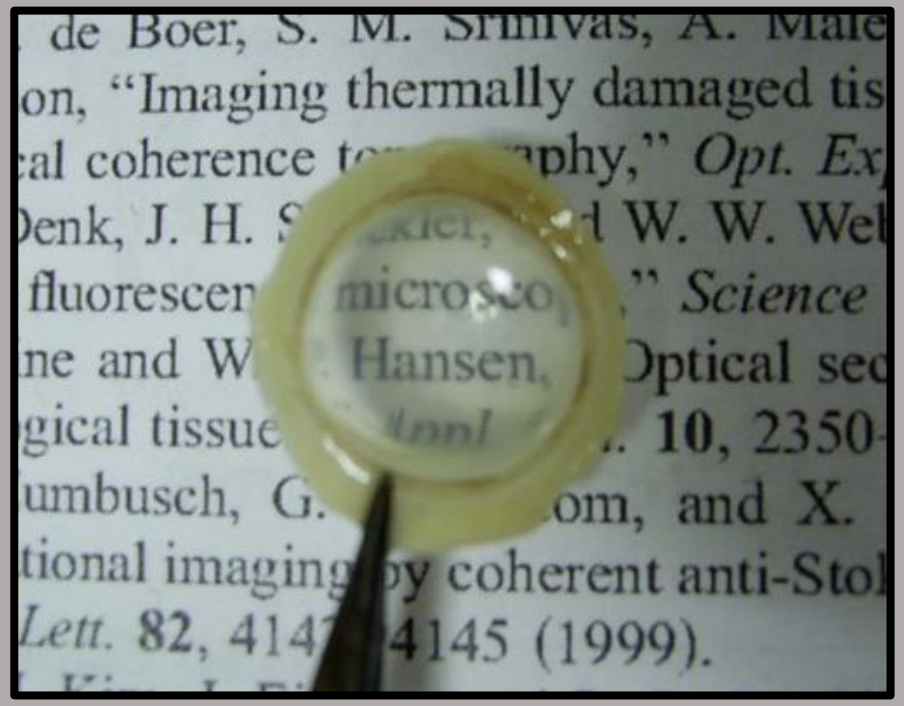
POLARIMETRIA IN OFTALMOLOGIA

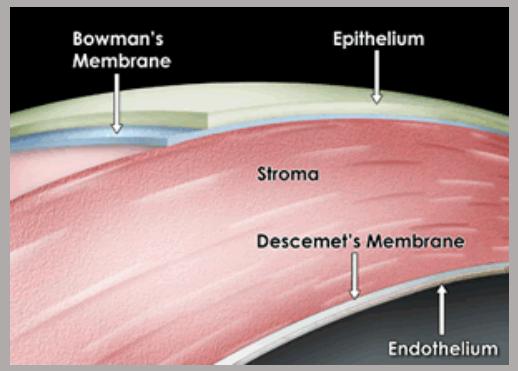
Eugenio LIPARI

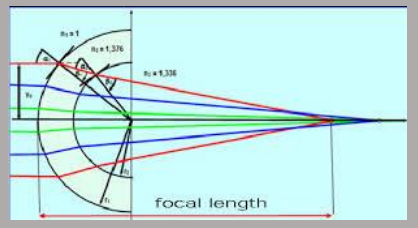
XVI Congresso Società Oftalmologica Calabrese

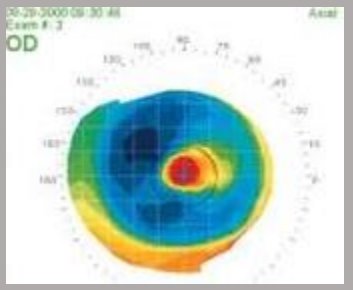
CATANZARO – 07 Ottobre 2016

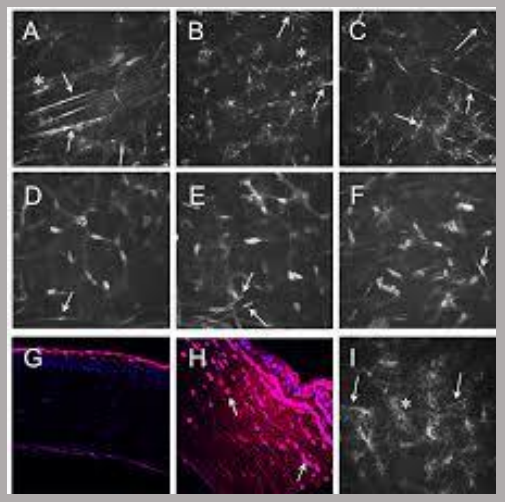
“If you change the way you look at things, the things you look at change” (*Wayne Dyer)*











Fibrils Geometry and Intrastromal Arrangment

X-rays analysis

Craig Boote, Christina S. Kamma-Longer , et al. , Quantification if Collagen Organization in the Peripheral Human Cornea at Micron-Scale Resolution- Biophysical Journal, Vol 101, July 2011, 33-34
McCally RL, Farrell RA - Small-angle light scattering and birefringence properties of chick cornea - J Refract Surg. 1999 Nov-Dec;15(6):706-10, Meek KM, Boote C. –The use of X-ray scattering techniques to quantify the orientation and distribution of collagen in te corneal stroma - Prog Retin Eye Res, 2009 Sep; 28(5) :369-92
Abahussin M., Hayes S, Knox Cartwright NE, Kamma-lorger CS, Khan Y, Marshall J, Meek KM – 3D collagen orientation study of the human cornea using X-ray diffraction and femtosecond laser technology – Jnvest Ophtalmol Vis Sci, 2009 Nov; 50(11): 5159-64
Boote C, Dennis S, Newton RH, Puri H, Meek KM - Collagen fibrils appear more closely packed in the prepupillary cornea: optical and biomechanical implications - Invest Ophthalmol Vis Sci. 2003 Jul;44(7):2941-8
Boote C, Christina S. Kamma-Lorger, Sally Hayes, Jonathan Harris, Manfred Burghammer, Jennif er Hiller, Nicholas J. Terril and Keith M. Meek – Quantification of Collagen Organization in the Peripheral Human Cornea at Micron-Scale Resolution – Biophysical Journal, Vol.11 July 2011 (33-42)
Hossein Aghamohammadzadeh, Richard H. Newton, and Keith M. Meek* - X-Ray Scattering Used to Map the Preferred Collagen Orientation in the Human Cornea and Limbus - Structure 2004 Feb;12(2):249-56
…

SHG (Second Armonic Generation)

Naoyuki Morishige, Yuki Takagi, Tai-ichiro Chikama, Atsushi Takahara and Teruo Nishida, **Three-Dimensional Analysis of Collagen Lamellae in the Anterior Stroma of Huma Cornea Visualized by Second Harminic Generation Imaging Microscopy-** IOVS, February 2011, vol 52, No 2
Nicolas Olivier, Florent Aptel, Karsten Plamann, Marie-Claire Schanne-Klein and emmanuel Beaurepaire, **Harmonic microscopy of isotropic and anisotropic microstructure of the human cornea- Optic Express 5028 – March 2010/vol.18, No.5**
…

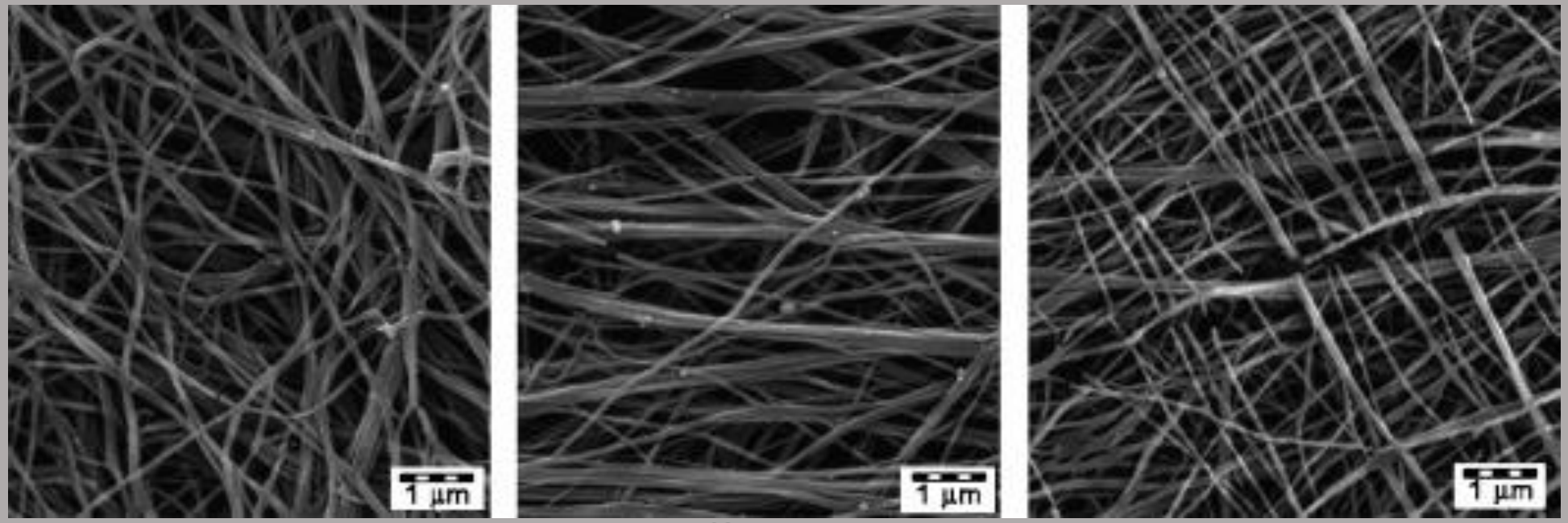
Combined Techniques (SHG, P-SHG, THG, X-rays)

Latour G, Gusachenko I, Kowalczuk L, Lamarre I, Schanne-Klein MC, **In vivo structural imaging of the cornea by polarization-resolved second harmonic microscopy - Biomed Opt Express 2012 Jan 1;3(1): 1-15**
Petsche SJ, Pinsky PM - The role of 3-D collagen organization in stromal elasticity: a model based on X-ray diffraction data and second harmonic-generated images - Biomech Model Mechanobiol. 2013 Jan 4
…

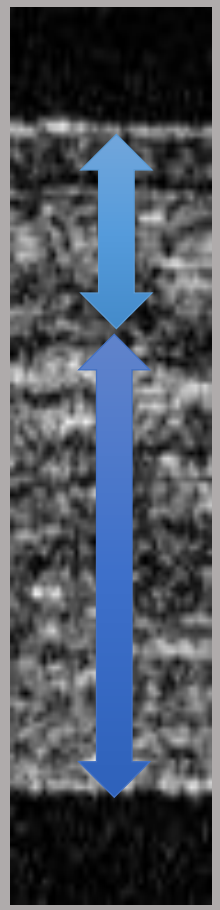
Stroma Structure

Collagen Fibrils:

- 20-30 nm avg. diameter
- organized in lamellae, average thickness of 10 μm
- ~ 50 layers through the full cornea thickness



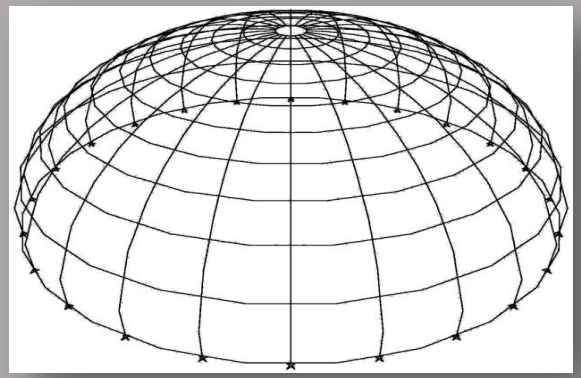
Fibrils Geometry and Intrastromal Arrangment



First third of cornea (anterior stroma):

"ISOTROPIC" Meridian Distribution

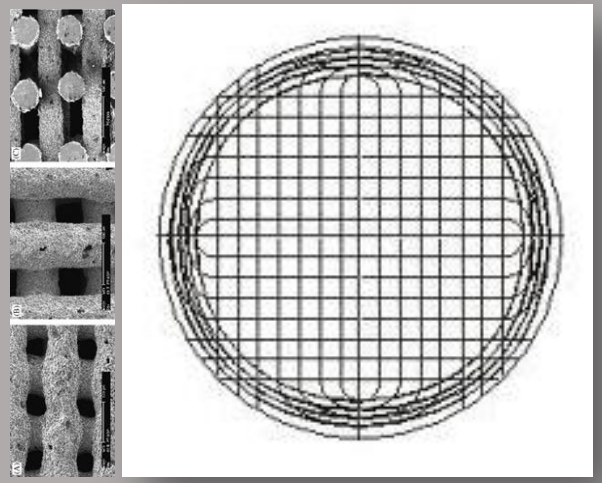
- Antero-posterior lamellar interconnections
- Responsible for cornea robustness



Two-thirds of cornea (posterior stroma):

"ANISOTROPIC" (Orthogonal) Distribution

- Superior-inferior and nasal-temporal lamellar interconnections



Hossein Aghamohammadzadeh, Richard H. Newton, and Keith M. Meek* - X-Ray Scattering Used to Map the Preferred Collagen Orientation in the Human Cornea and Limbus - Structure 2004 Feb;12(2):249-56

Peripheral Collagen Fibrils Arrangment

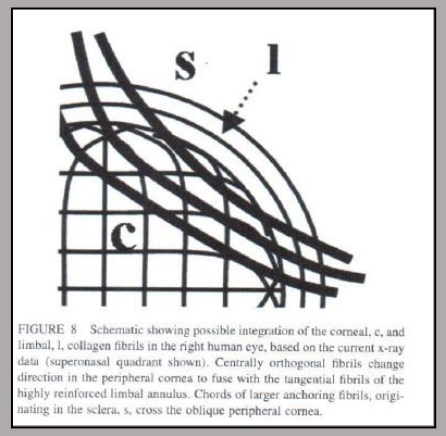
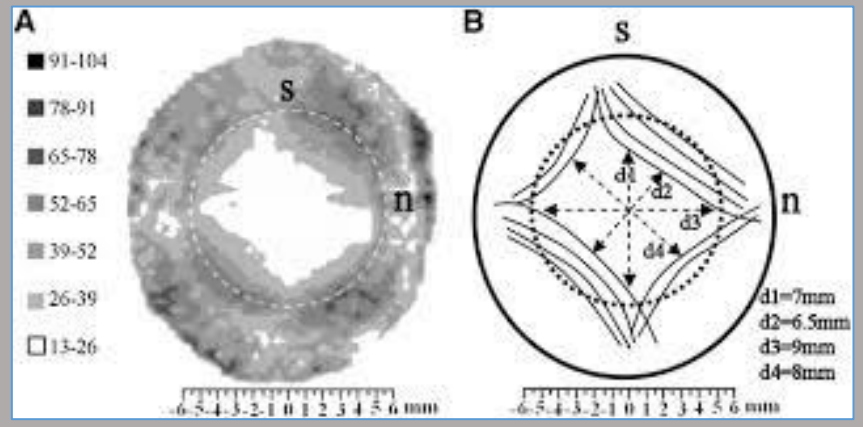
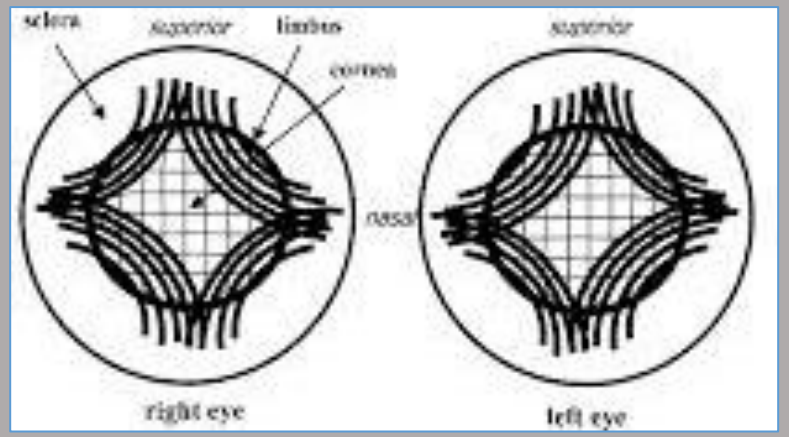


FIGURE 8 Schematic showing possible integration of the corneal, c, and limbal, l, collagen fibrils in the right human eye, based on the current x-ray data (superonasal quadrant shown). Centrally orthogonal fibrils change direction in the peripheral cornea to fuse with the tangential fibrils of the highly reinforced limbal annulus. Chords of larger anchoring fibrils, originating in the sclera, s, cross the oblique peripheral cornea.



Craig Boote, Christina S. Kamma-Longer , et al. , Quantification if Collagen Organization in the Peripheral Human Cornea at Micron-Scale Resolution- Biophysical Journal, Vol 101, July 2011, 33-34

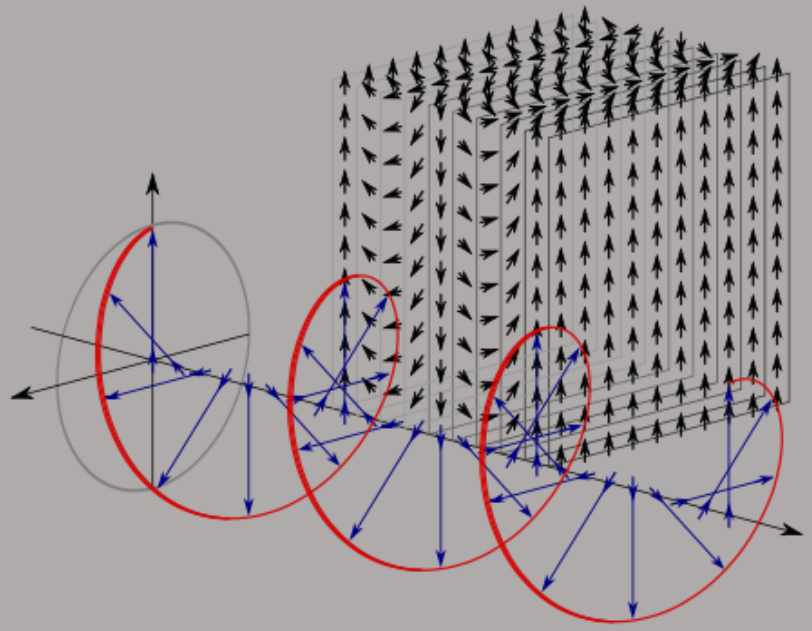


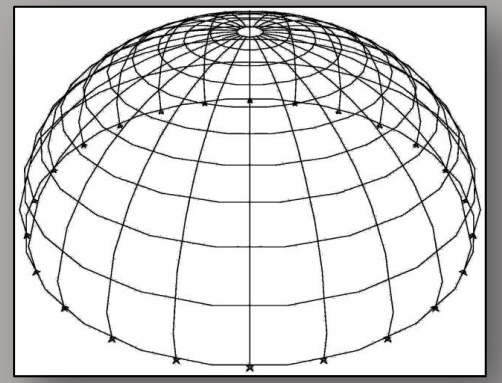
Meek K.M. , The Cornea and Sclera – Collagen, Structure and Mechanics, Springer, Cap 13, 2008 , 359-396

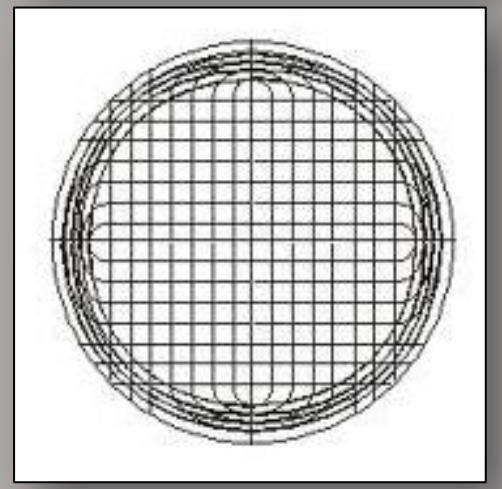
Light transmission in transparent medium

Two main categories of media exist:

- **ISOTROPIC**
- **ANISOTROPIC**

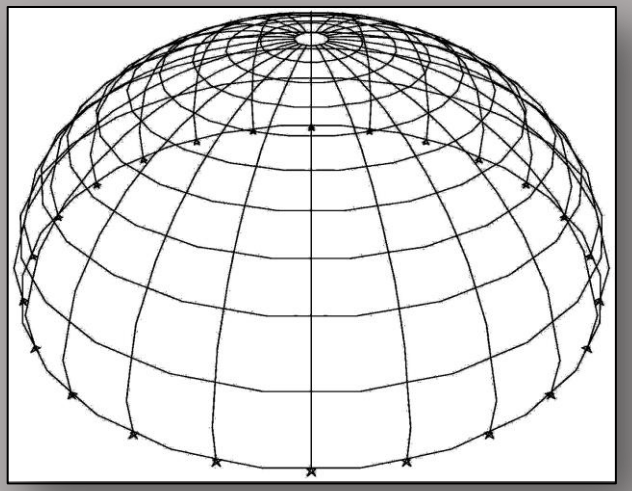




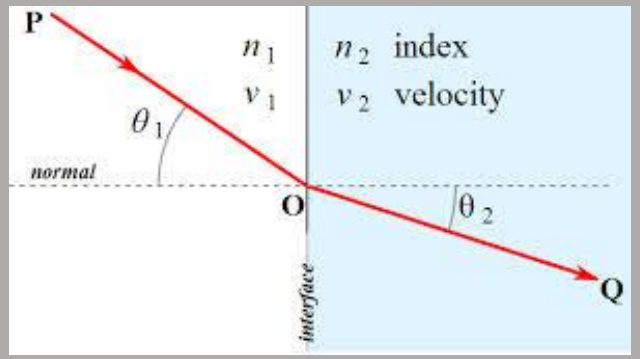


Isotropic Materials (gases, liquids, glasses …):

- Light travels with equal velocity in all directions
- Constant direction-independent refractive index

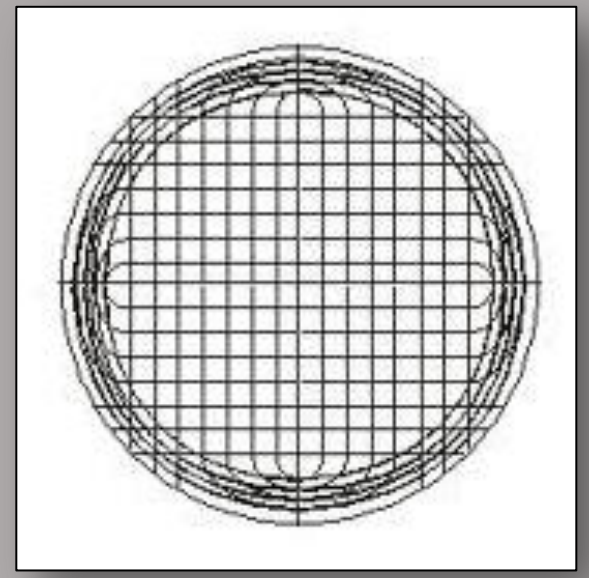


Isotropic materials transmit light in any polarized state without alteration !!!

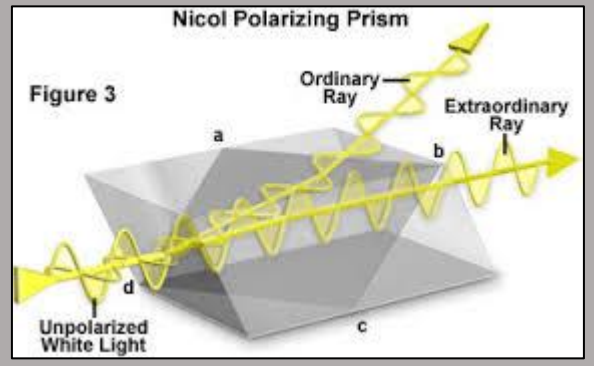


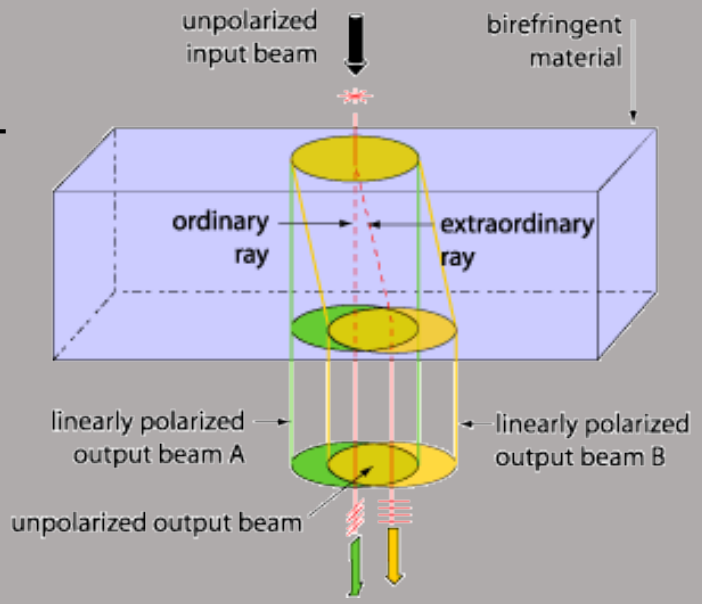
Anisotropic Materials

- Light velocity is direction-dependent according with the anisotropy of the molecular binding forces or structural features



BIREFRINGENCE OCCURS !

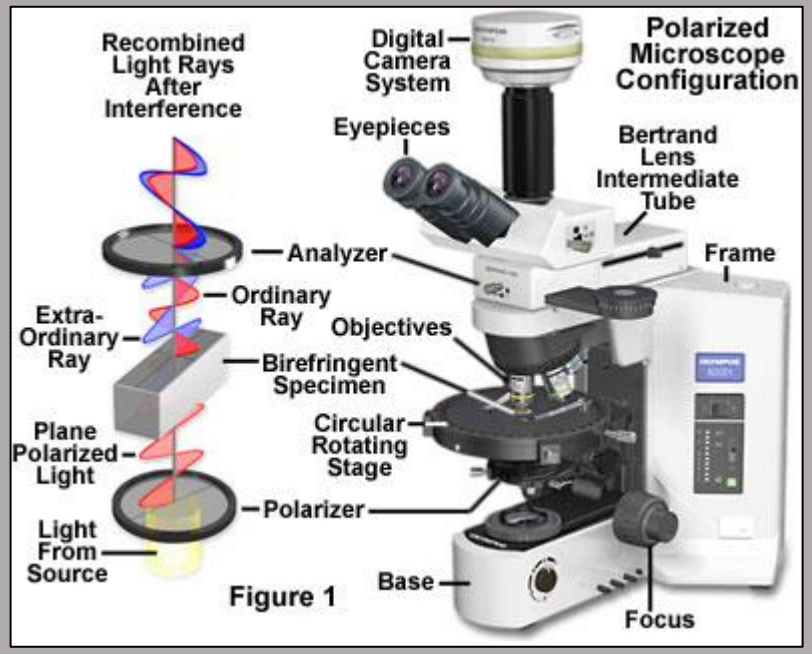


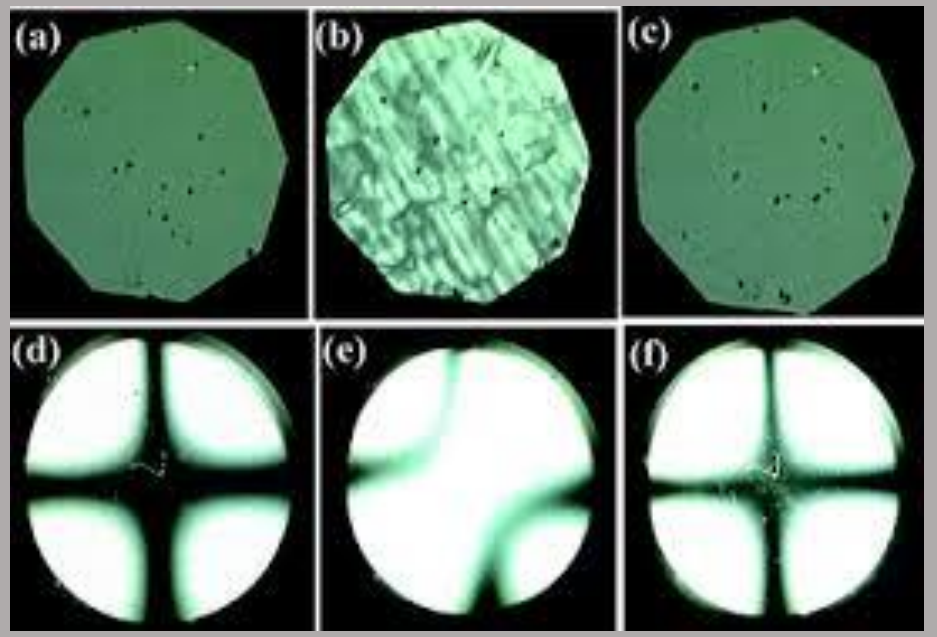


Birefringence phenomena is the *"splitting of incident light into two orthogonally polarized light rays with different velocities and hence different refractive indices"*.

Birefringence and Conoscopy

Optical property of birefringent medium can be analyzed with a polariscope and isogyres generation



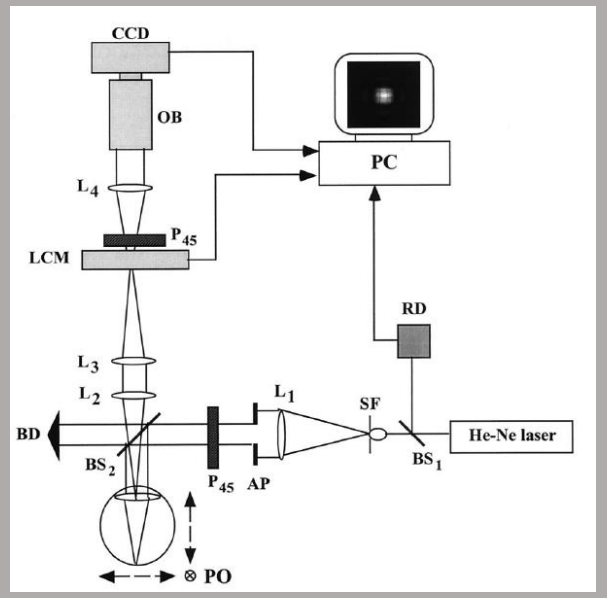


Birefringence and Stroma properties

Measurements of the corneal birefringence with a liquid-crystal imaging polariscope

Juan M. Bueno and Fernando Vargas-Martín

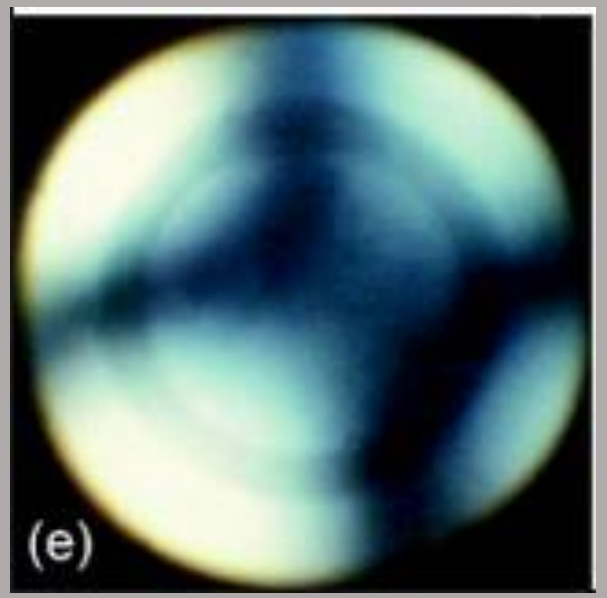
116 APPLIED OPTICS / Vol. 41, No. 1 / 1 January 2002



IS THERE A LINK BETWEEN CORNEAL STRUCTURE AND THE 'CORNEAL CROSS'?

BARBARA K. PIERSCIONEK[1] and ROBERT A. WEALE[2,3]

Eye (1997) 11, 361–364



Optical anisotropy of the human cornea determined with a polarizing microscope

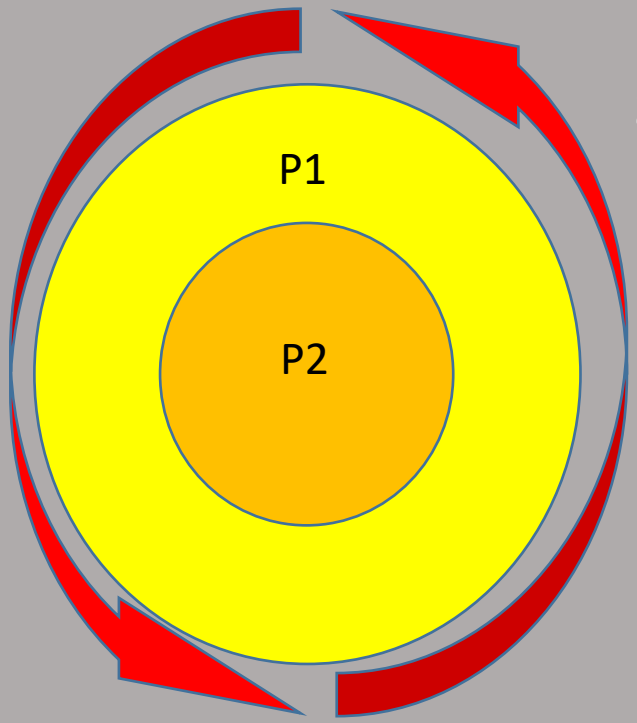
Richard A. Bone and Grenville Draper »View Author Affiliations

Applied Optics, Vol. 46, Issue 34, pp. 8351-8357 (2007)
http://dx.doi.org/10.1364/AO.46.008351

Lumaxis®: Polarimetric Interferometry

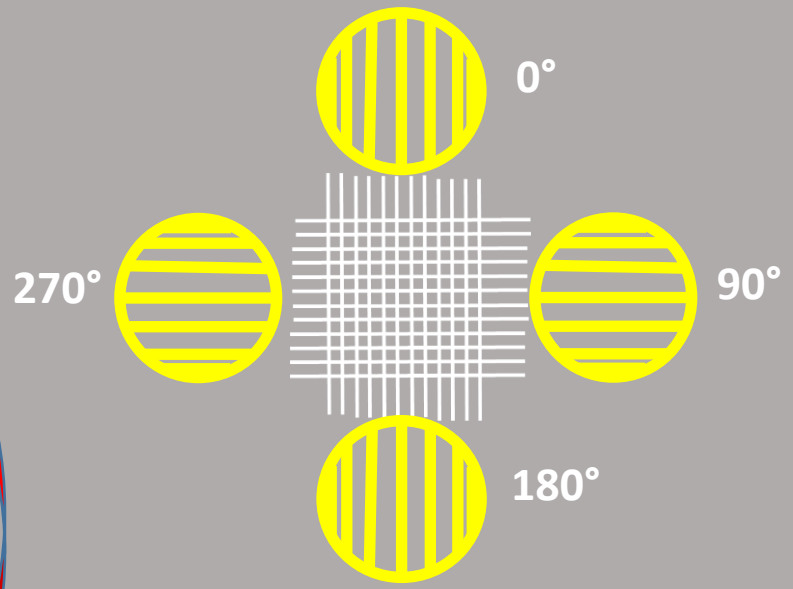
LUMAXIS™
CORNEAL LAMELLA PHASE ALIGNMENT

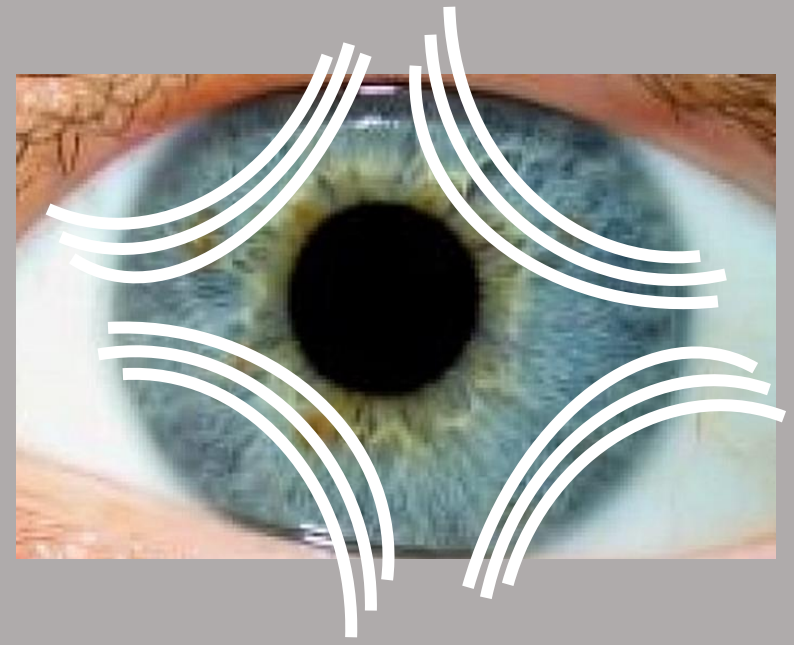
Lumaxis: Detection of collagen fibrils orientation

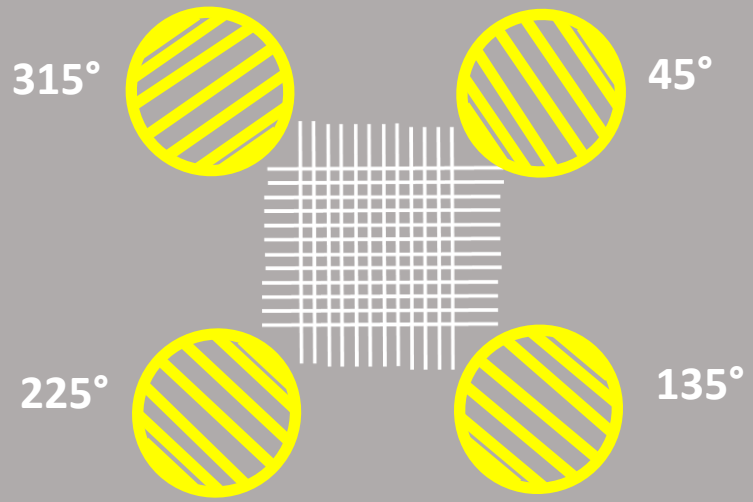


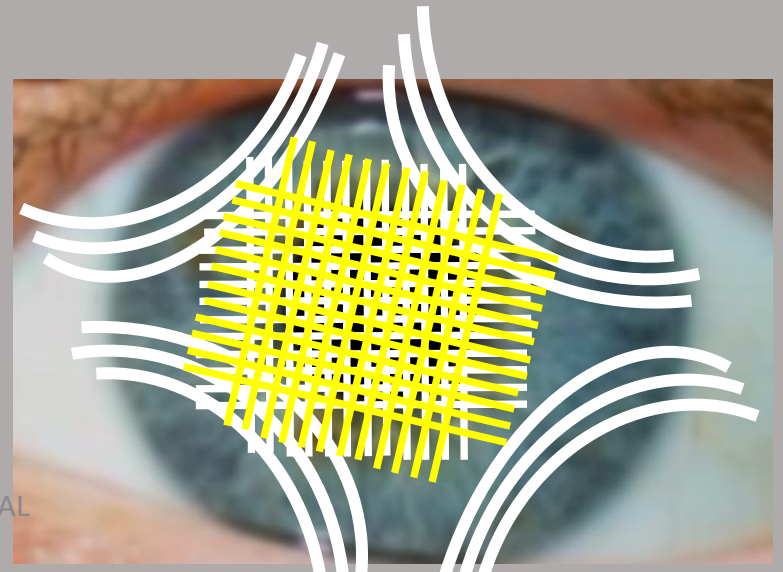
Patented Technology:

- **PCT/IB2013/058263**
- **PCT/IB2014/063482**

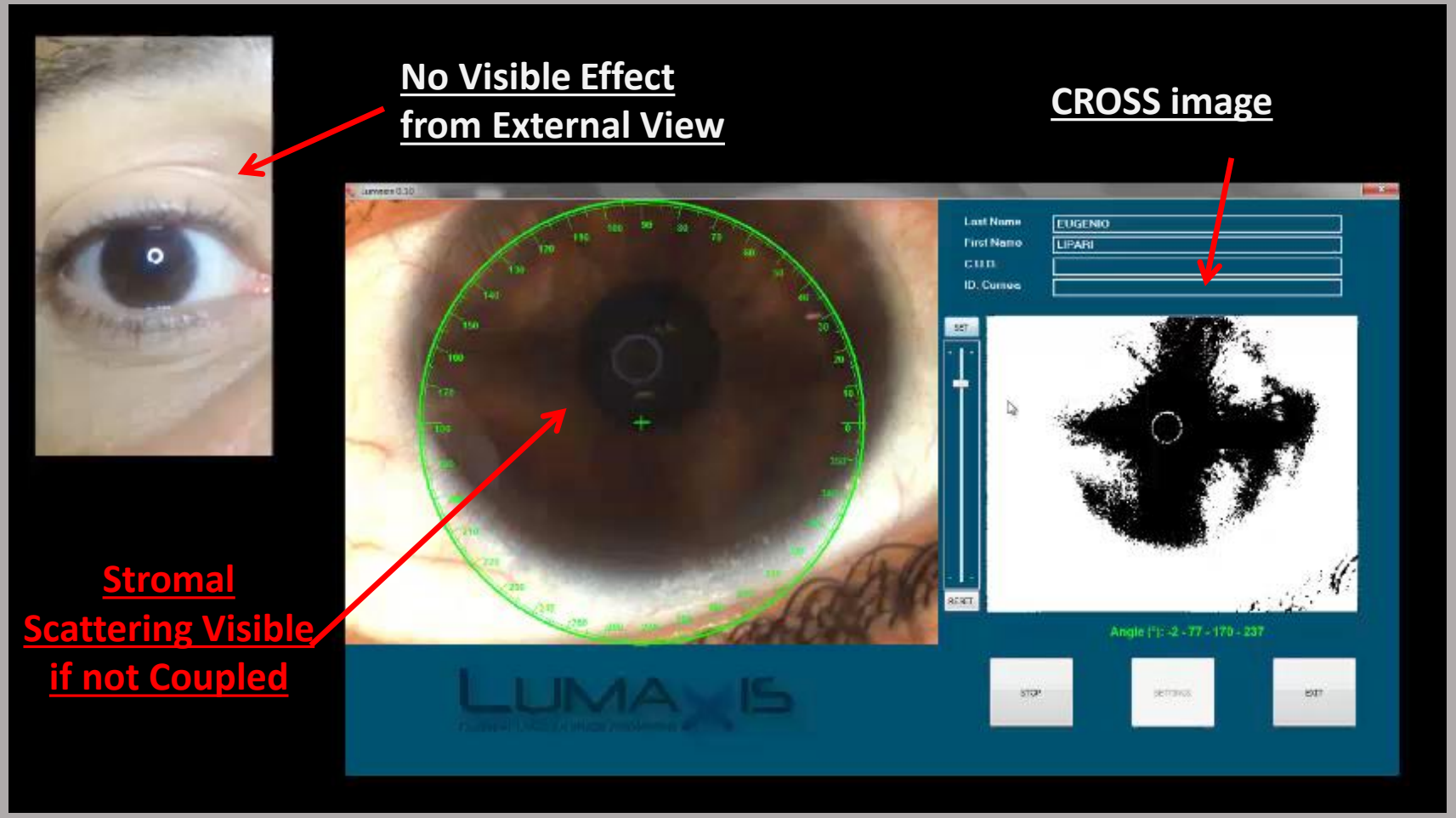






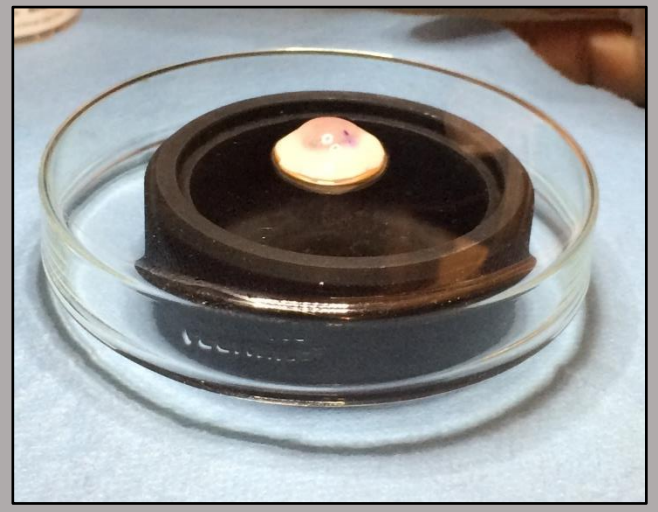


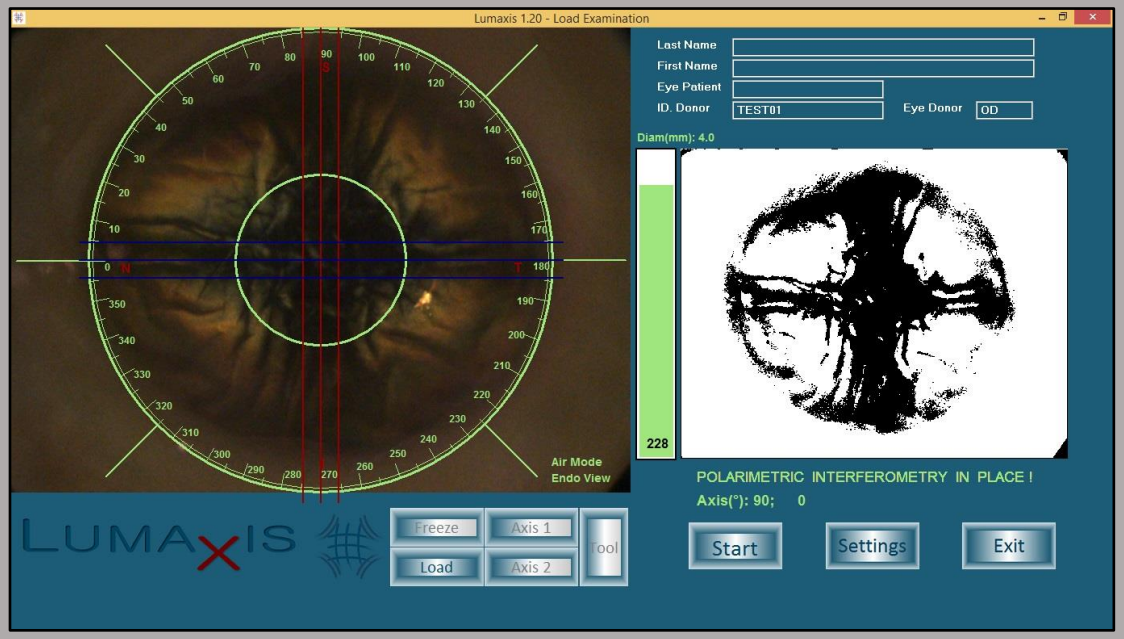
Real-Time Lumaxis Imaging



Real-Time Lumaxis Imaging for Donor Cornea

«'CORNEAL CROSS' IS CREATED ONCE POLARIZERS ARE ALIGNED WITH DEEP STROMA COLLAGEN FIBRILS DIRECTIONS»



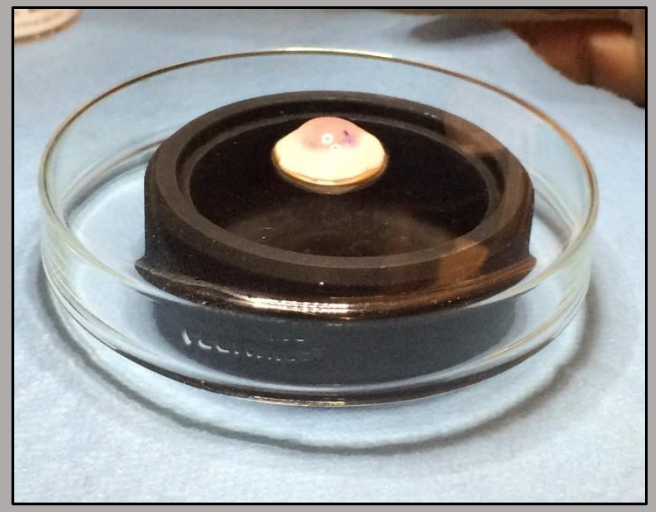


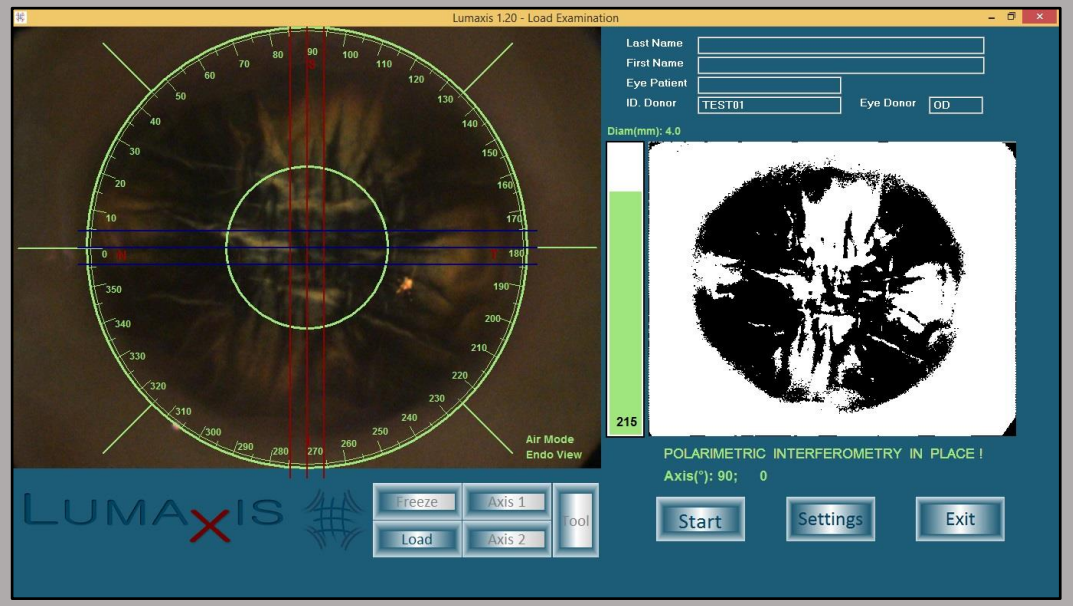
The Dark Bands (Isogyres) correspond to points of the cornea stroma where the state of polarization of the incident Light is unchanged

HUMAN CORNEA IS ANALYZED «ON AIR»

Real-Time Lumaxis Imaging for Donor Cornea

«’CORNEAL CROSS’ DISAPPEARS TO GENERATE TWO HYPERBOLAE SHAPED PATTERN ONCE POLARIZERS ARE 45° OFF TO THE DEEP STROMA COLLAGEN FIBRILS DIRECTIONS»

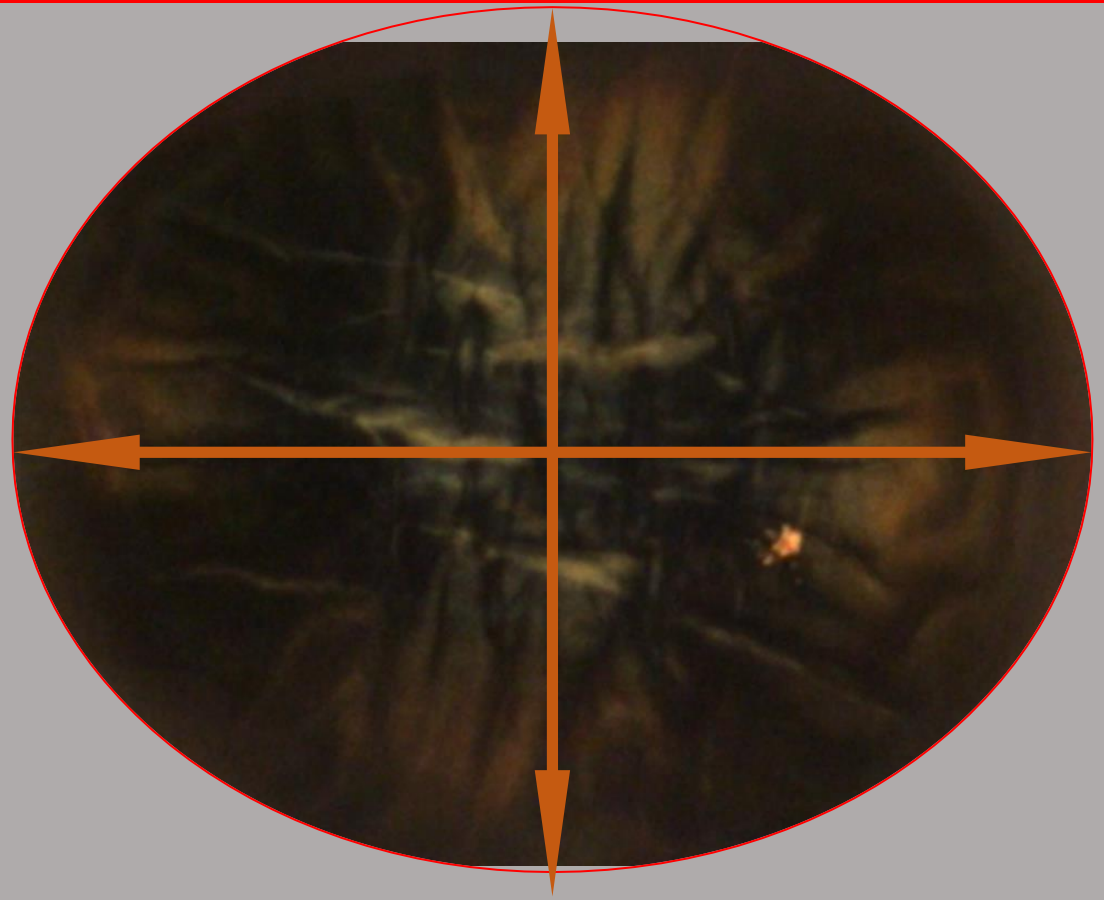




HUMAN CORNEA IS ANALYZED «ON AIR»

Real-Time Lumaxis Imaging for Donor Cornea

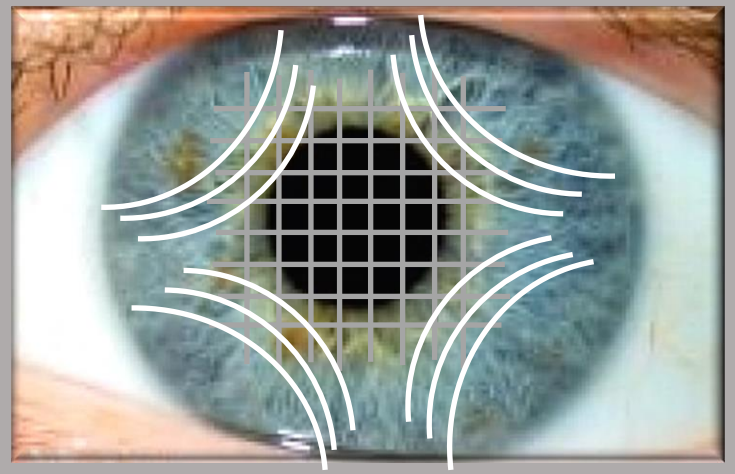
LIVE SCAN !!

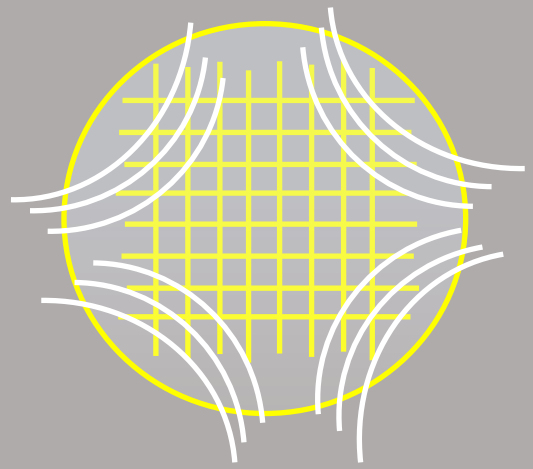


WHAT IS THE CLINICAL IMPORTANCE OF LUMAXIS?

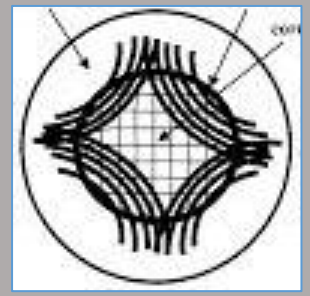
Corneal Keratoplasty:

- **<u>Lamellar Keratoplasty (Anterior and Posterior)</u>**: Lumaxis scans both donor and patient cornea and allows the surgeon to align each other to optimize the postop visual outcome;





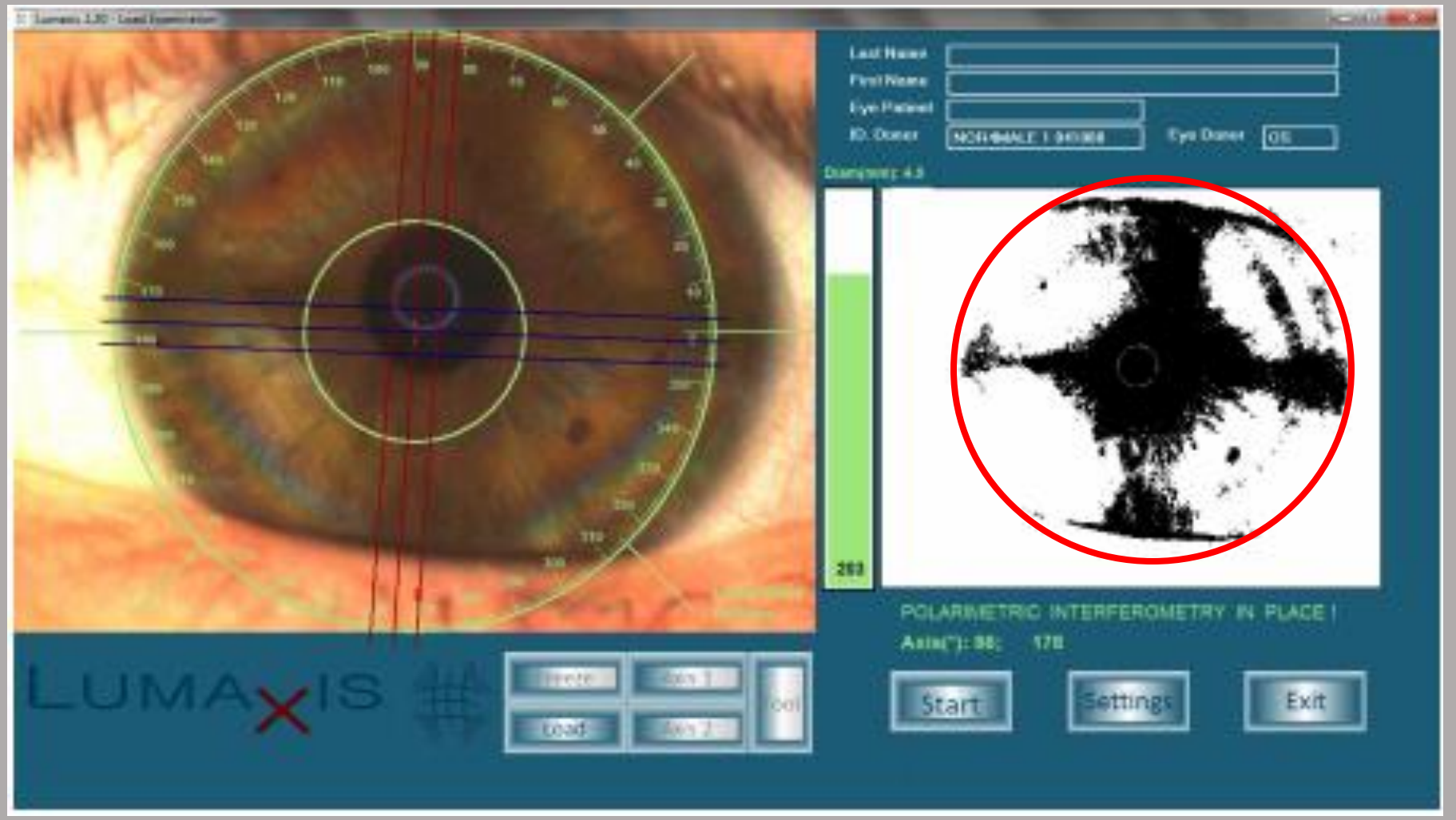
- **<u>Penetrating Keratoplasty</u>: Are Right and Left Eye Corneas Interchangeable???**



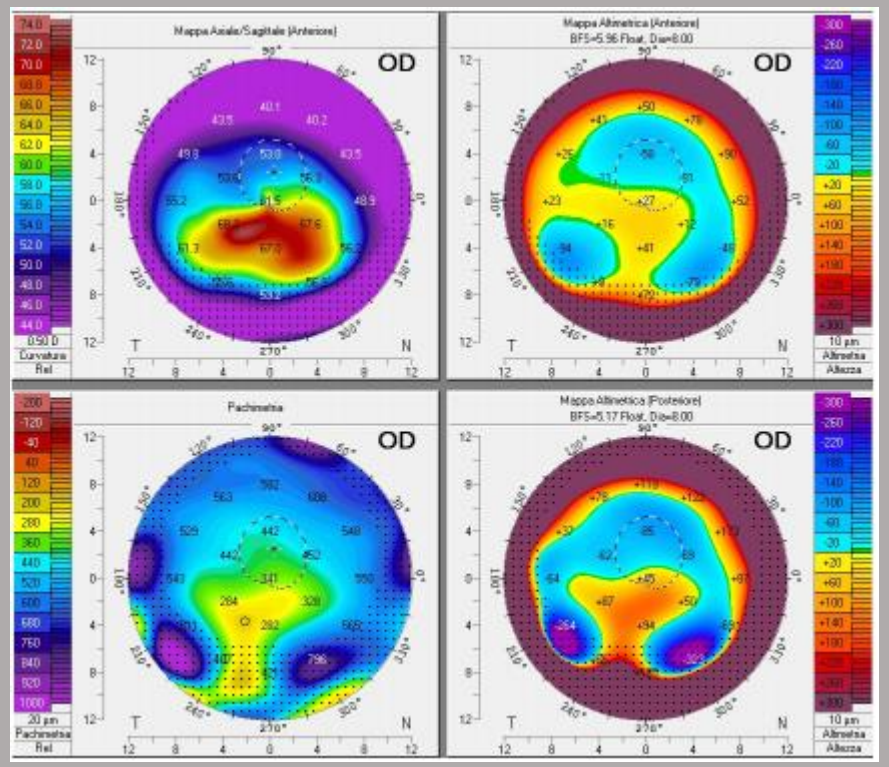
Vs.

OD OS

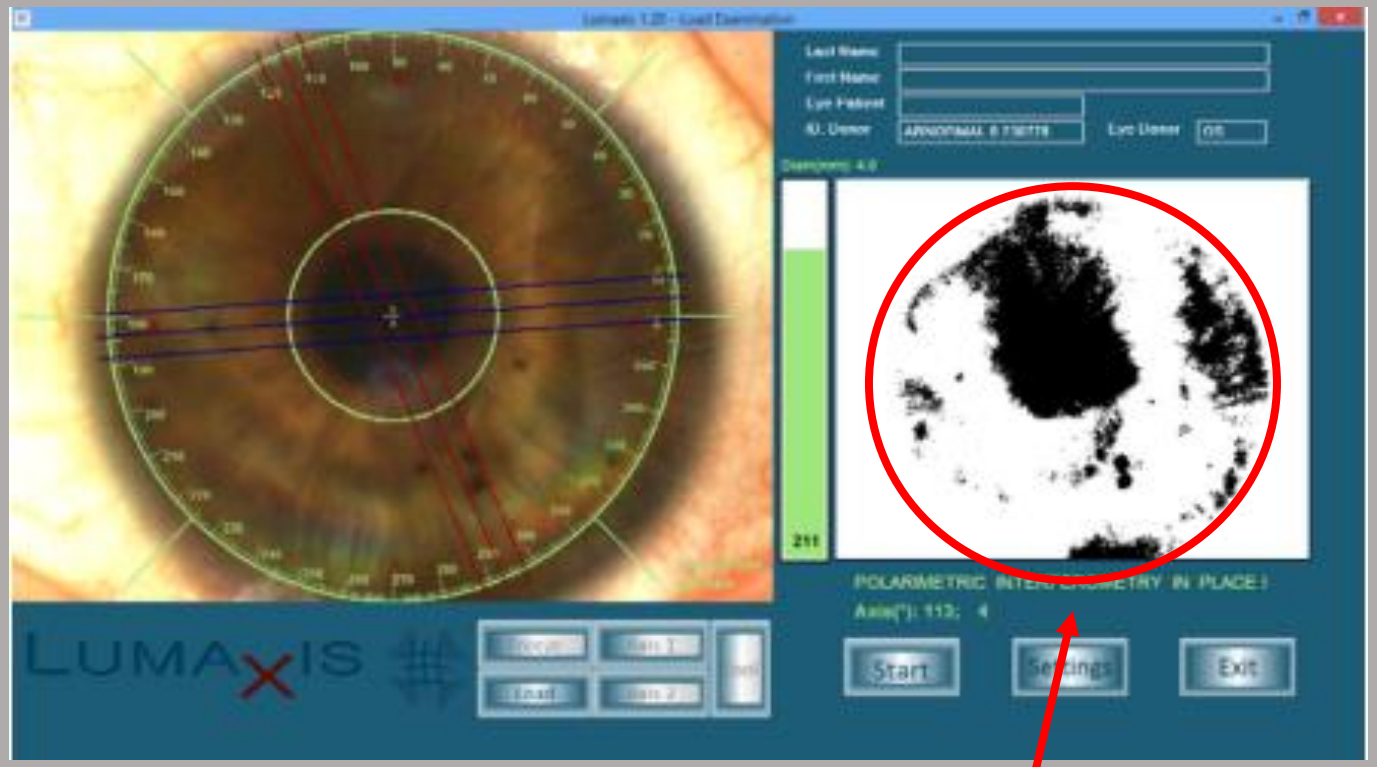
“CORNEAL CROSS” PATTERN IS REGULAR AND SIMMETRIC AS CONSEQUENCE OF THE FIBRILS ANISOTROPY



WHAT HAPPEN TO THE “CORNEAL CROSS” IF INTERNAL STROMA STRUCTURE IS COMPROMISED?

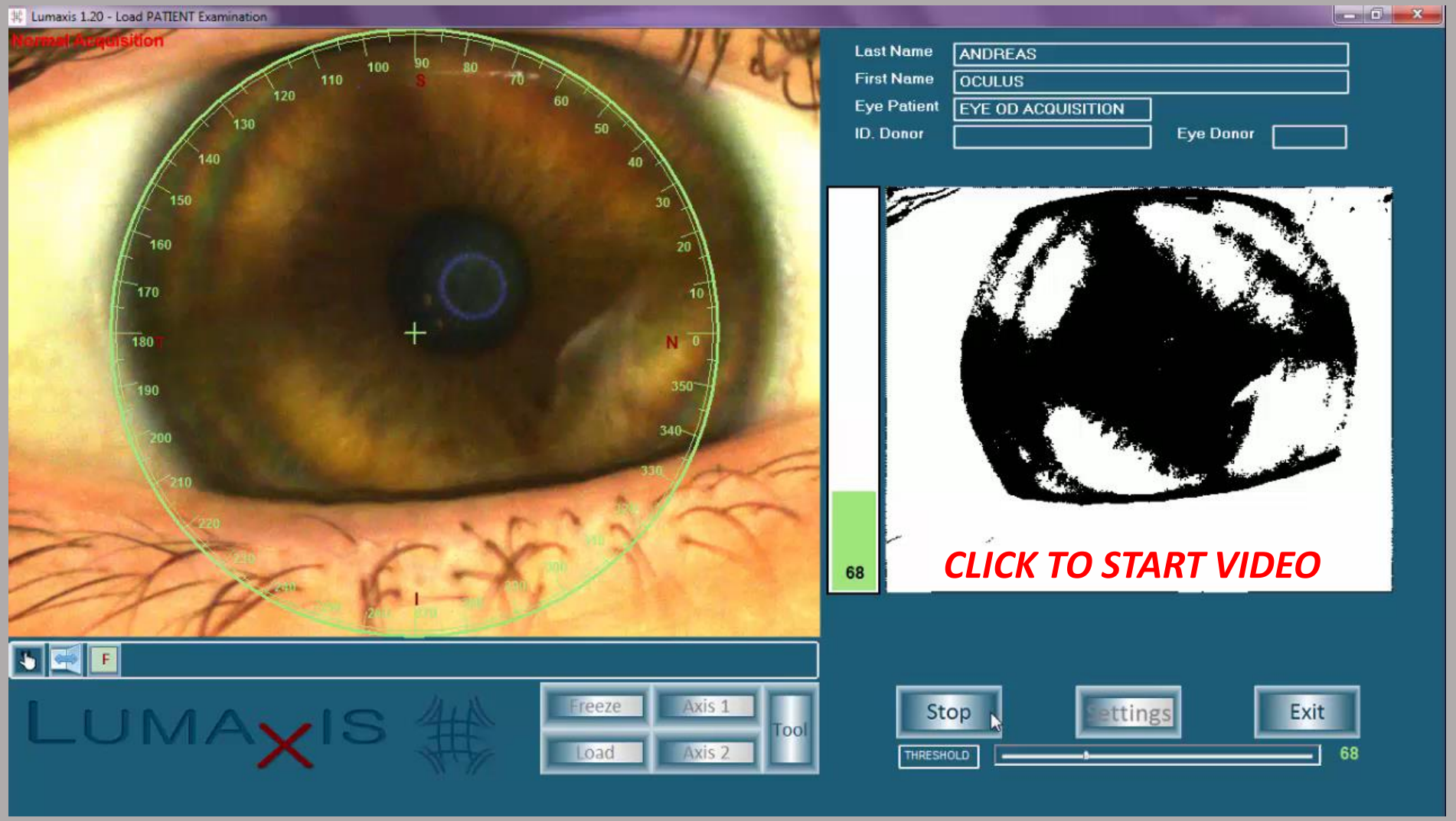


KC PATIENT

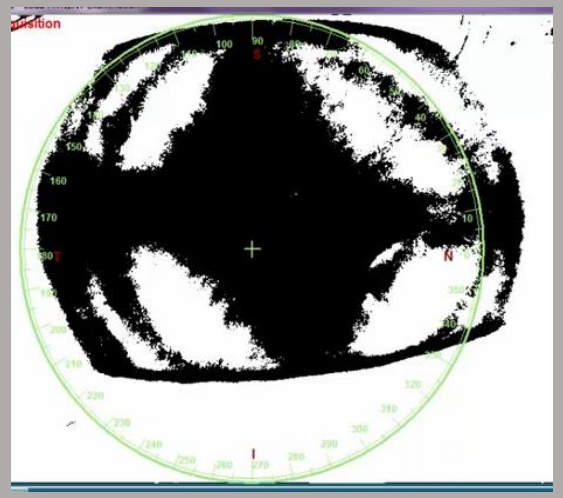


NO CROSS PATTERN ANY MORE !!!!

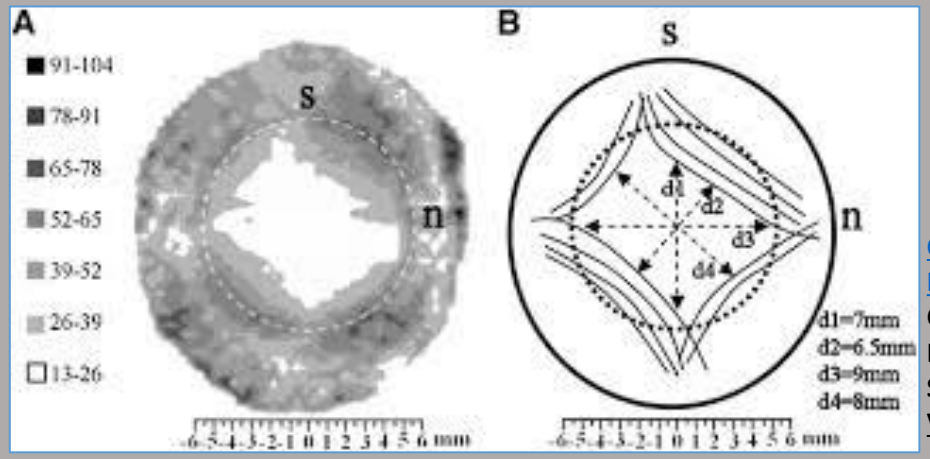
Acquisition on regular Eye



Acquisition on regular Eye: *E.L. OD*



vs.



Craig Boote, Christina S. Kamma-Longer , et al. , Quantification if Collagen Organization in the Peripheral Human Cornea at Micron-Scale Resolution- Biophysical Journal, Vol 101, July 2011, 33-34

Lumaxis®

(EUGENIO)

X-Rays Analysis

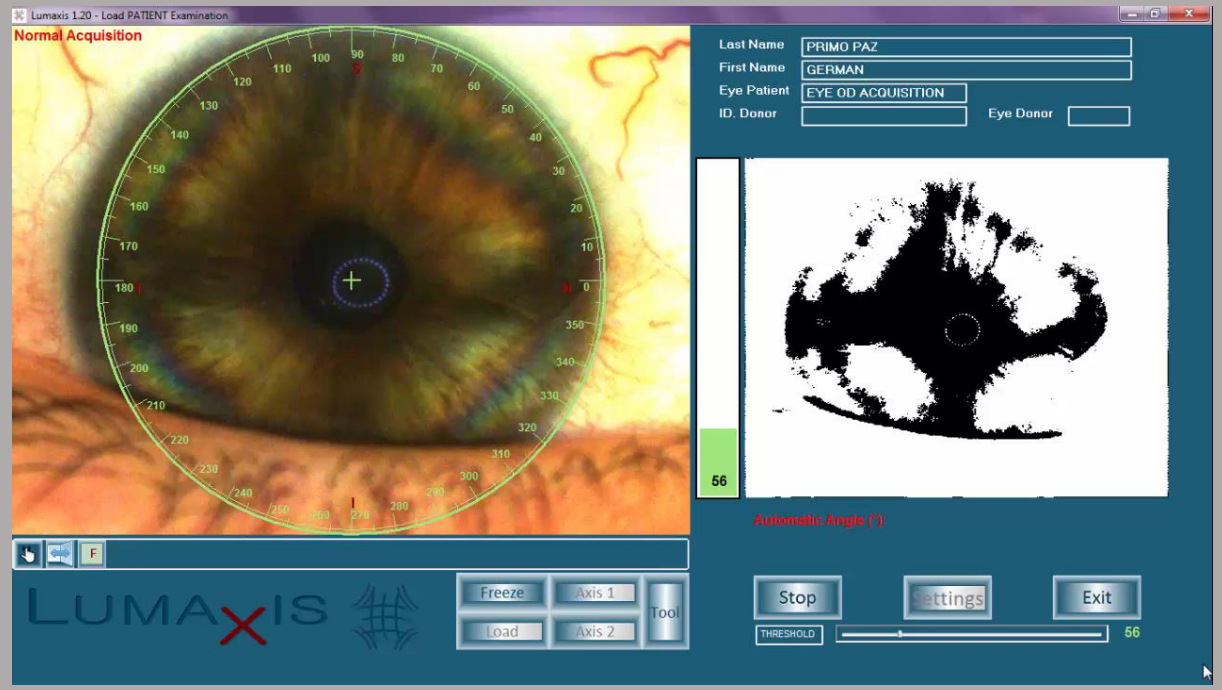
(Only Ex-Vivo)

Lumaxis Analysis is real time and not invasive technique which shows same pattern obtained with the X-Rays Analysis. The cross-like pattern is a consequence of the birefringences properties of the stroma.

Acquisition on «LOW KC» : Patient #1

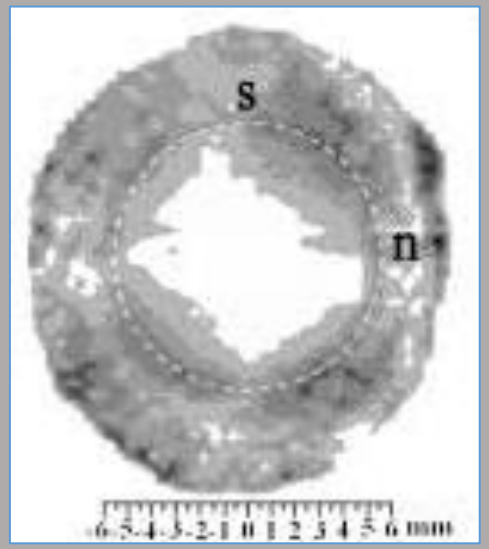
«OD»

VIDEO

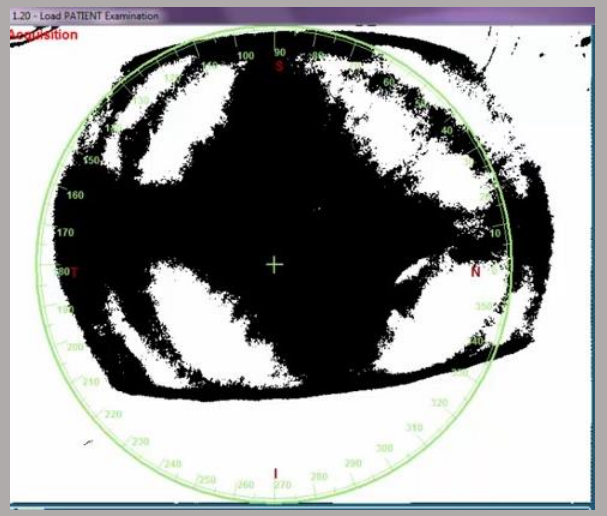


Once the stroma pathology occurs, Consequently the optical quality is Compromised and the cross pattern Move away from the theoretical shape. The arms of the cross start to modify And the center of the cross (optical axis) Moves aways from the center of the Cornea.

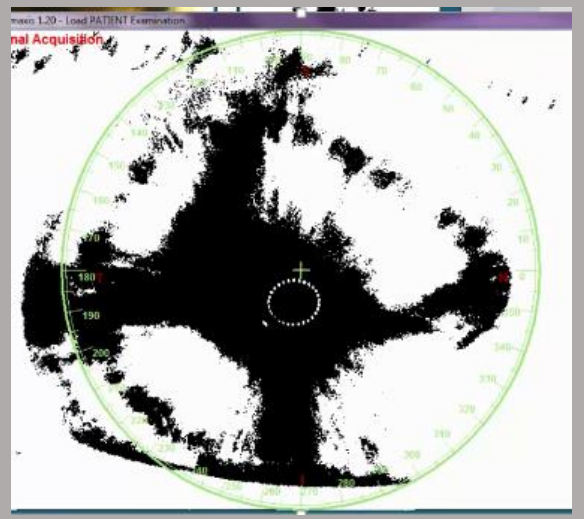
Theoretical (X.Rays)



Regular (E.L.)



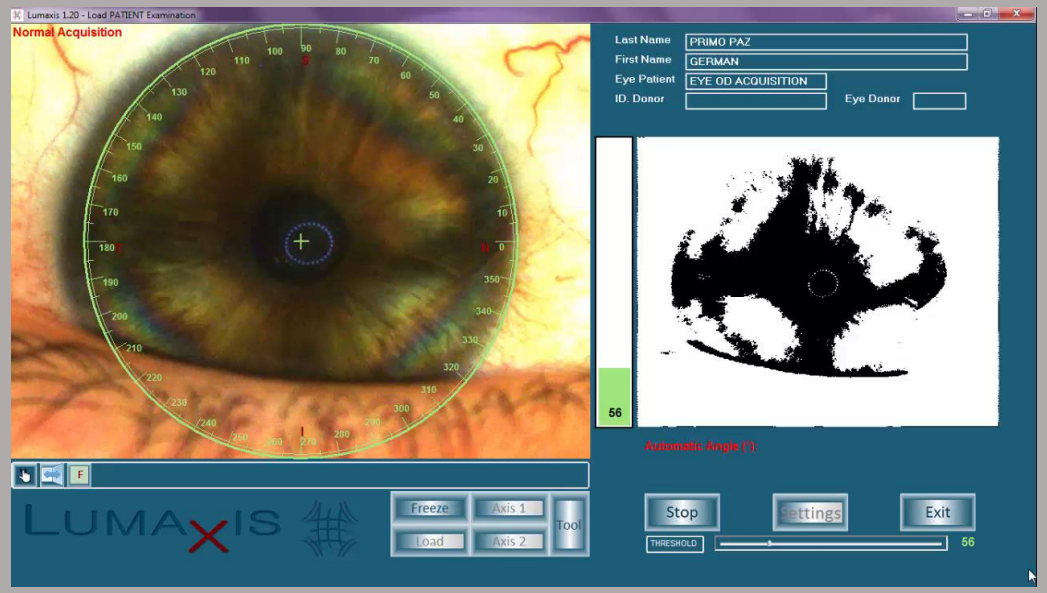
Irregular (Low KC)

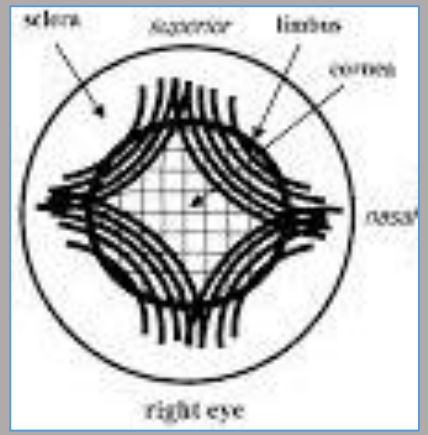


Acquisition on «LOW KC» : Patient #1

«OD»

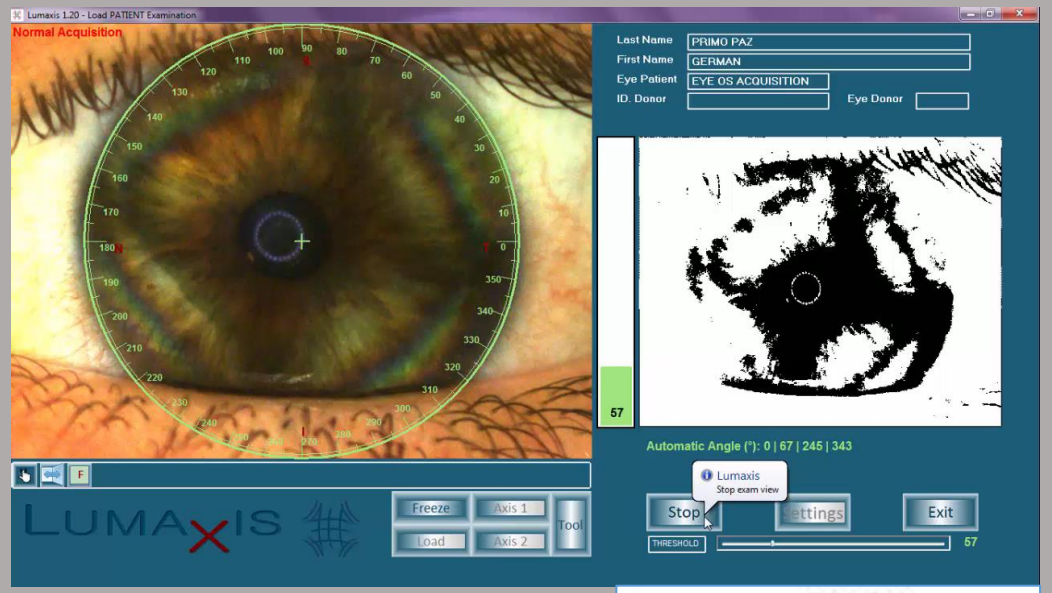
VIDEO

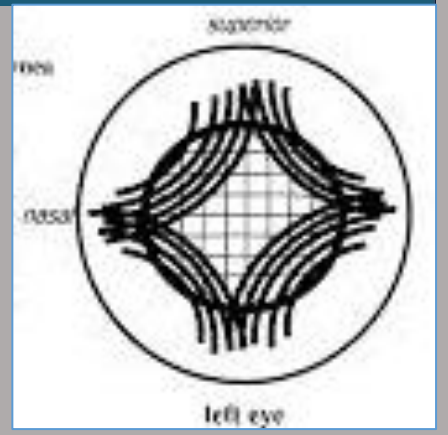




«OS»

VIDEO





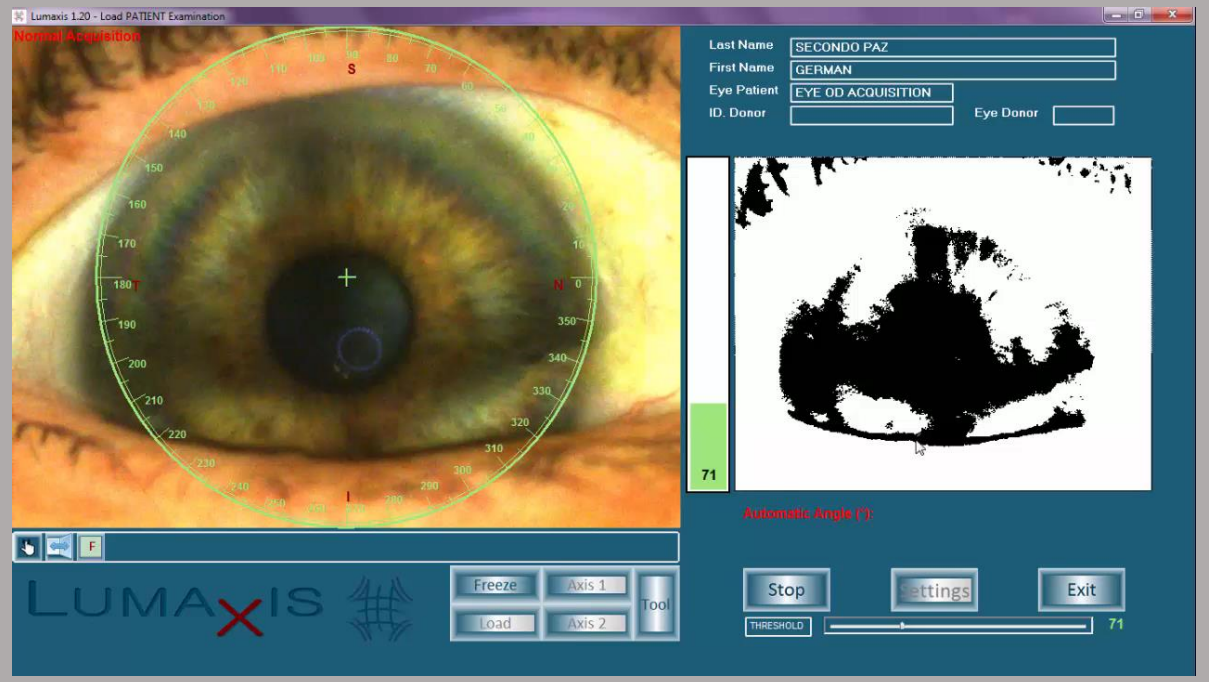
Cross-shaped collagen fibrils distribution is A-Symmetric ODvsOS as described by the X-Rays studies

Meek K.M. , The Cornea and Sclera – Collagen, Structure and Mechanics, Springer, Cap 13, 2008 , 359-396

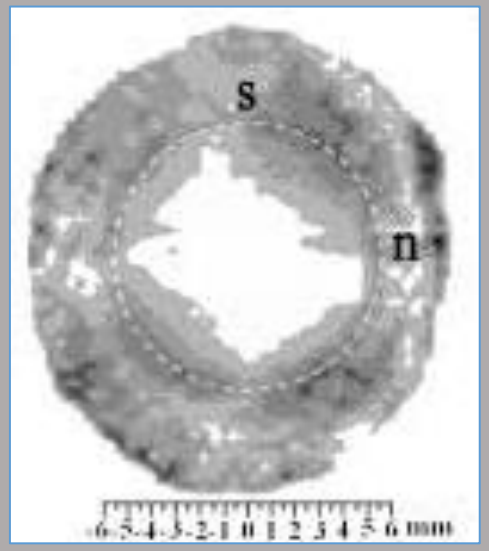
Acquisition on «MODERATE KC» : Patient #2

«OD»

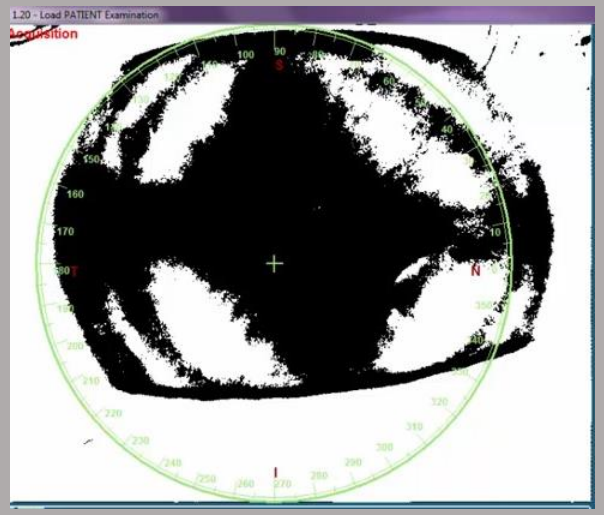
VIDEO



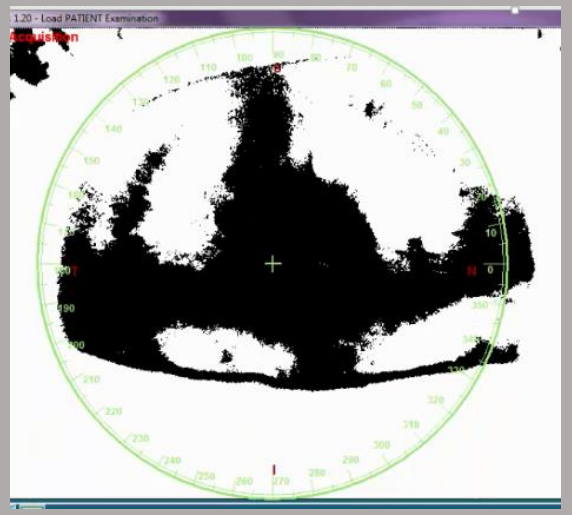
Theoretical (X.Rays)



Regular (E.L.)

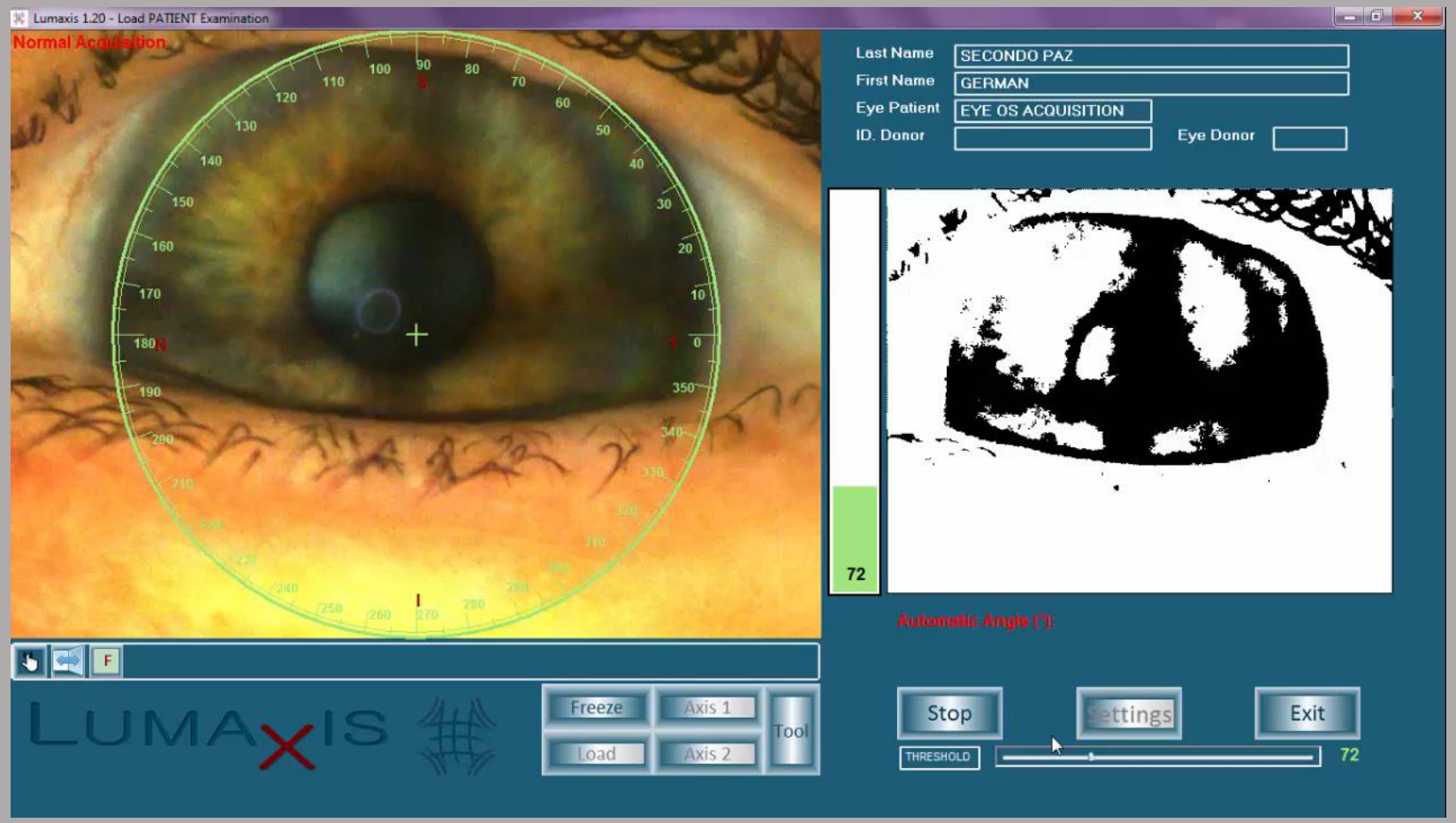


Irregular (Moderate KC)



Acquisition on «MODERATE KC» : Patient #2

«OS»



VIDEO

This video clearly shows how the center of The cross is moving out from the center of the Corneal. During the scan is evident how the Arms are not any more simmetric therefore The optical property of the stroma are going To be more and more compromised.
Once the cross shape pattern will not be visible Any more, than the stroma tissue will not Optically work any more and the only indication For the patient will be the PK (penetreting Keratoplasty)

DSAEK & POLARIMETRIC INTERFEROMETRY

Format: Abstract

Cornea. 2016 Apr;35(4):519-22. doi: 10.1097/ICO.0000000000000776.

Polarimetric Interferometry for Assessment of Corneal Stromal Lamellae Orientation.

Iovieno A[1], Yeung SN, Nahum Y, Teichman J, Lipari E, Busin M, Fontana L.

Author information

Abstract

PURPOSE: To analyze corneal stromal lamellae orientation in normal subjects and patients with various corneal conditions using a polarimetric interferometer.

METHODS: Thirty-two healthy control subjects (59 eyes) and 16 patients (22 eyes) with corneal conditions or postkeratoplasty were included in the study. All patients were imaged using the interferometer and slit lamp photography. The interferometer produces an orthogonal cross-like image of stromal lamellae by illuminating the cornea in phase-light polarization angle. Corneal haze was graded on a scale from 0 to 4. Interferometer cross-like images were graded on a scale from 0 to 5 by a masked observer. Keratometry, corneal central pachymetry, and optical densitometry were obtained with Scheimpflug corneal tomography.

RESULTS: The cross-like image was observed in 31 of 32 healthy control subjects (58 of 59 eyes) and in 13 of 16 patients (19 of 22 eyes). The image was not detectable in 3 patients, 1 with total corneal neovascularization and scarring, 1 with central leukoma, and 1 with failed deep lamellar keratoplasty. Corneal haze was the main factor obscuring the cross-like image ($P < 0.05$). Clarity of the images was influenced by older age, steeper keratometry, higher pachymetry, and optical density ($P < 0.05$). There was no correlation between the orientation of the keratometric axes and the orientation of the 2 arms of the cross-like image ($P > 0.05$).

CONCLUSIONS: Corneal stromal lamellae orientation can be efficiently assessed and displayed as a cross-like image by the polarimetric interferometer. Stromal lamellae orientation imaging may have potential implications in corneal diagnostics and surgery.

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Format: Abstract

Cell Tissue Bank. 2016 Jun;17(2):233-9. doi: 10.1007/s10561-016-9546-9. Epub 2016 Feb 27.

Polarization of human donor corneas.

Parekh M[1], Ruzza A[2], Ferrari S[2], Salvalaio G[2], Elbadawy H[2], Ponzin D[2], Lipari E[3].

Author information

Abstract

To investigate the de-orientation effect of DSAEK grafts by observing the cross patterns and polarization power of human donor corneas using a polarizing device (Lumaxis(®)). Forty human donor corneas were placed in small petri-plates with epithelial side facing up. Polarizing power (arbitrary unit) and crosses were monitored and recorded by the software. The tissue was marked at 'Superior' position to ensure that the base and the polarizer are in alignment with each other after the cut. The anterior lamellar cut was performed using microkeratome. The lenticule was placed back in the same position as marked to mimic the alignment. The tissue was further rotated by 45° ensuring that the base of the cornea and the polarizer were in alignment. The polarization power and 'crosses' were identified at each step. The average of forty corneas from pre-cut to post-45° angular change showed statistically significant difference ($p < 0.05$) in terms of polarizing power. The cross-shaped pattern deformed and lost the sharpness towards 45° angle. However, multiple variances in terms of 'cross-patterns' were observed throughout the study. Lumaxis(®) was able to determine the worst quality tissue in terms of polarization (no black zone and crosses). Despite the quality of cross pattern which can be used as an additional objective parameter to evaluate the optical properties of the corneal tissue, this preliminary study needs to be further justified in terms of clinical relevance whether polarization changes with oriented or de-oriented grafts have any effects and consequences on the visual acuity.

KEYWORDS: Cornea; Eye bank; Isogyres; Lumaxis®; Polarizer

GRAZIE

LUMAXIS
CORNEAL LAMELLA PHASE ALIGNMENT