Mohamed Shafik Shaheen MD, PhD

Professor & Head of Ophthalmology Department,
Alexandria University, Egypt
Vice President of the International Keratoconus Society (IKS)
CEO, Horus Vision correction Center
Elected Board Member of The Egyptian Ophthalmology Society (EOS)
Vice President of The Dry Eye & Ocular Surface Society (DEOSS)

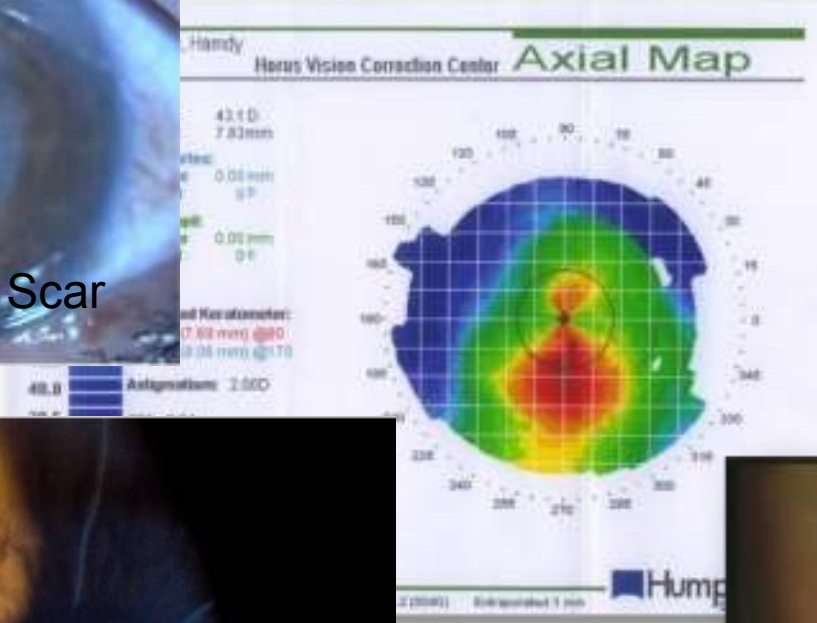
Ray Tracing-Guided Ablation:

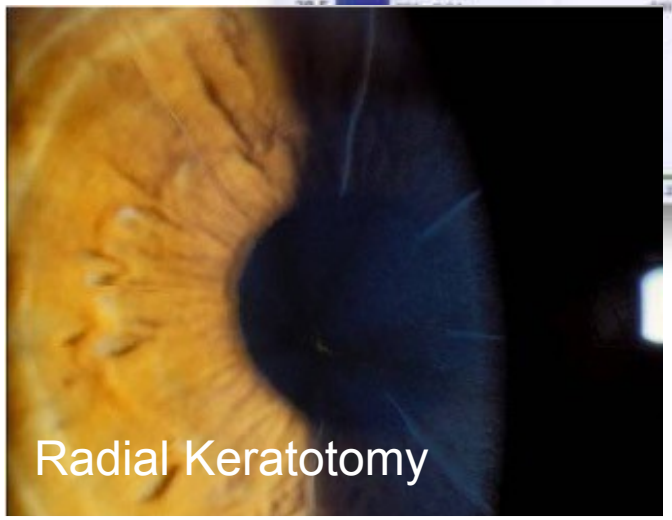
The game changer in corneal remodeling

Financial Disclosure

- Jhonson & Jhonson: Consultant, Researcher.
- Alcon Pharmaceuticals – Egypt : Speaker, Clinical Advisory Board.
- Orchidia Pharmaceuticals : Consultant, Clinical Trials Advisory Board.
- EVA Pharma : Consultant, Clinical Trials Advisory Board.
- IVIS Technology

Management of an irregular cornea has been always a real challenge in our daily practice. **Customization is a must!**





Complex/Irregular Corneas are really Common!

We meet complex corneas in everyday practice!

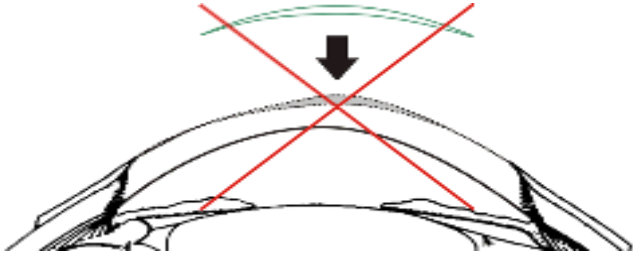
- **Irregular Astigmatism**
- **Hyperopia**
- **Hyperopic Astigmatism**
- **Mixed Astigmatism**
- **Iatrogenic Causes**
- **Keratoconus**
- **Ectasia**
- **Relevant Angle K**
- **Scars**
- **Opacities**
- **Pterygium**

The prevalence of progressive corneal pathologies varies from 2.1%[1] to 3%[2] of the population.
The prevalence of non-progressive corneal pathologies varies from 25%[3] to 42%[4] of the potential refractive surgery candidates, equal to 59.9%[5] of the global population, that is 15% to 25% of the population.

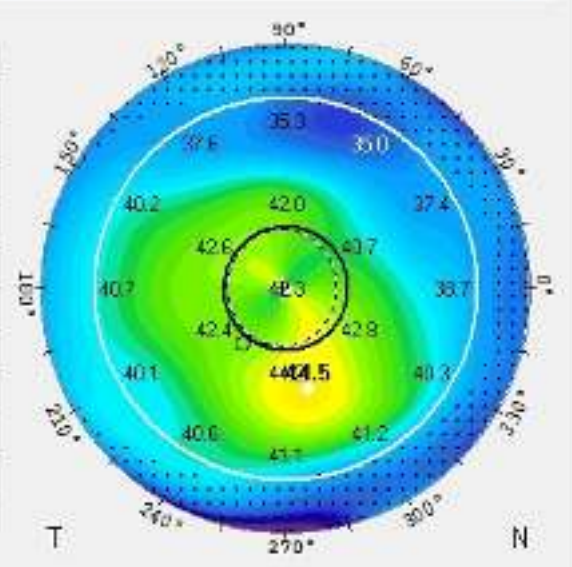
[1] *"Estimated prevalence of keratoconus in the largest metropolitan area of Italy", European Journal of Ophthalmology, 2024*
[2] *"Prevalence of keratoconus among young Arab students in Israel" by Shneor et al., Journal of Keratoconus and Ectatic Corneal Diseases, 2014*
[3] "2020 Global Consensus On Corneal Irregularity", *Cataract and Refractive Surgery Today, 2021*
[4] *"Validity of autorefractor based screening method for irregular astigmatism compared to the corneal topography- a cross-sectional study", International Journal of Ophthalmology, 2017*.
[5] *"Refractive Surgery Market Report", Market Scope, 2021.*

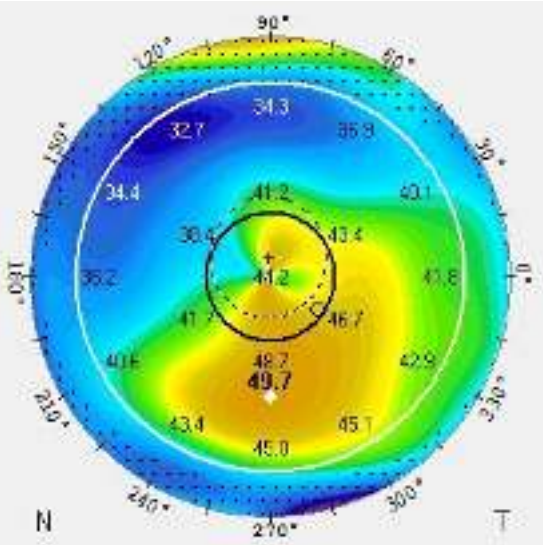
Legacy Refractive Surgery

The classic teaching of refractive surgery is to deliver refractive or wavefront maps, by means of tomographers and aberrometers, to design the customized treatment, in a form of a **lens to be printed onto the cornea**



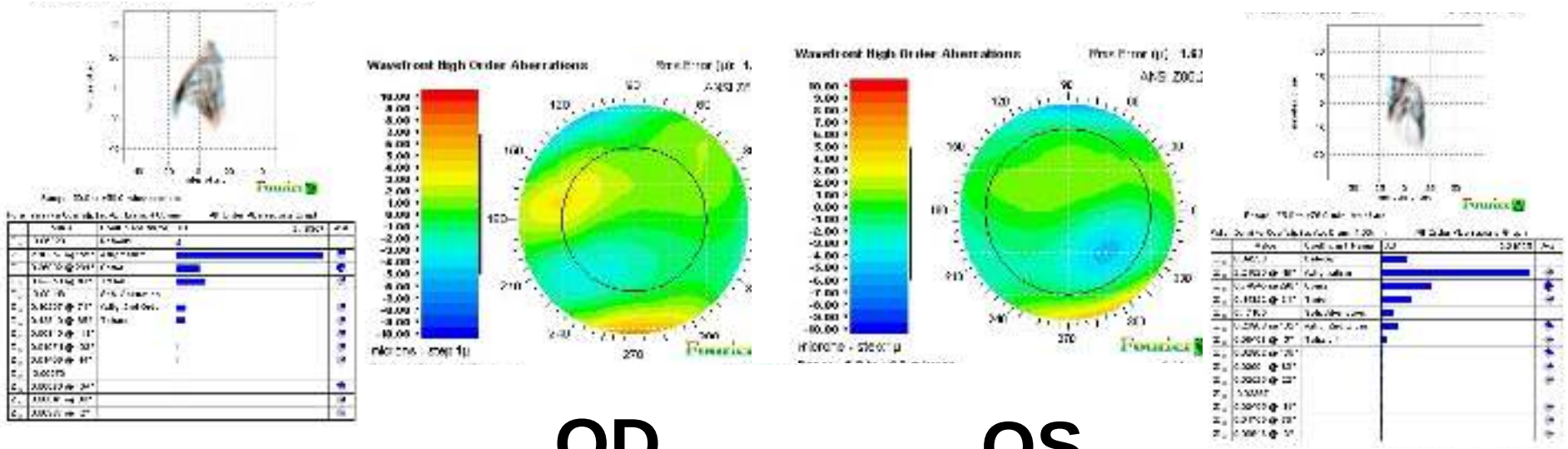
Bilateral Cases:
Mr. M. 21 ys. A post CXL Keratoconic patient





Prof. Mohamed Shafik
Horus Vision Correction Center (HVCC)
Alexandria, Egypt

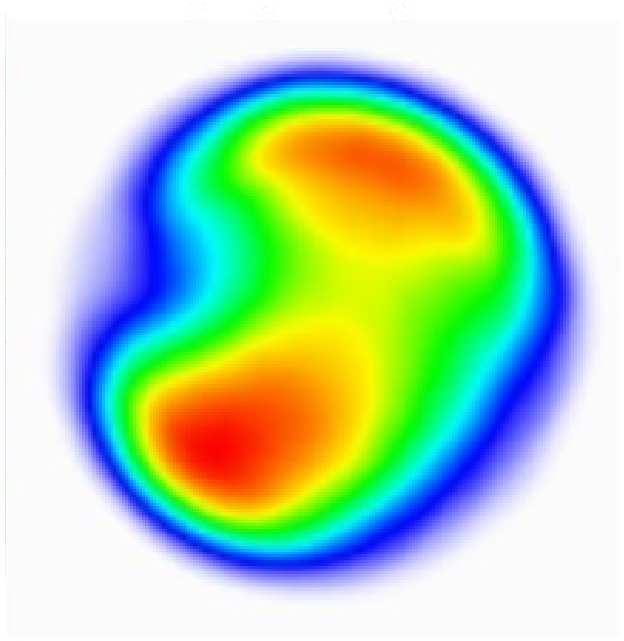
Bilateral Cases:
Mr. M. 21 ys. A post CXL Keratoconic patient

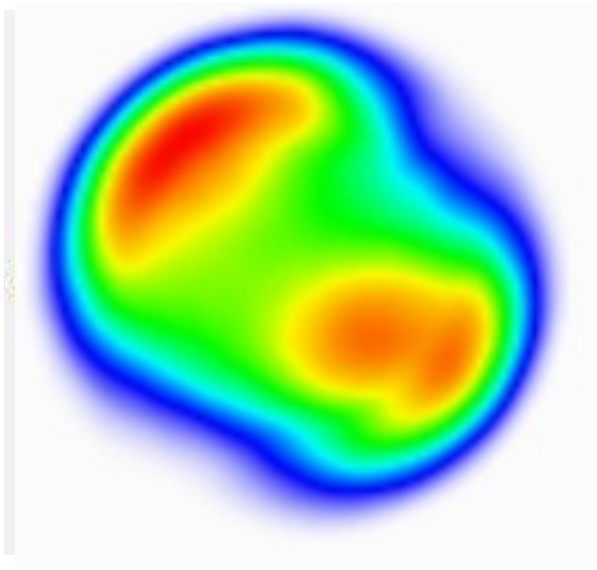


OD **OS**

Prof. Mohamed Shafik
Horus Vision Correction Center (HVCC)
Alexandria, Egypt

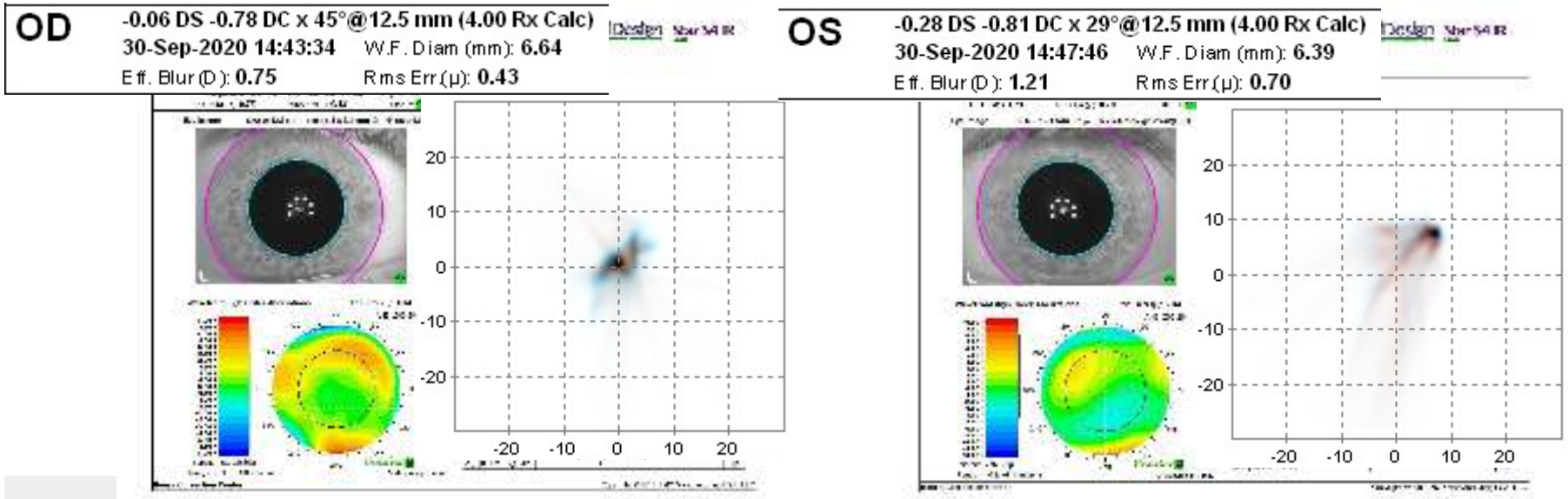
Bilateral Cases:
Mr. M. 21 ys. A post CXL Keratoconic patient





Prof. Mohamed Shafik
Horus Vision Correction Center (HVCC)
Alexandria, Egypt

Bilateral Cases:
Mr. M. 21 ys. A post CXL Keratoconic patient

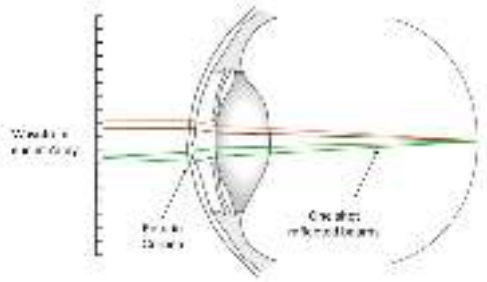


Prof. Mohamed Shafik
Horus Vision Correction Center (HVCC)
Alexandria, Egypt

Legacy Refractive Surgery

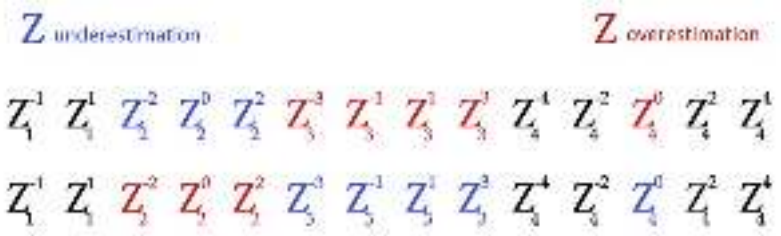
Aberrometers added a great value in refractive surgery, nevertheless they still show lack of reliability in determining the refractive properties of the eye, especially in complex corneas

-**Crossover effect**



-**Loss of information due to extrapolation and interpolation**

-**Polynomial grade interdepend**

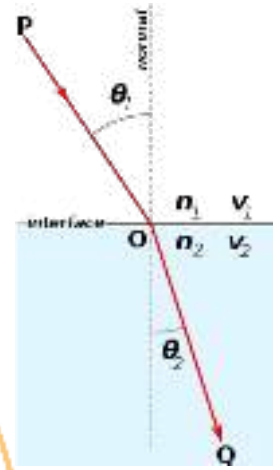


Time for Technology to take a major change!

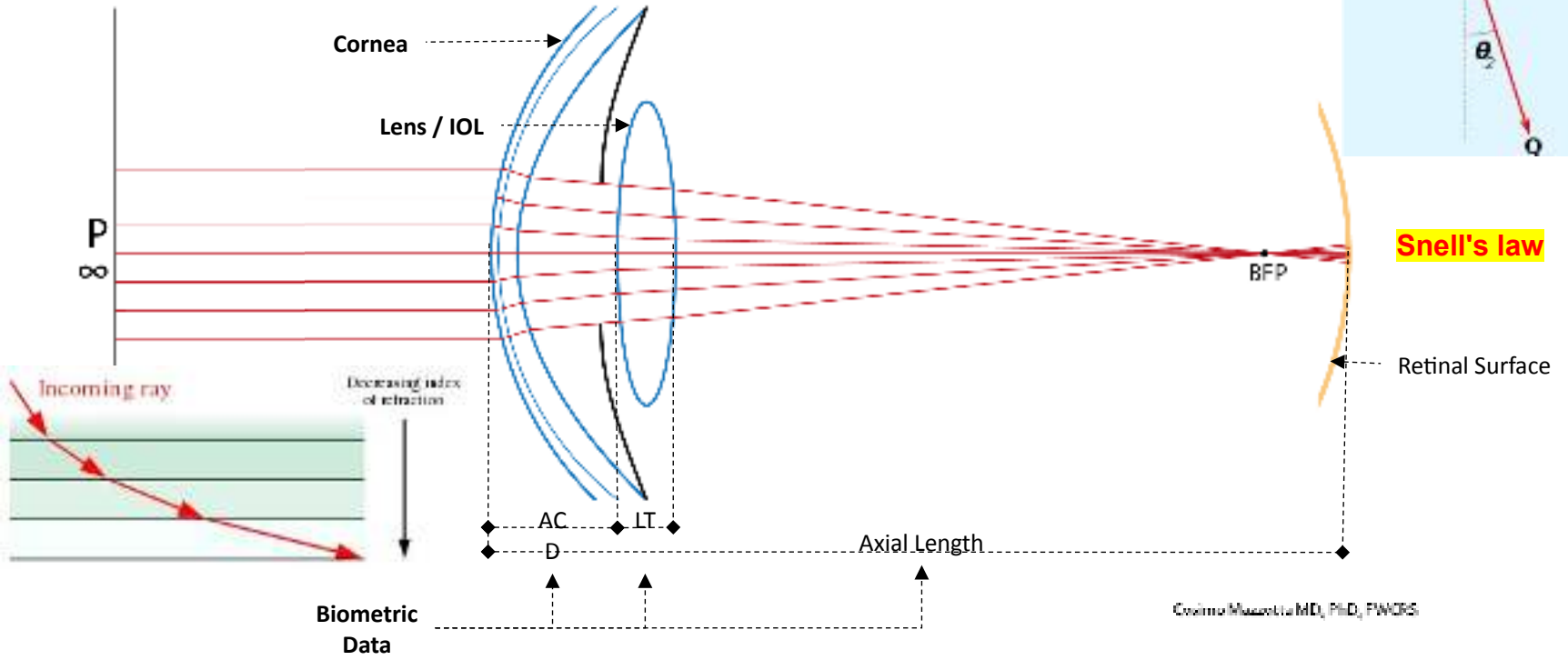
Ray-Tracing principles applied to the human eye

Ray Tracing Principles

The Effective Refractive Power Of The Eye is determined Ray-Tracing the light beams from the point of view (P), located at infinite distance for far vision, through all refractive surfaces (epithelium, anterior and posterior cornea, lens).



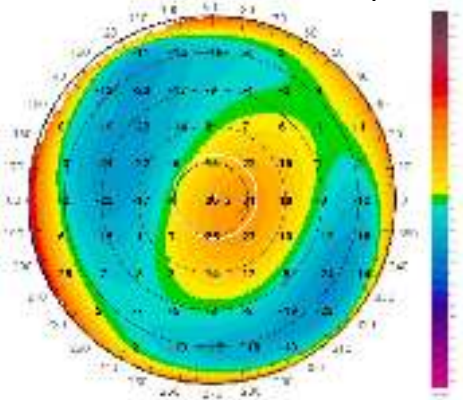
Snell's law



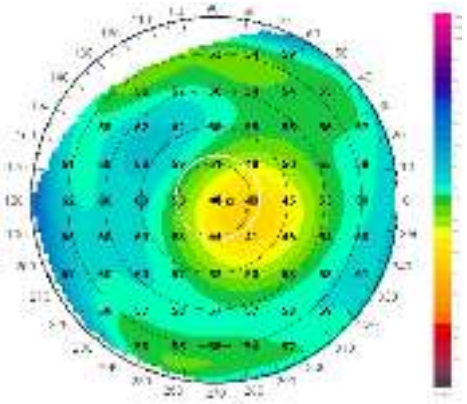
Complex Corneas

The cornea is sophisticated optical system, incorporating the refractive contribute of the epithelium and posterior shape, both acting as smoothing agents of the corneal aberrations. In the ectatic cases, the epithelium becomes thinner in the bumped region, to compensate stromal irregularities. The posterior shape shows a protrusion in correspondence with the anterior shape.

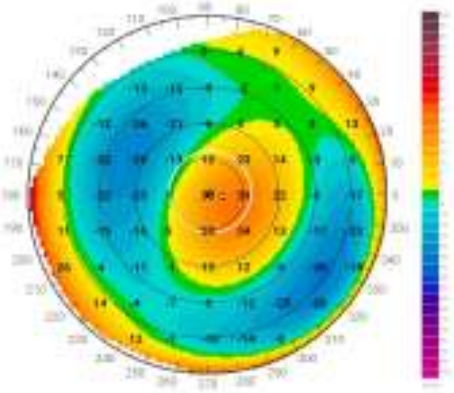
Anterior Elevation Map



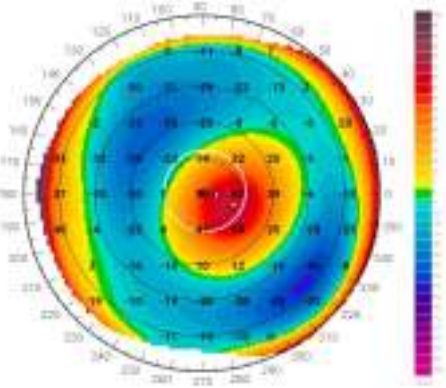
Epithelium Pachimetry Map



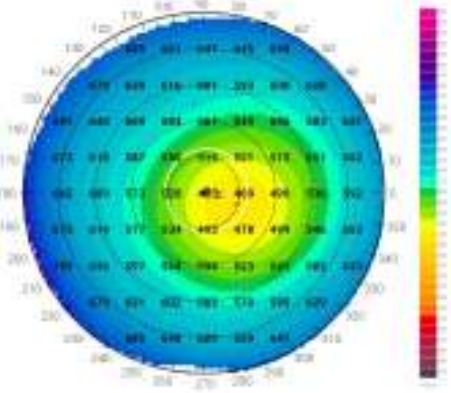
Stromal Elevation Map



Posterior Elevation Map



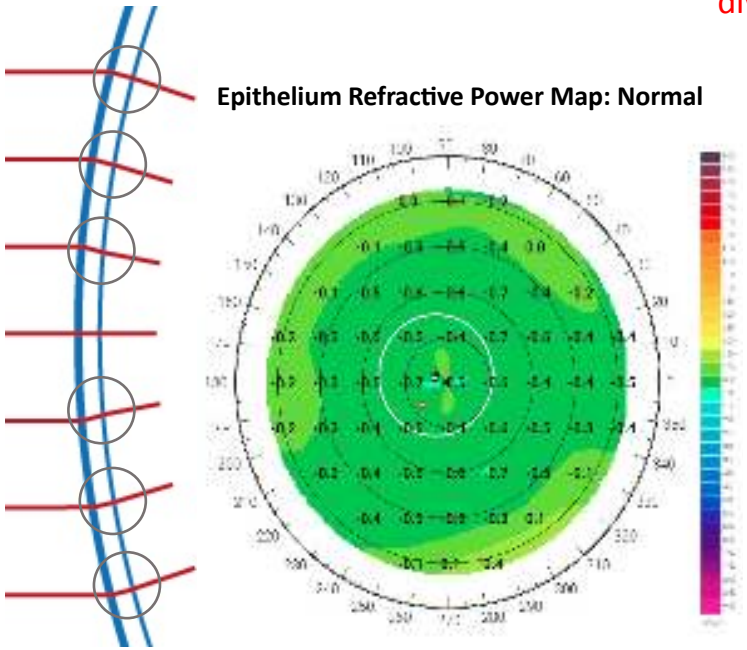
Total Pachimetry Map



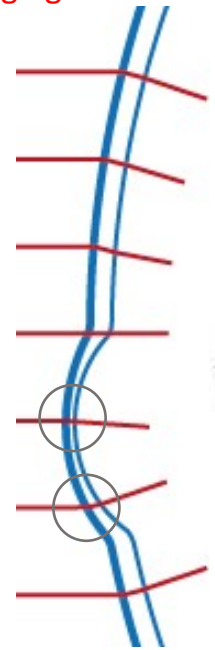
Epithelium refractive power: NORMAL *vs* *IRREGULAR CORNEAS*

The epithelium Ray-tracing power, difference between the anterior and the stromal power is diverging lens about -0.5D for normal eyes (NID).

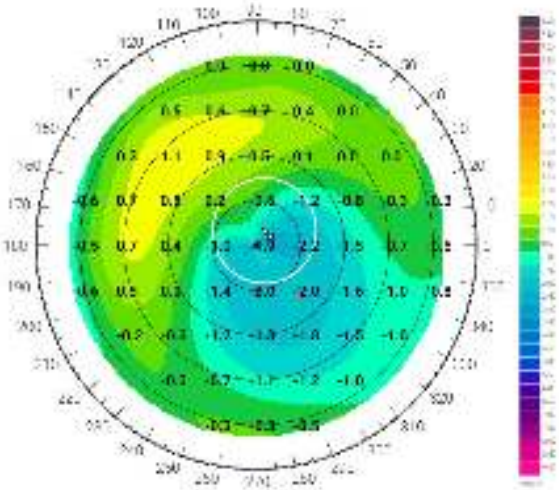
The epithelium Ray-tracing power may reach relevant diverging and comatic power for ectatic eyes (EID)



Epithelium Refractive Power Map: Normal



Epithelium Refractive Power Map: Ectasia



FORWARD RAY-TRACING

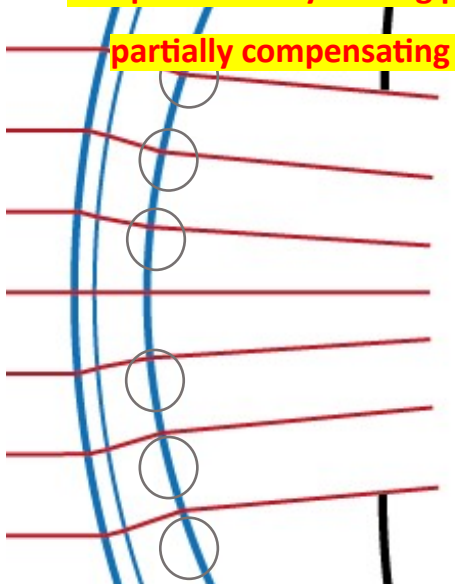
FORWARD RAY-TRACING

Posterior Corneal Surface Refractive Power

The posterior ray-tracing power, difference between the total corneal and the anterior corneal power ranges between -2.0D and -6.0D for normal eyes (NID).

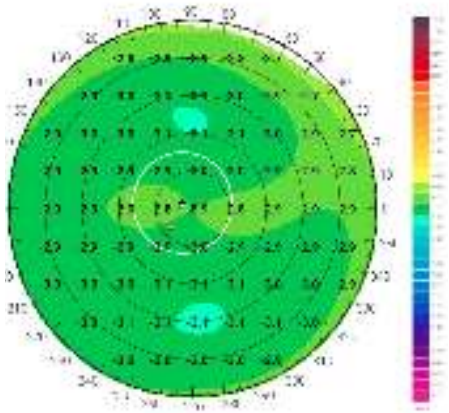
The posterior ray-tracing power may reach relevant diverging comatic contribution

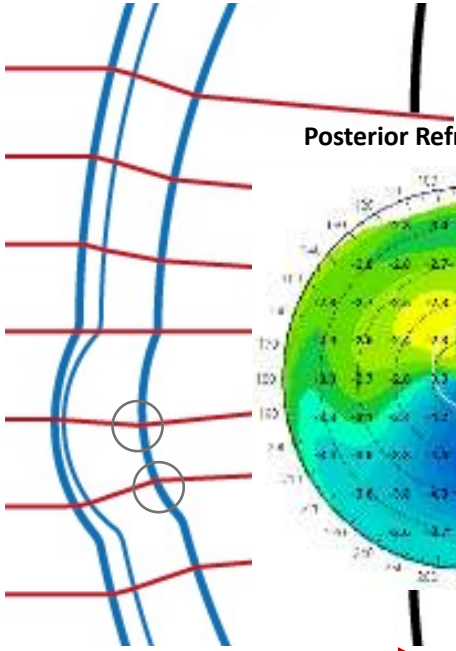
partially compensating the aberrations of the anterior shape for ectatic eyes



FORWARD RAY-TRACING

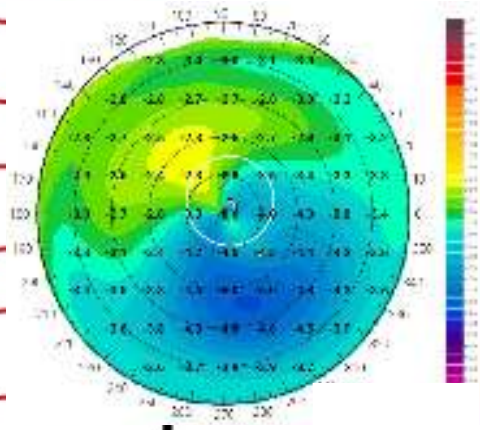
Posterior Refractive Power Map





FORWARD RAY-TRACING

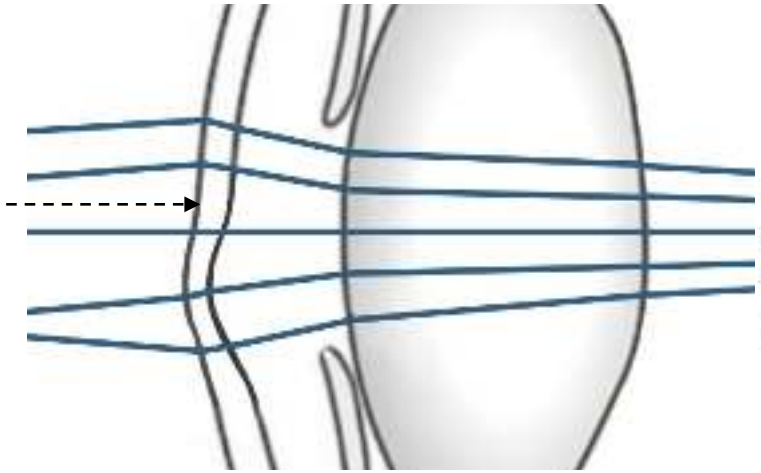
Posterior Refractive Power Map



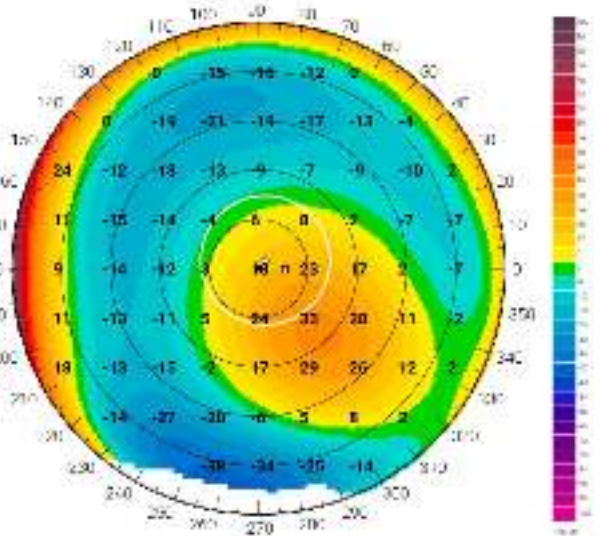
The Ideal Shape

Refractive surgery was in a real need to define the Ideal Shape to match patient's refractive needs minimizing surgical invasiveness as much as possible, by taking care of the refractive contribute of the epithelium and the posterior shape.

Elevation pre-op



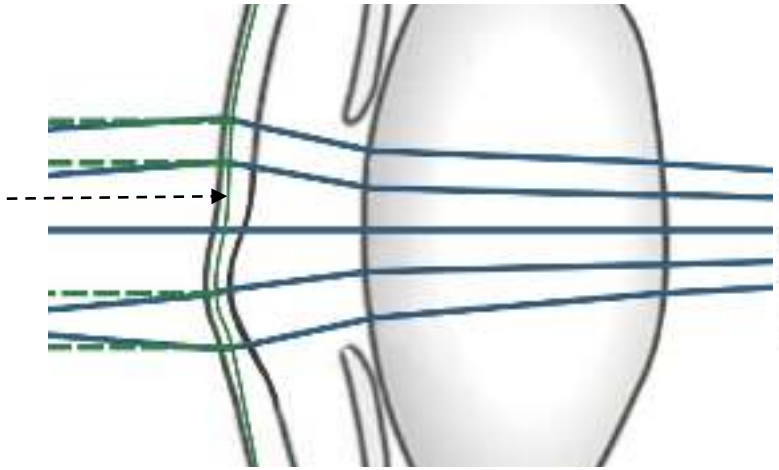
Elevation pre-op



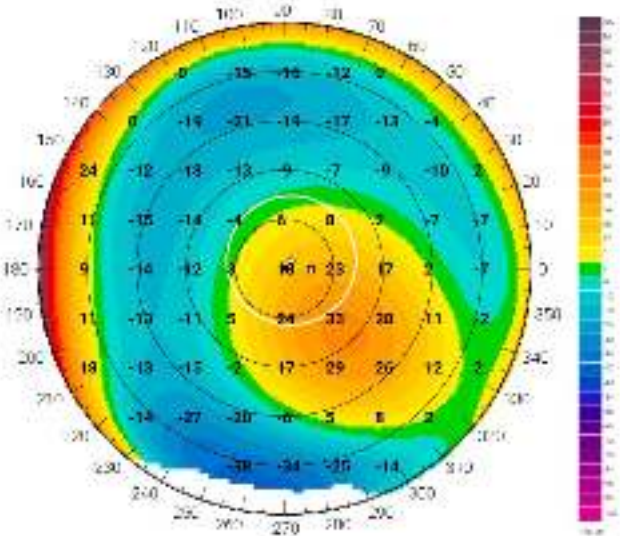
The Ideal Shape

Refractive surgery was in a real need to define the Ideal Shape to match patient's refractive needs minimizing surgical invasiveness as much as possible, by taking care of the refractive contribute of the epithelium and the posterior shape.

Ideal shape

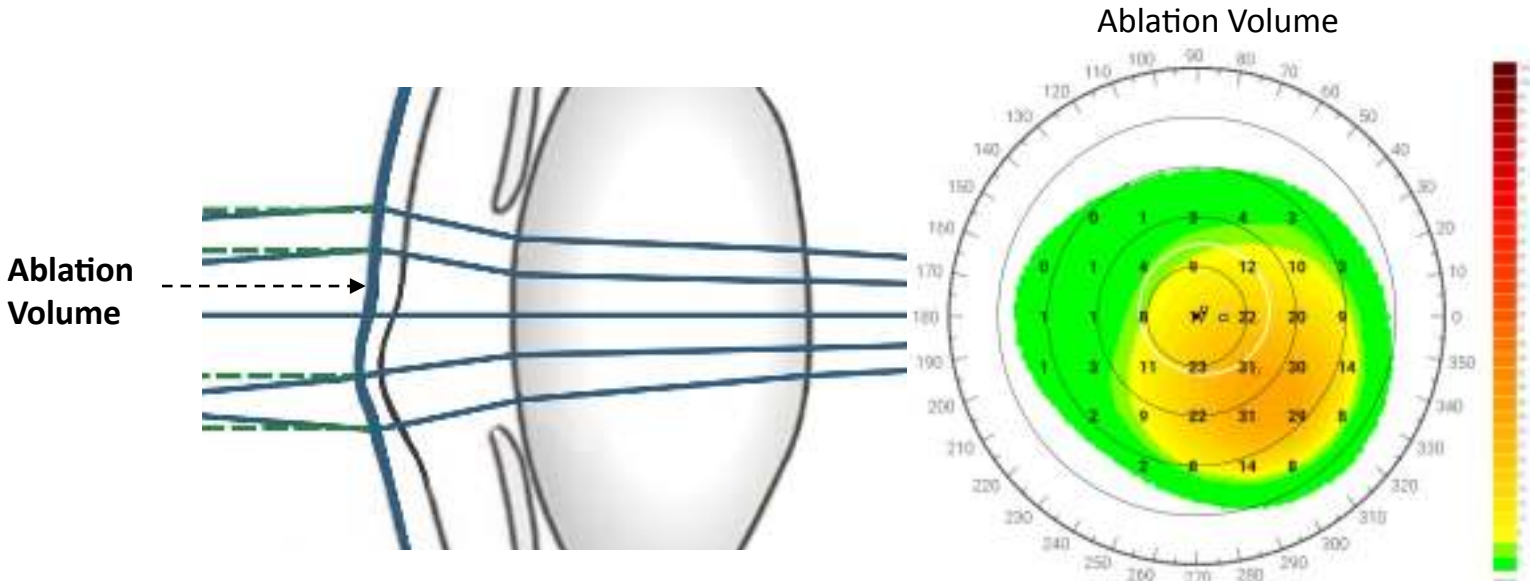


Elevation pre-op



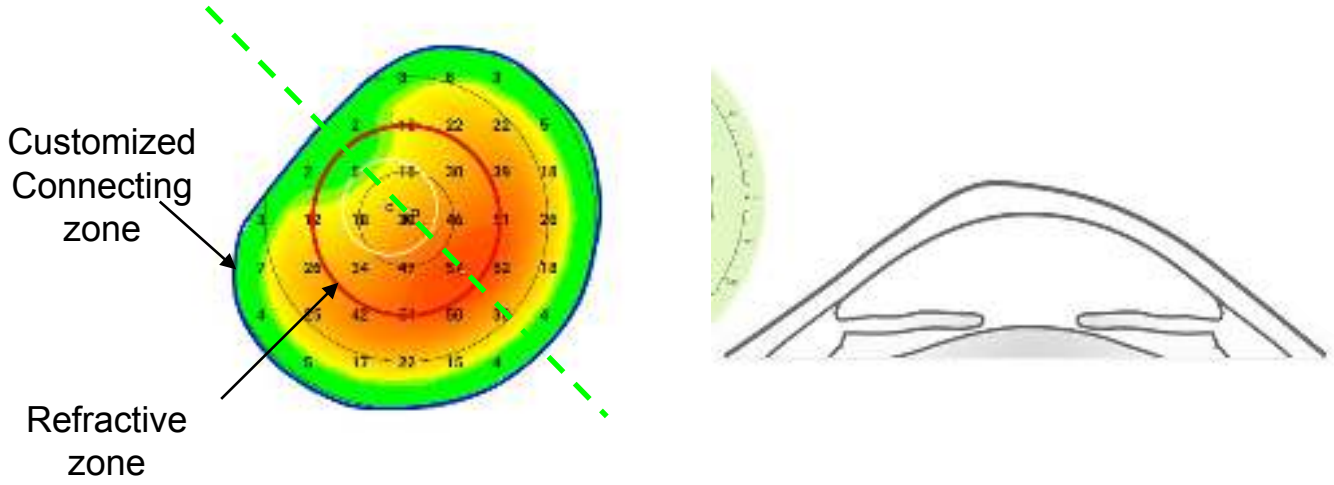
The Ideal Shape

Refractive surgery was in a real need to define the Ideal Shape to match patient's refractive needs minimizing surgical invasiveness as much as possible, by taking care of the refractive contribute of the epithelium and the posterior shape.



The Ideal Shape

The connecting zone plays a crucial role to grant treatment stability, quality of vision and proper healing, delivering a customized width to connect the refractive zone with the untouched cornea, by means of a constant gradient change of curvature.



pMetrics®

- Dynamic, binocular pupillometer
- Records eye-tracked pupil function in 6 lighting environments from scotopic to photopic
- Uniquely, pupil dimensions are statically evaluated with a patented *lifestyle weighting* to calculate the ***Ideal Pupil*** dimension

Precisio®

Precisio®2 is a tomographer validated for surgical applications, **with repeatability below 3um**, granted by:

- **the 30um ultrathin blue laser slit**, to maximize the detection of the corneal epithelium;
- **the dedicated 6D eye-tracker**, to compensate the eye movements during the exam;
- the voice driven exam **auto-acquisition** to negate reproducibility errors.

IVIS
LIVE YOUR VISION

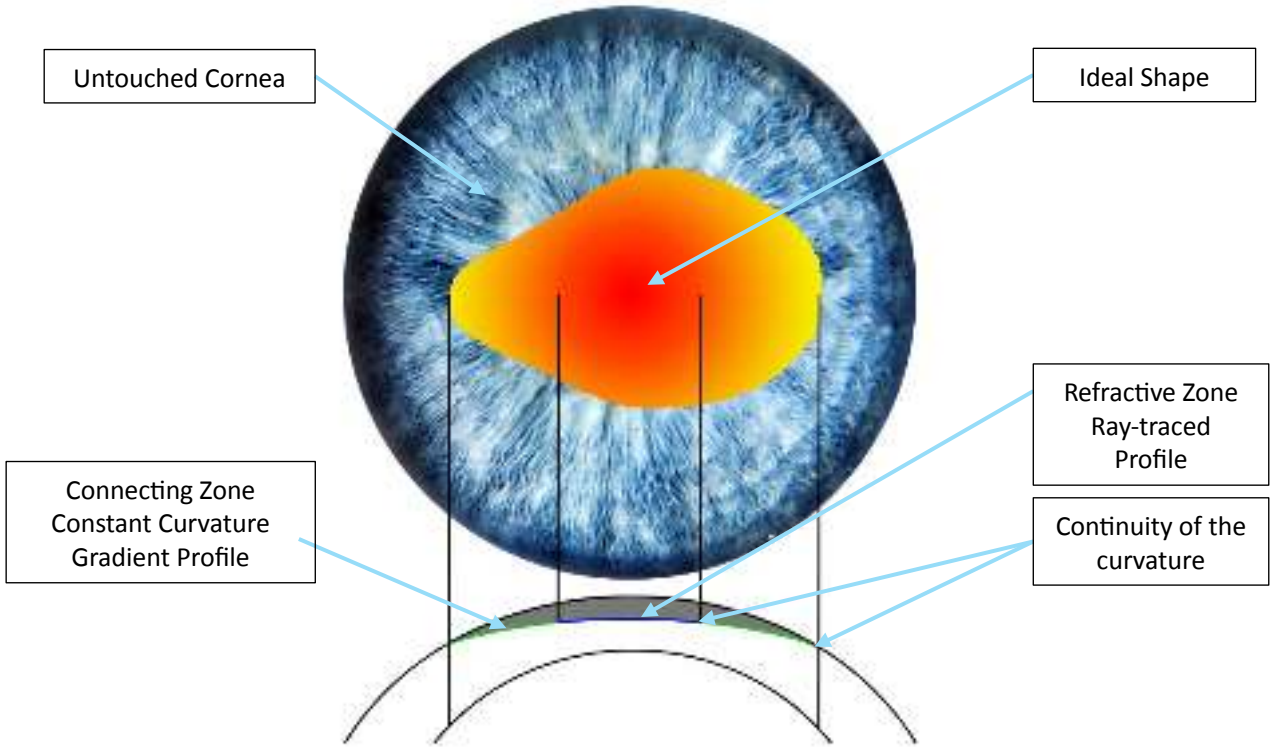
The Ideal Shape

The genius of **Michelangelo** revolutionized the concept of beauty in art during Renaissance, extracting a masterpiece out a block of marble

He was able to see the perfection out of the block and remove the excess of marble to bring the beauty to the light

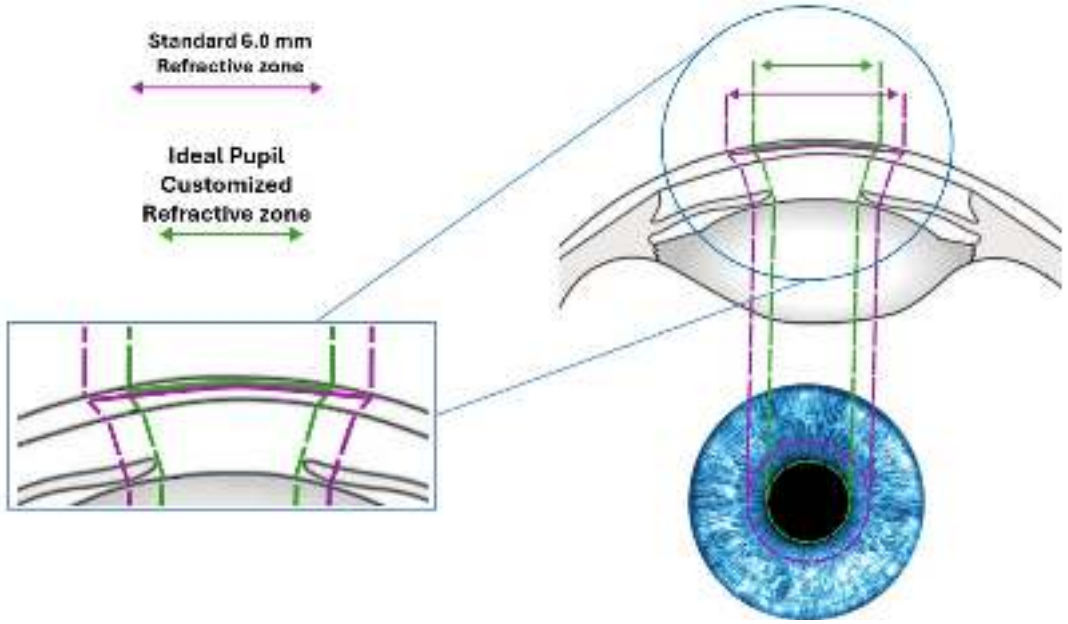
The Ideal Shape

The Ideal Shape is determined by the Cipta® Web Application, defining
the Refractive Zone, by means of Ray-Tracing, to optimize vision and minimize invasiveness
the Connecting Zone applying a constant gradient curvature algorithm to grant treatment stability



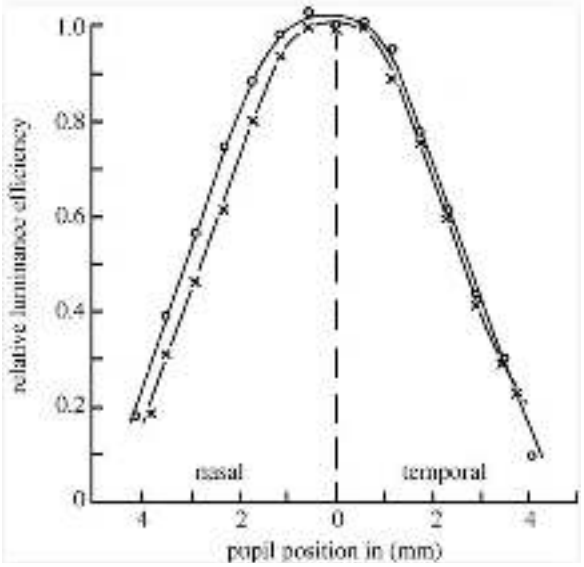
The Ideal Shape

The Ideal Shape tailors the refractive zone according to the effective needs of the patients, determining the Ideal Pupil which covers the ordinary light conditions a patient encounters during his daily life, taking into account pupil dynamics, lifestyle and profession.



The Ideal Shape

To minimize invasiveness, the Refractive Zone can be further reduced below the Ideal Pupil, to grant treatment stability, maximizing smoothness and minimizing tissue ablation, thanks to the Stiles-Crawford Effect which demonstrates that over 80% of the photons contributing to the formation of clear vision at the level of the fovea come from the central two millimeter of the pupil



Thus, the customization of the refractive zone save a tremendous amount of precious tissue.

Refractive zone diameter (mm)	2	3	4	5	6
Tissue consumption per diopter (µm)	1.3	3.0	5.3	8.3	12.0

The Ideal Shape

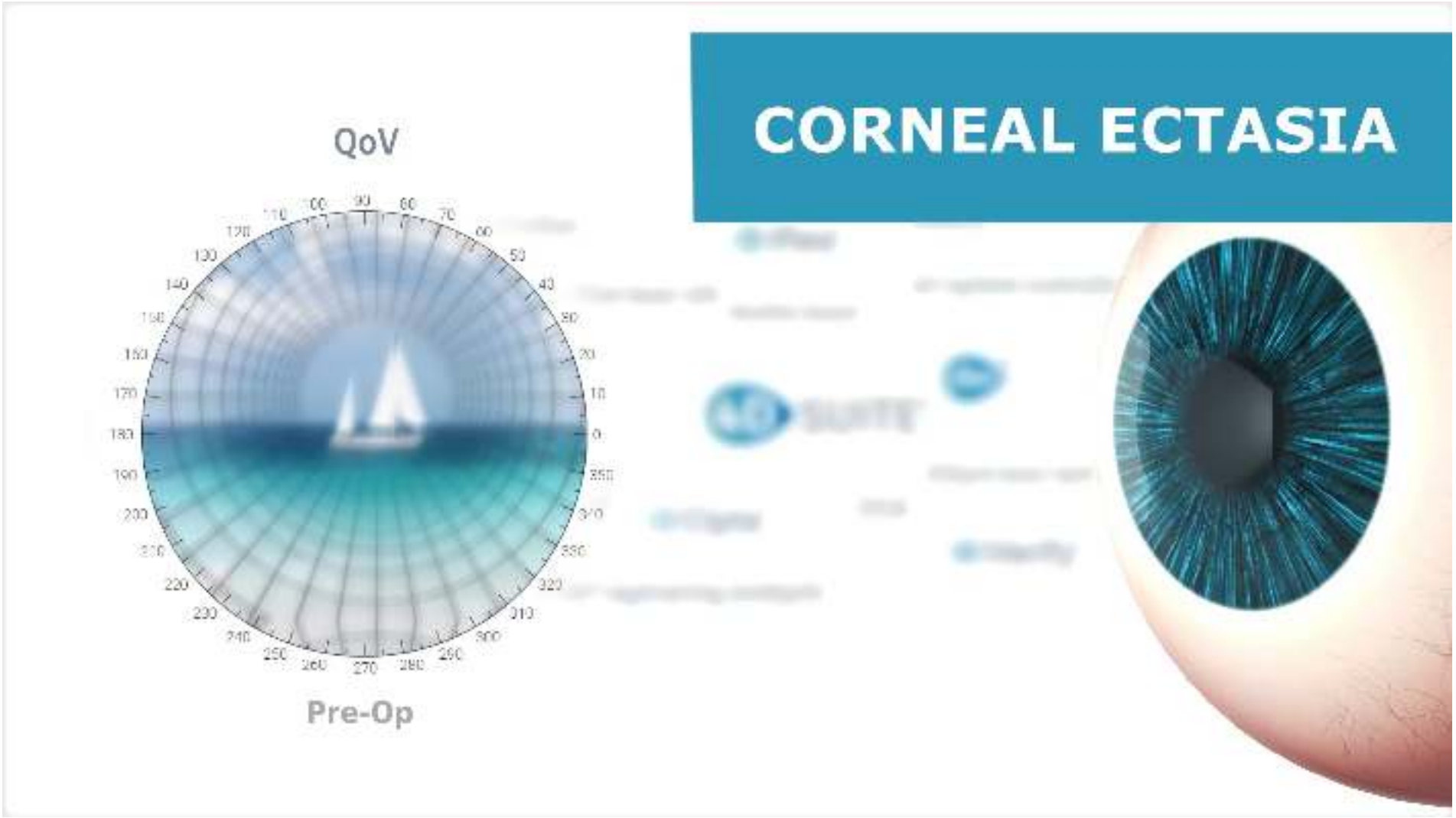
The concept of designing the Ideal Shape for the cornea, exploiting Ray-tracing, comes from the technology and knowledge that iVis developed over the past three decades of R&D in refractive surgery

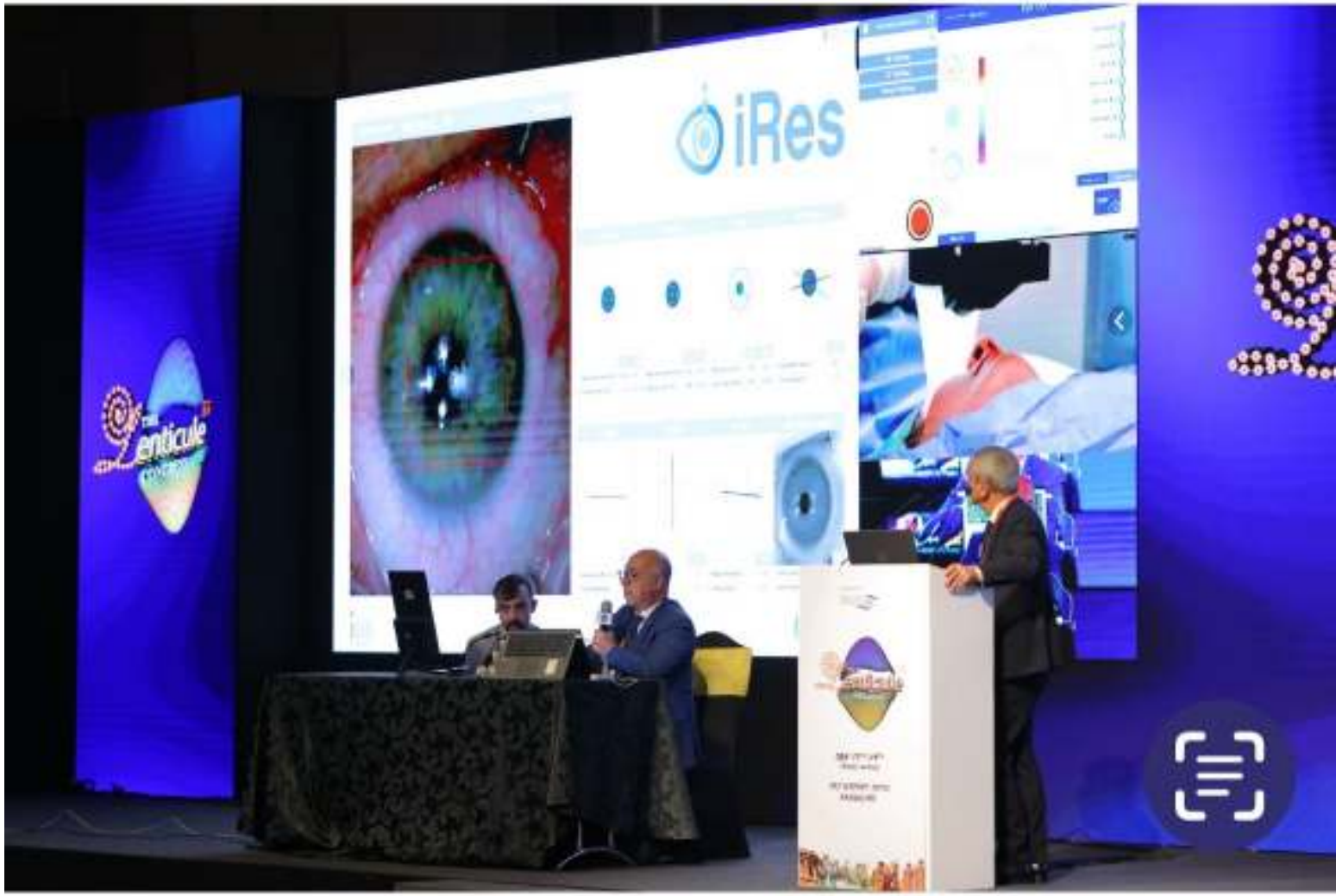
---

4D SUITE

The Ideal Shape

Exactly as the Ideal Shape of the cornea that iVis delivers by means of the 4D Suite

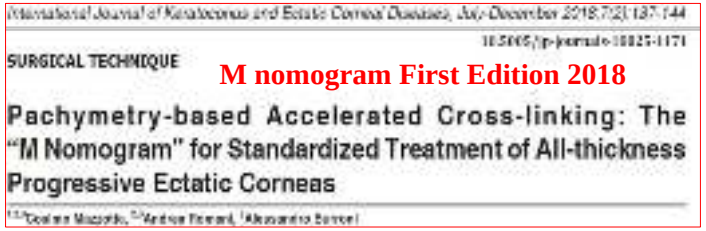




Remote Refractive Surgery is Possible!
Operating from India on a patient in Italy!

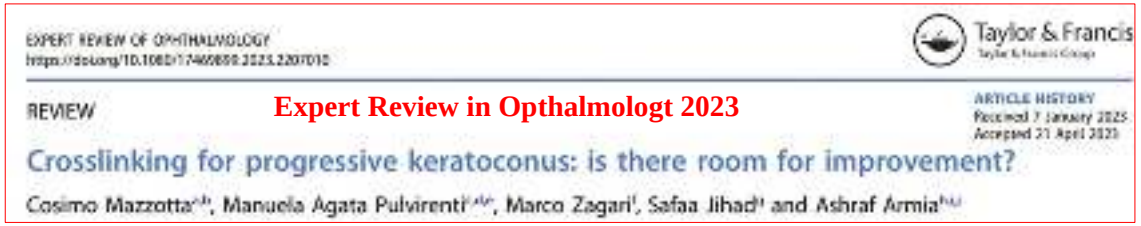
March, 2024

Ray-tracing–guided central corneal remodeling aims to regularize the anterior cornea, taking care of the refractive contribution of the posterior corneal surface aberration to optimize the final QoV and minimize the consumption of stromal tissue. The posterior corneal shape introduces posterior corneal HOAs, which partially compensate for the anterior corneal HOAs


SURGICAL TECHNIQUE

M nomogram First Edition 2018

Pachymetry-based Accelerated Cross-linking: The "M Nomogram" for Standardized Treatment of All-thickness Progressive Ectatic Corneas


EXPERT REVIEW OF OPHTHALMOLOGY

Taylor & Francis

REVIEW

Expert Review in Opthalmologt 2023

ARTICLE HISTORY

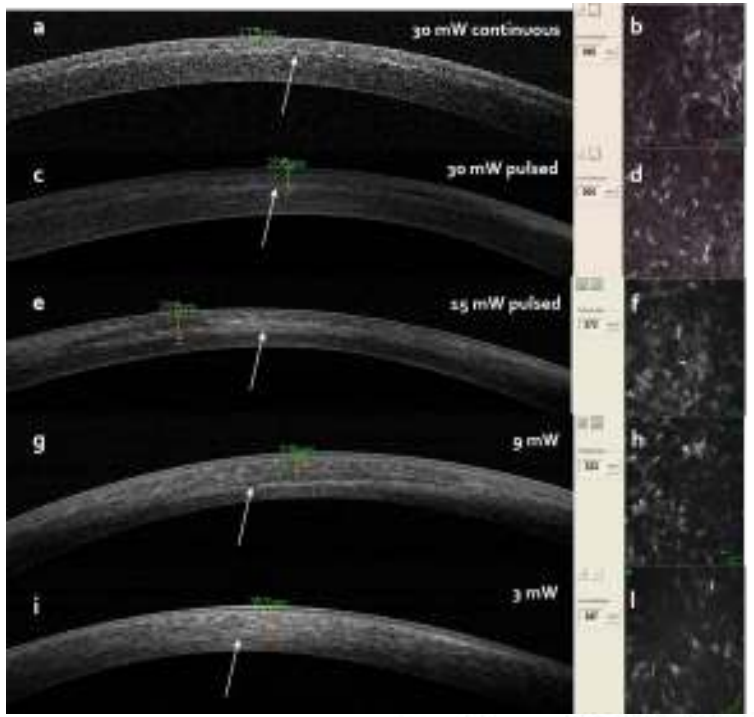
Crosslinking for progressive keratoconus: is there room for improvement?

Cosimo Mazzotta, Manuela Agata Pulvirenti, Marco Zagari, Safaa Jihad and Ashraf Armia


CORNEA

Cornea 2024 M nomogram NEW EDITION

Ray-Tracing Transepithelial Excimer Laser Central Corneal Remodeling Plus Pachymetry-Guided Accelerated Corneal Crosslinking for Keratoconus



Cosimo Mazzotta MD, PhD, FWCRS

Constant Dresden Fluence delivered 5.4J/cm²

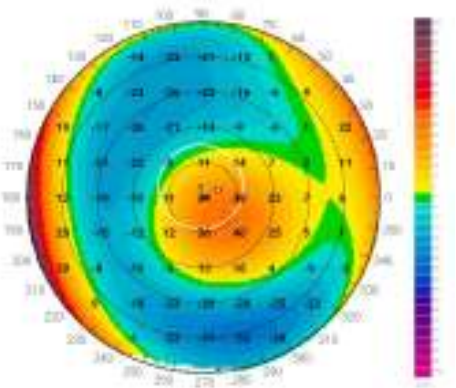
Thinnest inclusion MCT 250µm w.e.

Safety offset for endothelium 50 µm

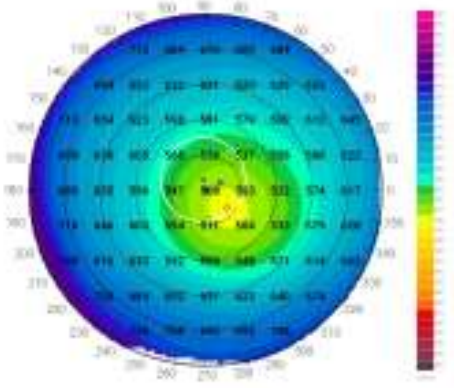
- **MCT ≥250-300 µm 30mW/5.4J/cm² Pulsed 10 min R + 6 min UV-A (R iso 0.25%)**
- **MCT >300-350 µm 18mW/5.4J/cm² Pulsed 10 min +10 min UV-A (R iso 0.2%)**
- **MCT >350-400 µm 15mW/5.4J/cm² Pulsed 10 min + 12 min UV-A (R iso 0.15%)**
- **MCT > 400 µm 9mW/5.4J/cm² Continuous 10 min + 10 min UV-A (R iso 0.1%)**

KC ST II LEFT EYE – PreOP – CDVA 4/10 (Sph -3 = Cyl -3.00 axis 140°)

Anterior Elevation Map



Total Pachimetry Map

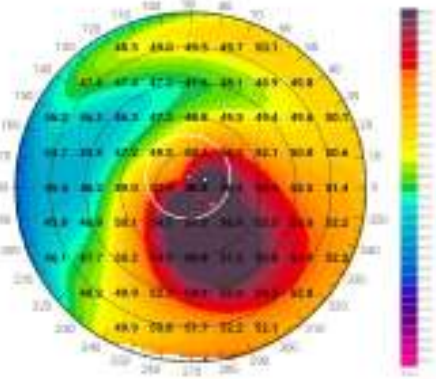


Siena Crosslinking Center

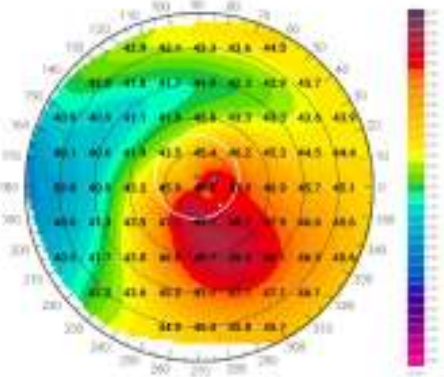
Oculo-Medical-VISION

Head. Prof Cosimo Mazzotta MD, PhD, FWCRS

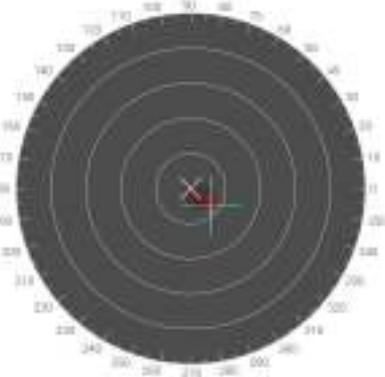
Anterior Ray-Tracing Power Map



Total Cornea Ray Tracing Power Map



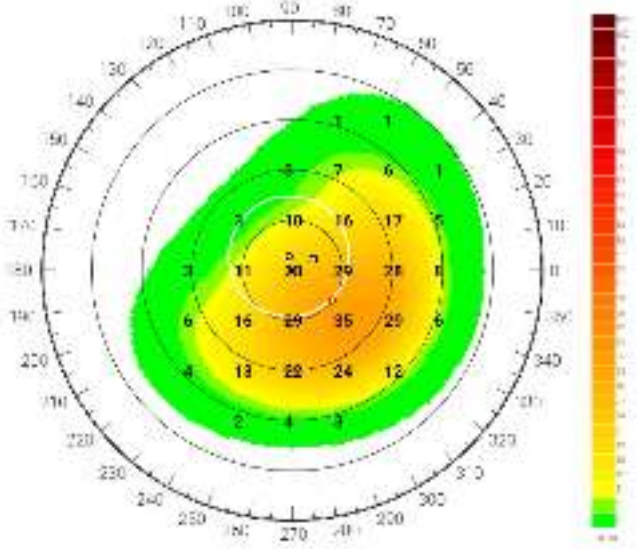
PSF



PhD

Ray-Tracing Ablation Plan

Ablation map



Siena Crosslinking Center

Head: Prof Cosimo Mazzotta MD, PhD, FWCRS

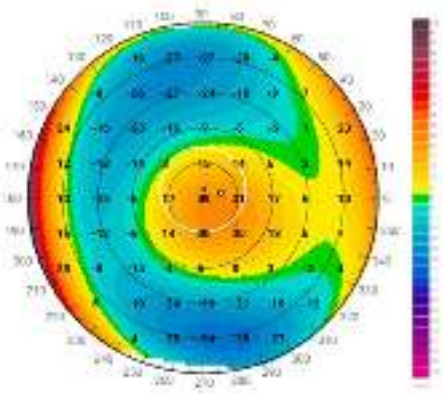
aETCR

Surgical Technique	Epithelium Profile	Debridement Border
cTen	Standard - 54 µm	Circular - 9.0 mm
Max Stromal Depth [	Max Epithelium Dep	Max Total Depth [µm]
36	65	92
Stromal Volume [m...	Epithelial Volume [m...	Total Volume [mm³]
0.4	3.8	4.2
Refractive Zone [mm]	Max Connecting Zo...	Min Connecting Zon...
3.2	8.0	4.4
Photopic Pupil [mm]	Ideal Pupil [mm]	Validated Border [m...
1.0	4.6	9.5
Constant Gradient [...	Max Power [D]	Min Power [D]
16.5	55	34
Sphere [D]	Cylinder [D]	Axis [°]
-2.10	-1.85	141
ΔKx [°]	ΔKy [°]	Δcmi at d = 3.5 mm ...
0.2	0.3	33
Residual Minimum Pachymetry Va...	Treatment Center Offset [mm]	
460 (0.7, -0.7)	(-0.1 ; 0.3)	

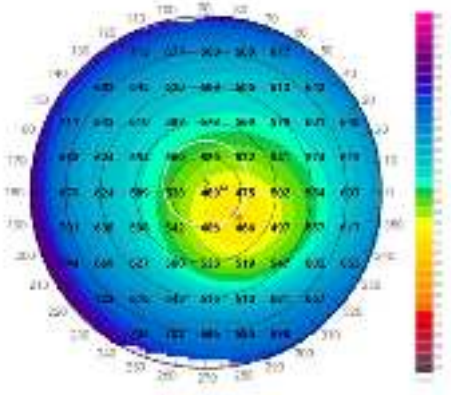
Cosimo Mazzotta MD, PhD, FWCRS

LEFT EYE – PreOP – CDVA 4/10 (Sph -3 = Cyl -3.00 axis 140°)

Anterior Elevation Map



Total Pachimetry Map

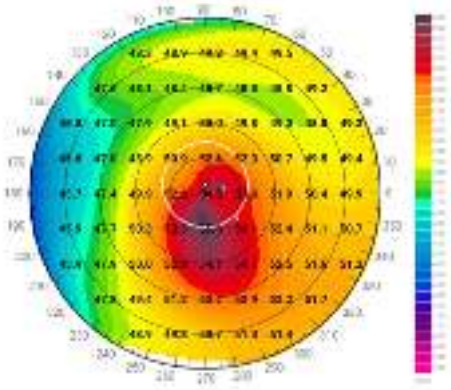


Siena Crosslinking Center

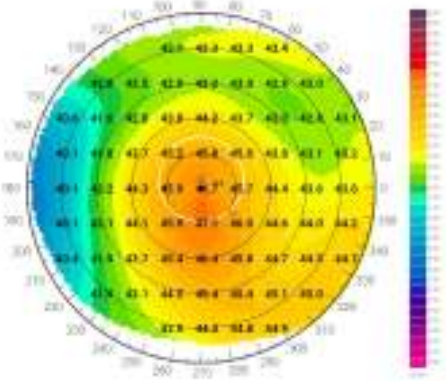
Oculo-Plastical-Vision

Head. Prof Cosimo Mazzotta MD, PhD, FWCRS

Anterior Ray-Tracing Power Map



Total Cornea Ray Tracing Power Map

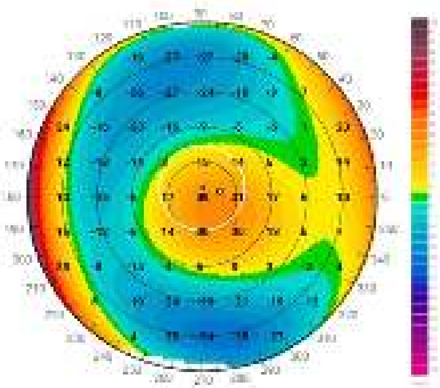


PSF

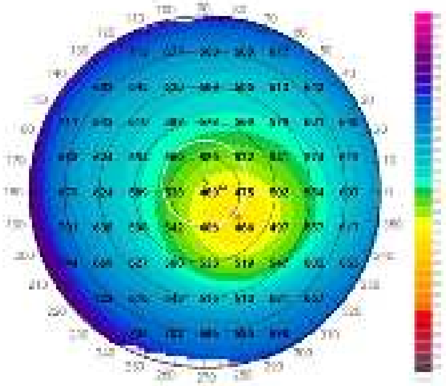
FHBHD

LEFT EYE – PostOP – CDVA 10/10 (Sph -1.00 Cyl = -1.25 axis 10°)

Anterior Elevation Map



Total Pachimetry Map

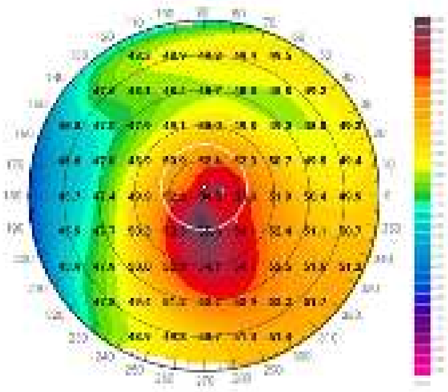


Siena Crosslinking Center

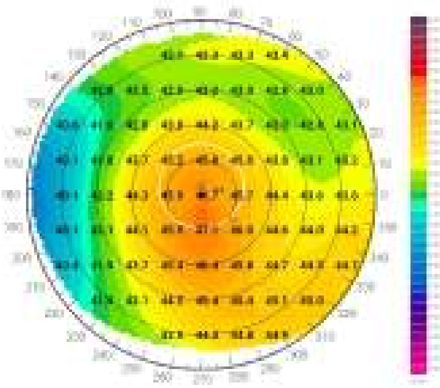
Ocu-Medical-VISION

Head: Prof Cosimo Mazzotta MD, PhD, FWCRS

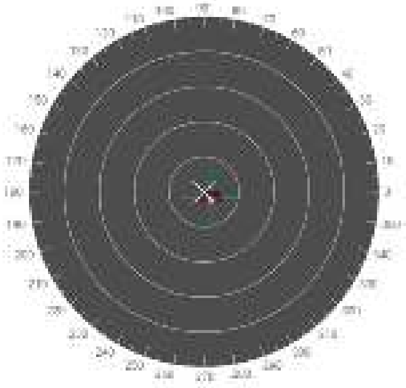
Anterior Ray-Tracing Power Map

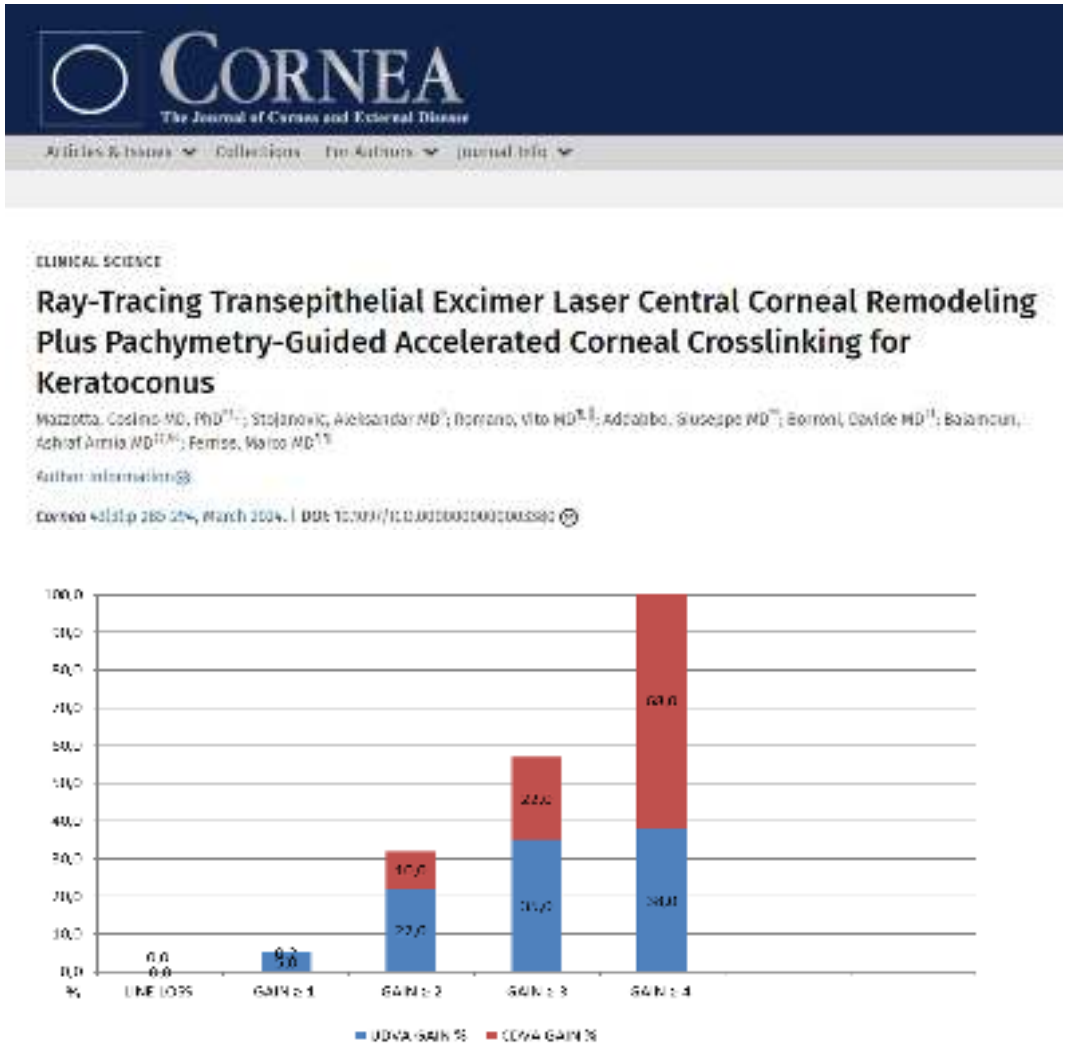


Total Cornea Ray Tracing Power Map



PSF





Gain % UDVA CDVA

- UDVA avg Gain : + 3.5 S lines
- UDVA + 4.4 S lines 38%
- UDVA + 3.2 S lines 35%
- UDVA +2 S lines 22%
- UDVA + 1 Snellen Lines 5%
- No Lines Loss

- CDVA avg Gain + 4.3 S lines
- CDVA + 4.5 (68%)
- CDVA + 3.2 (30%)
- No lines Loss

Cosimo Mazzotta MD, PhD, FWORS

2ND THE INTERNATIONAL KERATOCONUS SOCIETY
WORLD KERATOCONUS CONGRESS

WKC 2025

INTERNATIONAL KERATOCONUS SOCIETY

Save the Date

12-14 JUNE | ATHENS GREECE

www.wkcongress.com