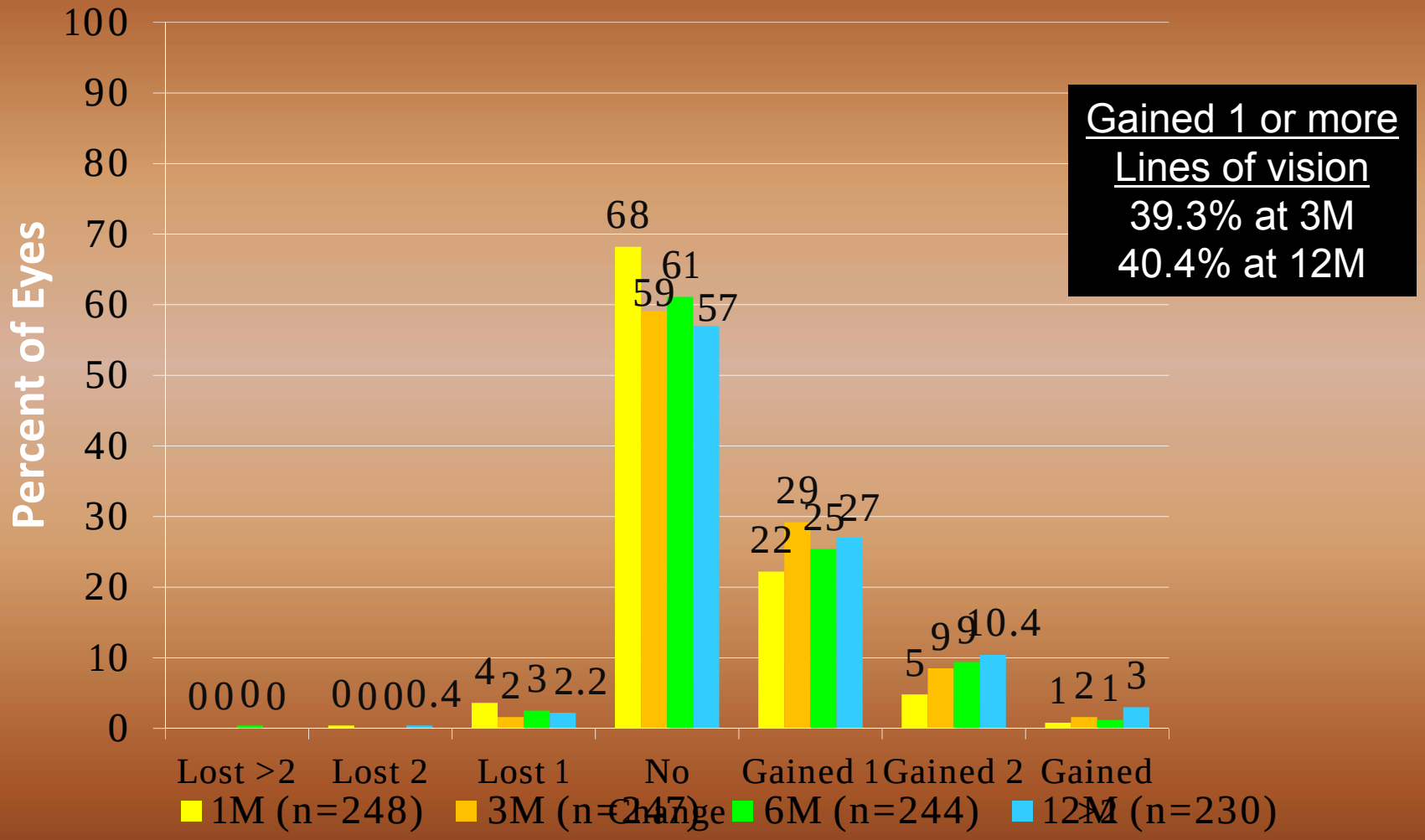


Cumulative Postop UCVA (ETDRS)



SSED page 30, Table 23

Postop BSCVA Compared to Preop BSCVA (Change in Lines)



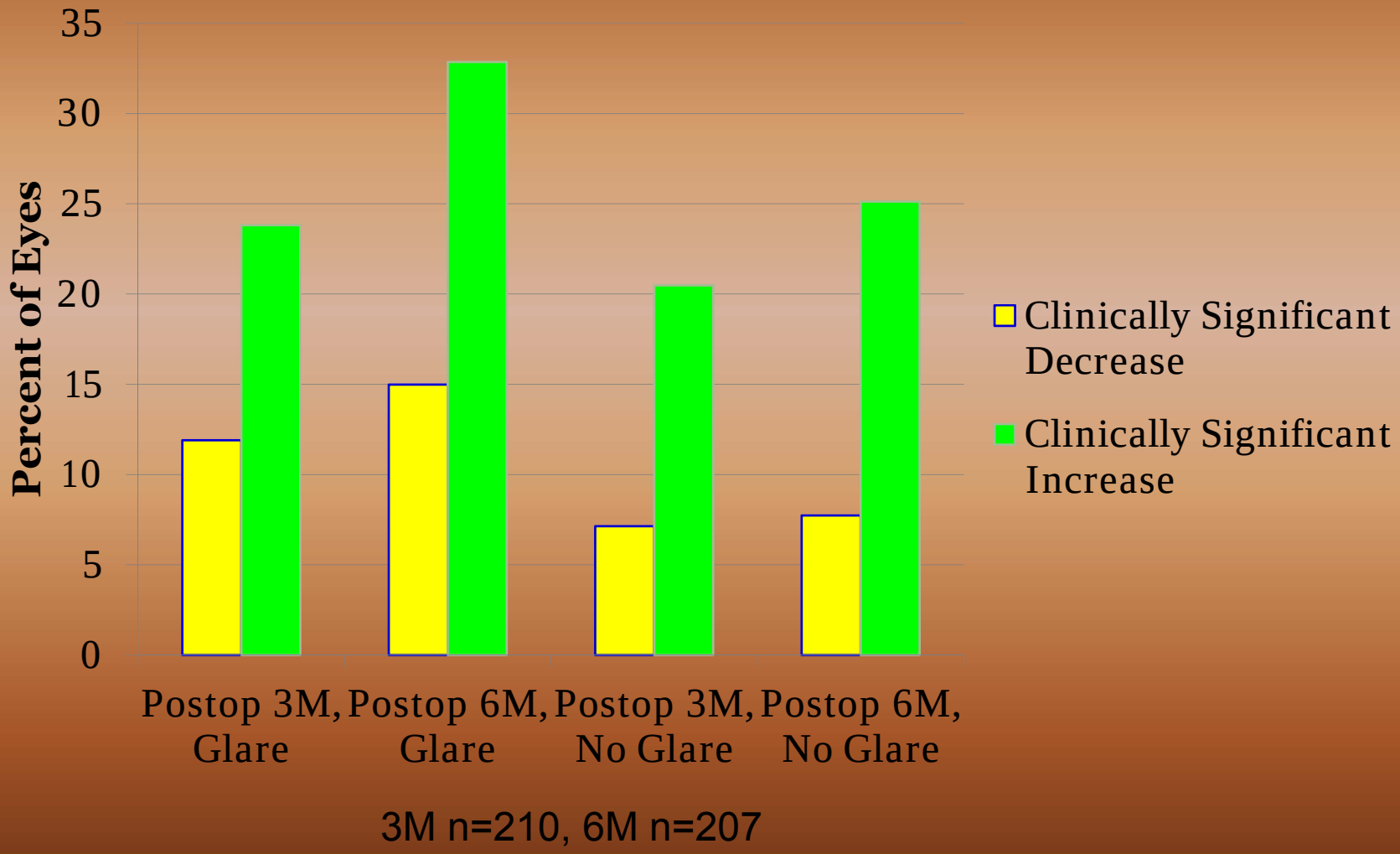
Gained 1 or more Lines of vision
39.3% at 3M
40.4% at 12M

1 eye with >2 line loss at 6M (0.4%)

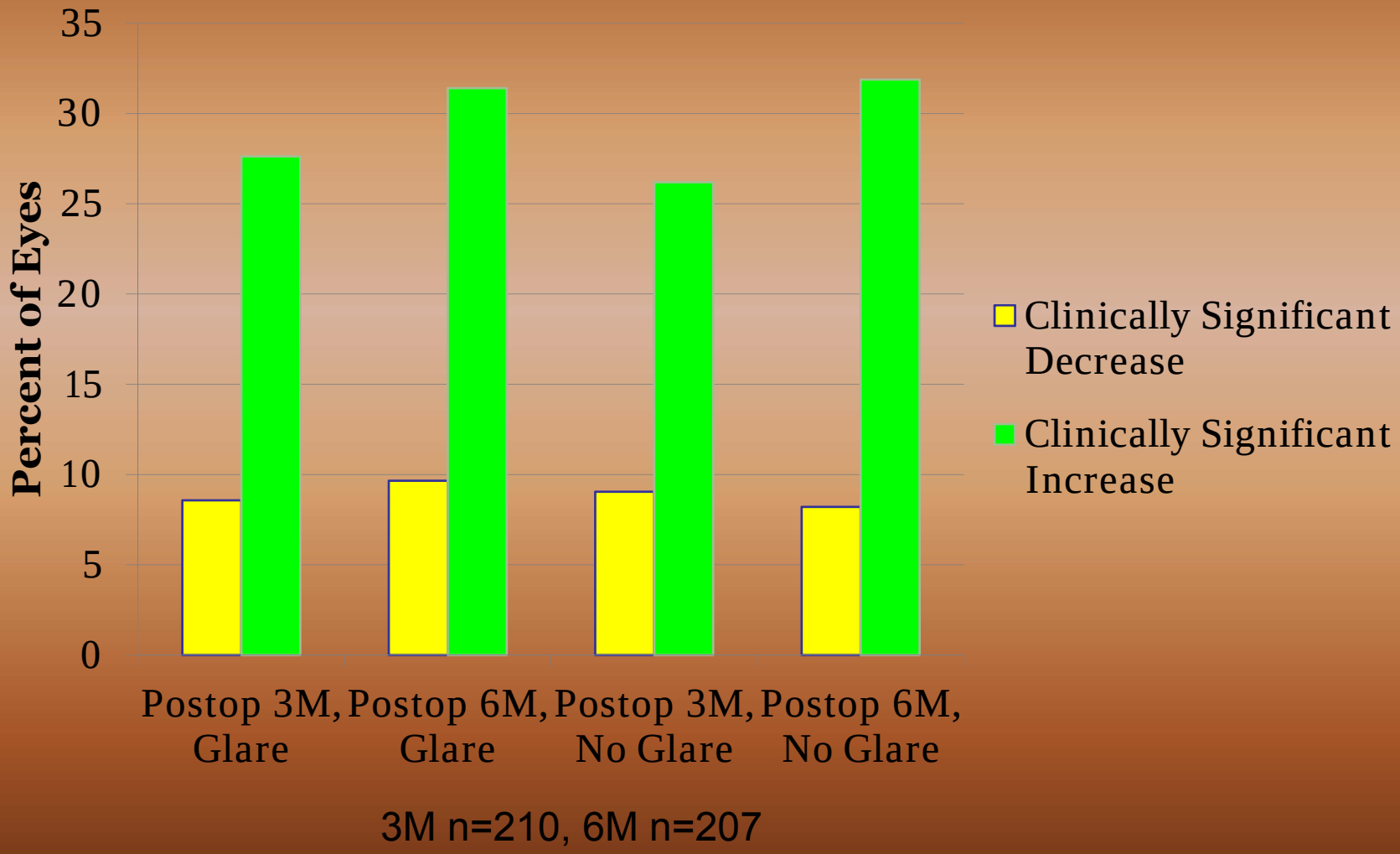
Visual Symptoms: Preop to 6M, n=244

Question	None - Moderate		Marked - Severe		Difference in Marked – Severe	p-value
	Baseline	6M	Baseline	6M		
Light Sensitivity	94.8%	99.6%	5.2%	0.4%	-4.8%	**0.0012**
Difficulty Driving at Night	91.6%	98.0%	8.4%	2.1%	-6.4%	**0.0014**
Reading Difficulty	90.0%	97.5%	10.0%	2.5%	-7.6%	**0.0005**
Double Vision	98.8%	98.4%	1.2%	1.6%	0.4%	0.6852
Fluctuation in Vision	98.4%	100.0%	1.6%	0.0%	-1.6%	**0.0459**
Glare	95.2%	100.0%	4.8%	0.0%	-4.8%	**0.0004**
Halos	96.8%	100.0%	3.2%	0.0%	-3.2%	**0.0044**
Starbursts	96.8%	99.6%	3.2%	0.4%	-2.8%	**0.0196**
Dryness	95.2%	97.5%	4.8%	2.5%	-2.4%	0.1630
Pain	99.6%	100.0%	0.4%	0.0%	-0.4%	0.3222
FBS	99.6%	100.0%	0.4%	0.0%	-0.4%	0.3212

Contrast Sensitivity Testing (Mesopic Illumination)



Contrast Sensitivity Testing (Photopic Illumination)



Case: High Myopic Contoura Vision LASIK

- 43 yo male CEO with -8.25 +0.75 x105 (20/15) OD desires LASIK for distance

1st CCF Contoura Vision LASIK

Difference Map

- Laser Flap:

9 mm, 100 um

- Laser Rx:

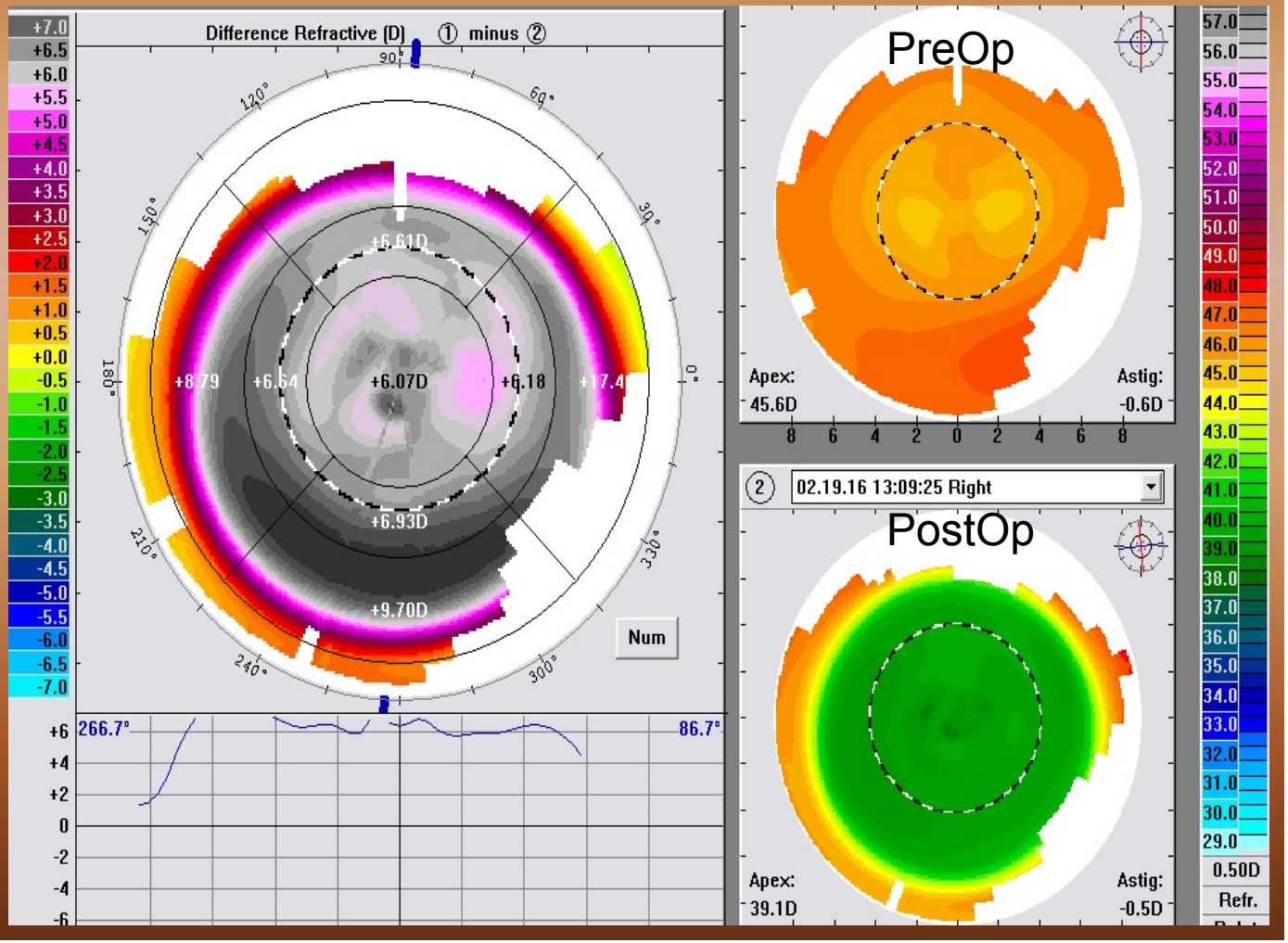
-6.44 -0.60 x 05

- Custom Topo Rx:

^ 6.07 D central
6.18-6.93 D mid
7.40-9.70 D periph
>Central Cyl Rx

1 wk UCVA = 20/15+

Difference Map shows why Contoura Vision works so well!



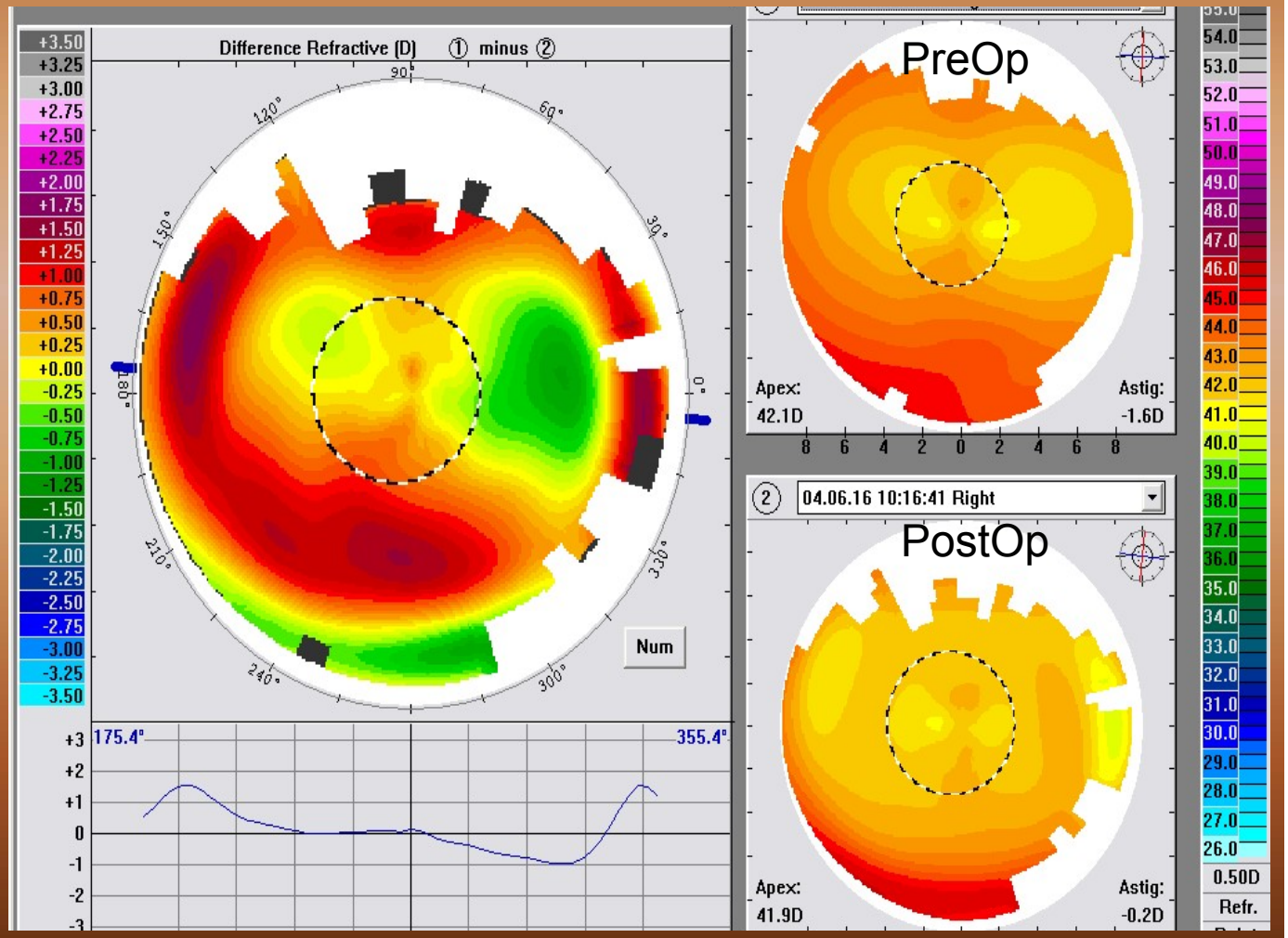
Case: High Myopic Contoura Vision LASIK

- Low Myopic Astigmatism Case

Difference Map

- Custom Topo Rx:

^ 0.75 D central Cyl
But much greater peripheral cyl with vertical +1.0 D and horizontal -1.0 D
1 wk UCVA = 20/10-
Difference Map shows nasal region of green (-1.00 D) change. Tissue not added, but far peripheral Rx made nasal region steeper



Examples of TGA Platforms:

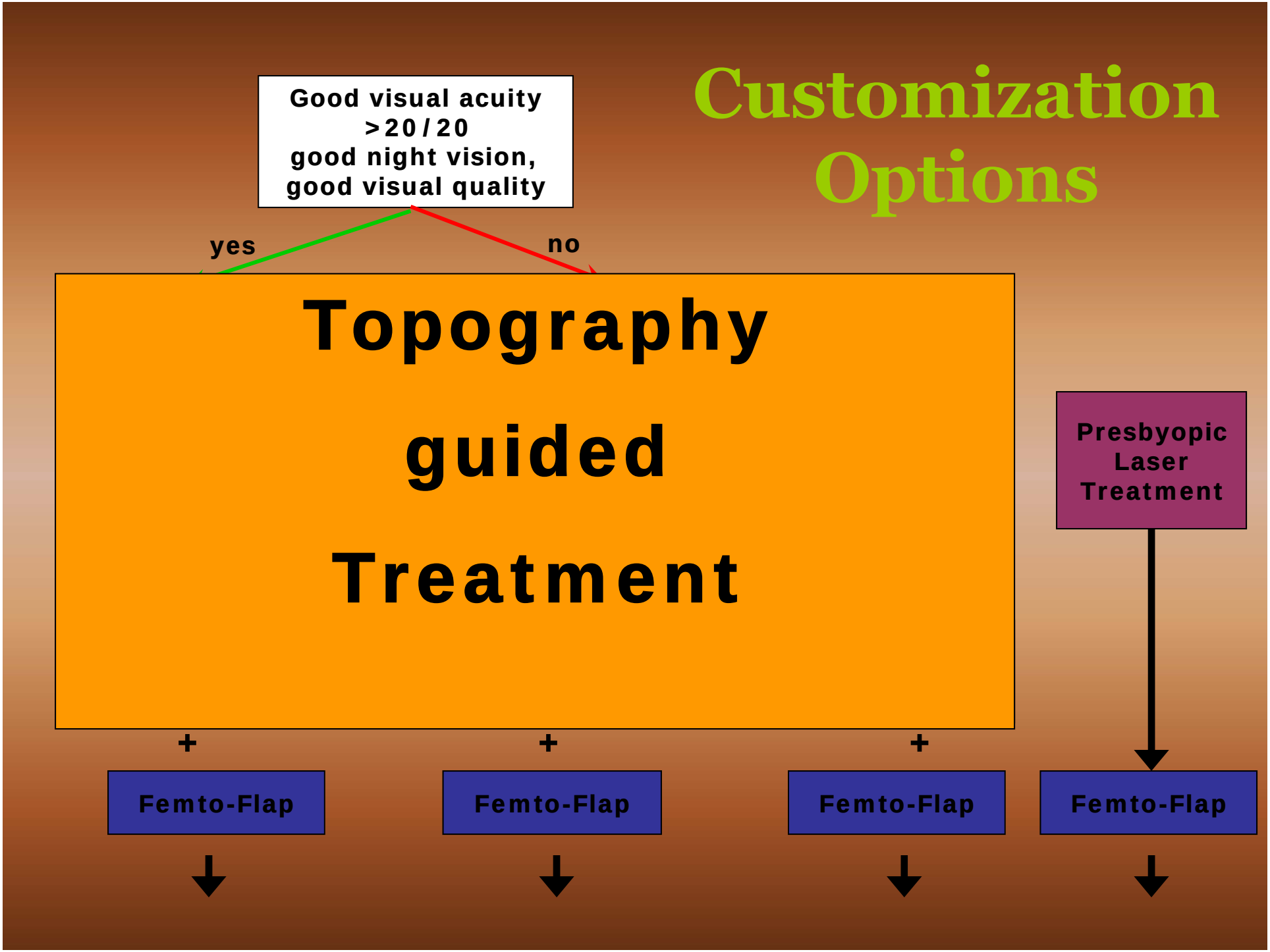
- Topography-guided Customized Ablation Treatment (T-CAT; Topolyzer topographer; Wavelight ALLEGRETTO platform; Alcon),
- Customized aspheric transition zone (CATz; OPD scan topographer, NAVEX laser platform; Nidek)
- Corneal Interactive Programmed Topographic Ablation (CIPTA; Precisio topographer, iVis Suite)
- CRS-Master (Atlas topographer, MEL-80 platform, Carl Zeiss Meditec)
- TOPOLINK (Technolas, Bausch and Lomb)

Debate exists over which method of topography (Placido-disk versus Scheimpflug) is superior

Conclusion

- The Spectrum of Custom Laser Vision Correction includes:
  - Wavefront Guided Ablation
  - Wavefront Optimized Ablation
  - Topography Guided Ablation
  - Presbyopic Customized Ablation
  - Other Customization
- The future will hold a whole menu of different options for customizing the visual experience of Laser Vision Correction

Customization Options



Thank You

The 18th International Congress of

Wavefront Presbyopic Refractive Corrections

Feb 24 & 25, 2017 Napa Valley, CA

www.wavefront_congress.org