المؤتمر السنوي الدولي للجمعية الرمدية المصرية
INTERNATIONAL CONGRESS OF THE
EGYPTIAN OPHTHALMOLOGICAL SOCIETY
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Milestones in Assessment of Corneal Biomechanics

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Corneal Biomechanics: Relevance

Biomechanics means the mechanical properties of biological tissue.

The <u>NEED</u> to study Corneal Biomechanics IN VIVO:

- ***Early Diagnosis of ectatic corneal conditions (KC and post LVC ectasia).***
- ***Follow UP (Progression or after surgery; CXL).***
- *Screening of THE HIGH RISK population.*

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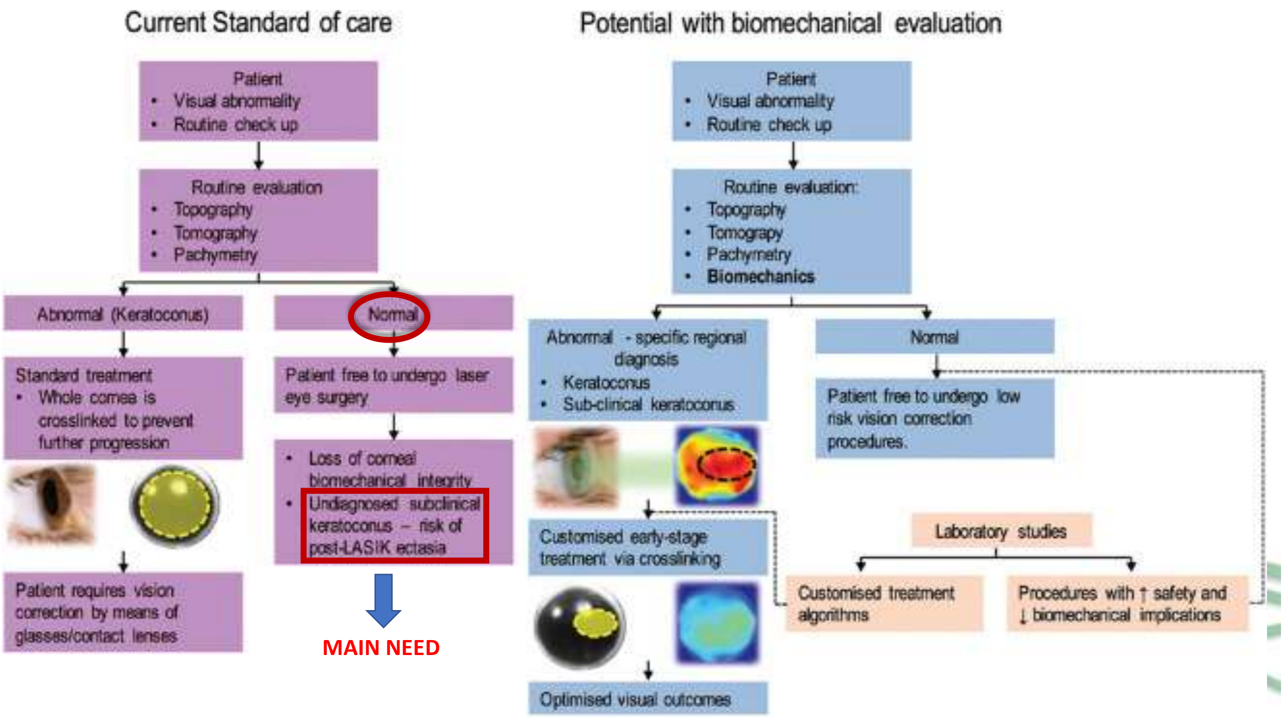


Factors influencing Corneal Biomechanics

❑ ***Ultrastructure :***

- **The anterior stroma:**

50% stiffer than mid or posterior stroma : a network of highly interwoven collagen lamellae that insert into Bowman's layer.

Factors influencing Corneal Biomechanics

❑***<u>Changes with Age:</u>***
- Natural age-related crosslinking.

❑***<u>Changes with Diabetes:</u>***
- Glycation of proteoglycan increasing crosslinking.

❑***<u>Changes with KC:</u>***
- Enzymatic (Proteolytic Enz.), Cellular (low Keratocytes)and Ultrastructural (decrease fibril diameter, disruption of orthogonal arrangement, undulation of collagen lamella)

❑***<u>Changes with LVC</u>***
- Flap vs Flapless techniques.
- Myopic Vs Hyperopic Ablation.

❑***<u>Others:</u>***
- CCT, Axial length, IOP, Contact Lens Wear

Simplifying Corneal Biomechanics

- ***Viscoelastic Nature***

<u>Elasticity:</u> Changing shape in response to a pressure, and recovering upon the removal of the pressure.

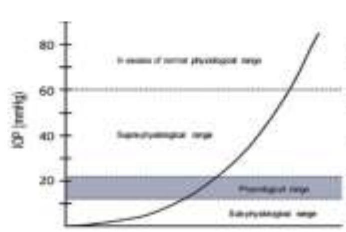
<u>Viscosity:</u> Resisting change in shape in response to a pressure.

- ***Non Linear Behavior under pressure***

J Refract Surg. 2007 Oct;23(8):808-18. doi: 10.3928/1081-597X-20071001-11.

Determination of the modulus of elasticity of the human cornea

Ahmed Elsheikh [1], Defu Wang, David Pye



The Ocular Response Analyzer (ORA)

the first to measure in vivo (2005)

Dynamic measurement; monitoring the movement of the cornea in response to air puff

CH - Corneal Hysteresis (Viscosity)
CRF - Corneal Resistance Factor (Elasticity)
IOPG - Goldmann Correlated IOP
IOPCC - Corneal Compensated IOP

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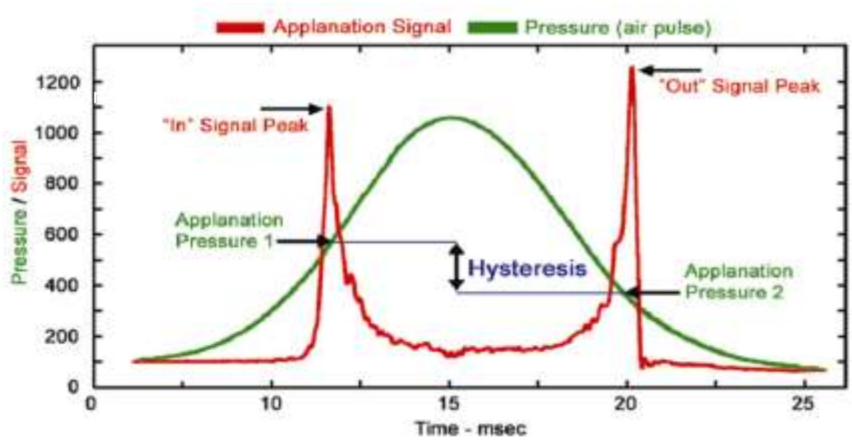
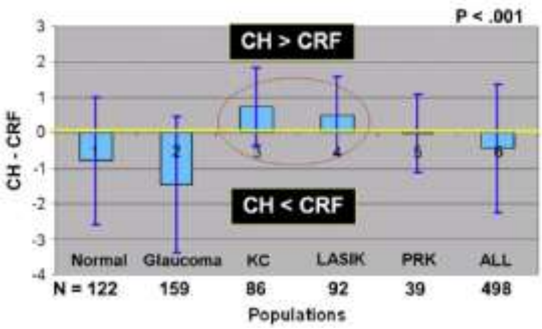


CH/CRF



CRF under 8 mm Hg positive (CH / CRF)

Correlations between corneal hysteresis, intraocular pressure, and corneal central pachymetry.
Touboul D, Roberts C, Kérautret J, Garra C, Maurice-Tison S, Saubusse E, Colin J.
J Cataract Refract Surg. 2008 Apr;34(4):616-22

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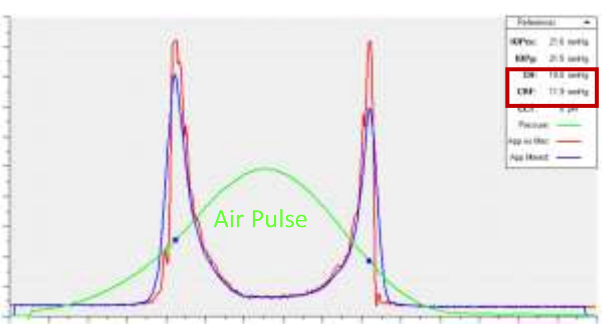
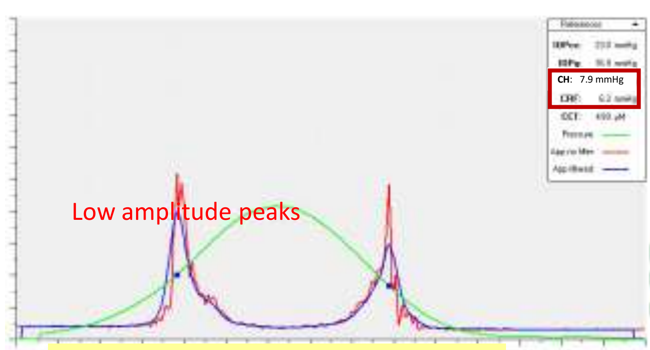
ORA Signal Analysis



NORMAL

KERATOCONUS

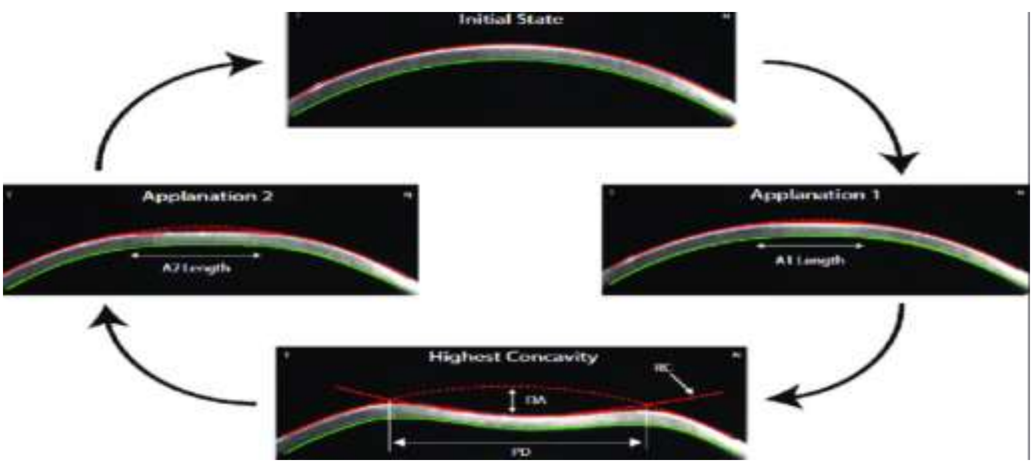


Noisy signals with less repeatable values

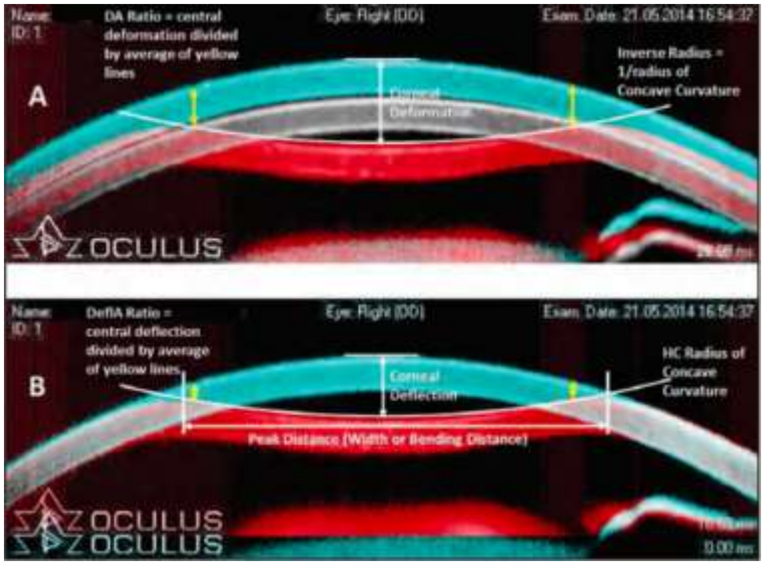
The Oculus Corvis ST

Corneal **Vis**ualization **S**cheimpflug **T**echnology

- Measures corneal deformation in a non-contact mode by a released air puff (pressure:60 mmHg & diameter:3.05 mm).
- Video footage of the corneal deformation is obtained by an Ultra High-Speed (UHS) Scheimpflug camera angled at 45° towards the apex of the cornea.
- 140 cross-sectional images of the cornea in 30 ms (4,330/sec).
- 8 mm horizontal coverage



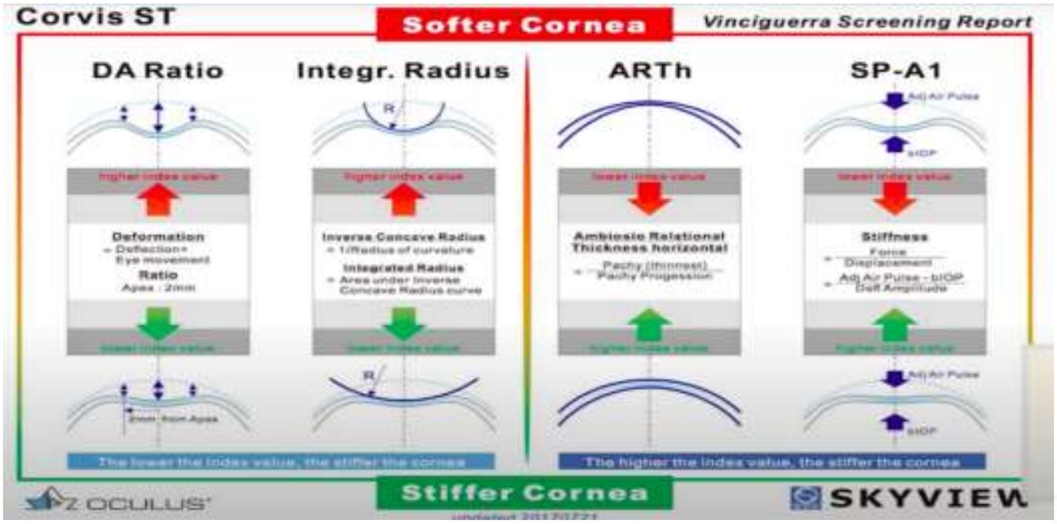
1. Applanation point A1.
2. The highest concavity point: the deformation amplitude (DA in mm), peak distance (PD in mm), and the radius of curvature (RC in mm) are measured.
3. Applanation point A2.



Superimposed frames **A:** Cornea in the Predeformation phase (pseudocolored blue), at maximal corneal deflection (pseudocolored red), and at maximal whole eye movement (pseudocolored white). **B:** Correction for whole eye motion by aligning all corneal images in the periphery to that at predeformation

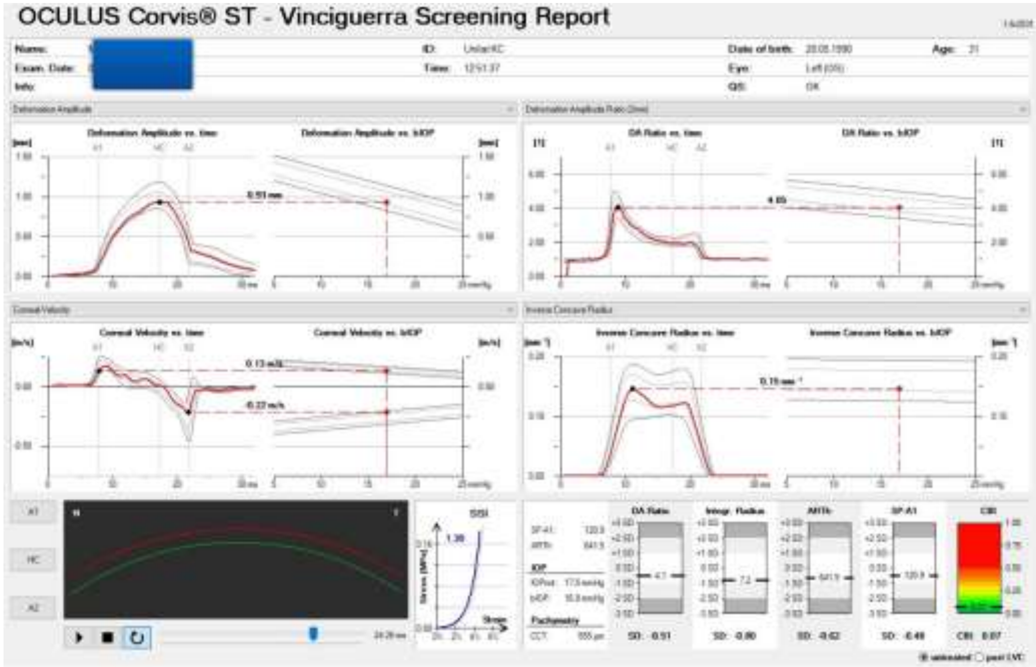
Corvis ST: Clinical Parameters

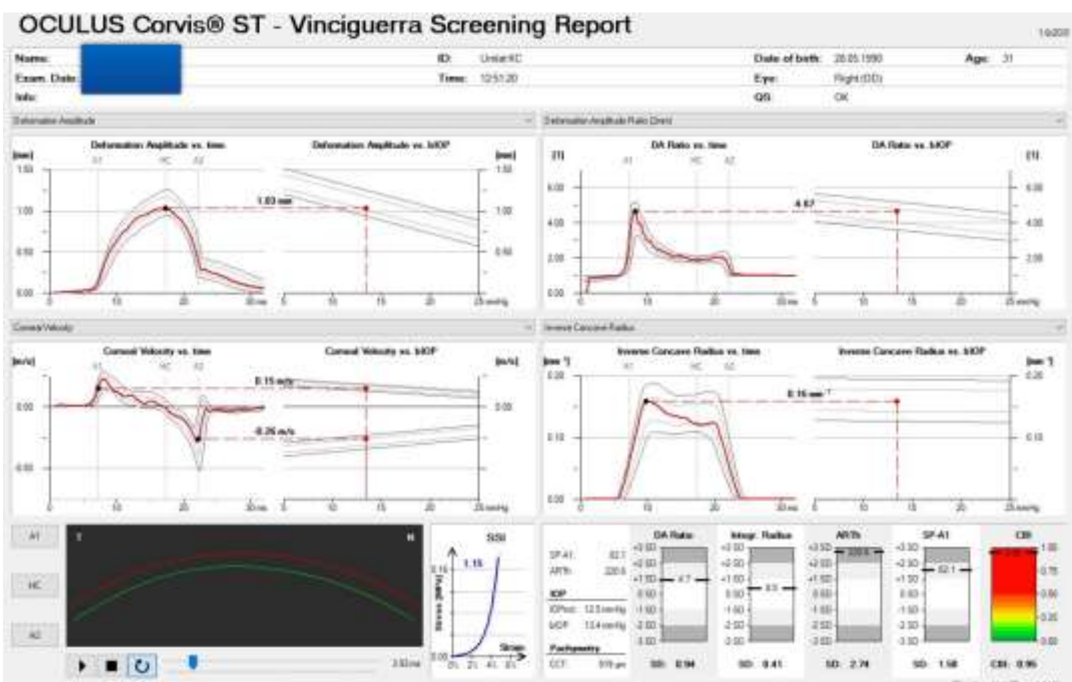
1st Applanation	Moment at the first applanation of the cornea during the air puff (in miliseconds). In parenthesis is the length of the applanation at this moment (in milimeters)
Highest Concavity	Moment that the cornea assumes its maximum concavity during the air puff (in miliseconds). In parenthesis is the length of the distance between the two peaks of the cornea at this moment (in milimeters)
2nd Applanation	Moment at the second applanation of the cornea during the air puff (in miliseconds). In parenthesis is the lenght of the applanation at this moment (in milimeters)
Maximum Deformation	Measurement (in milimeters) of the maximum cornea deformation during the air puff
Wing Distance	Length of the distance between the two peaks of the cornea at this moment (in milimeters)
Maximum Velocity (in)	Maximum velocity during the ingoing phase (in meters per secons [m/s])
Maximum Velocity (out)	Maximum velocity during the outgoing phase (in meters per secons [m/s])
Curvature Radius Normal	Radius of curvature of the cornea in its natural state (in milimeters)
Curvature Radius HC	Radius of curvature of the cornea at the time of maximum concavity during the air puff (in milimeters)
Cornea Thickness	Measurement of the corneal thickness (in milimeters)
IOP	Measurement of the intraocular pressure (in milimeters of Mercury [mmHg])
DAratio 2 mm	Ratio between vertical displacement at apex and at 2 mm
Inverse concave Radius	Inverse of the Radius of curvature during concave phase of the deformation
Integrated Radius	Area under the inverse concave Radius vs. time curve
SP-A1	Parameter reflecting bending stiffness of the cornea as defined by force/replacement
bIOP	Biomechanical corrected IOP
CBI	Corvis Biomechanical Index: overall biomechanical index for kc detection
TBI	Tomographic Biomechanical Index: combines tomographic and biomechanical data for enhanced ectasia detection

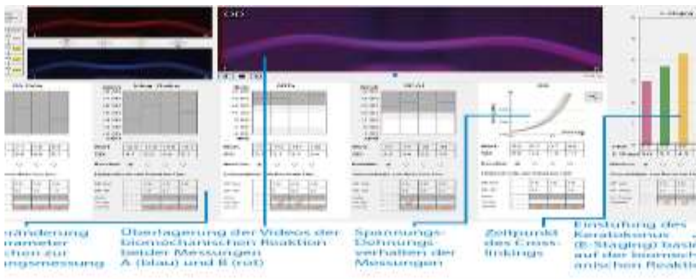


CBI

Corvis Biomechanical Index is based on a logistic regression formula including different Dynamic Corneal Response (DCR) parameters, the Stiffness Parameter and the corneal thickness profile.


OCULUS Corvis® ST - Vinciguerra Screening Report

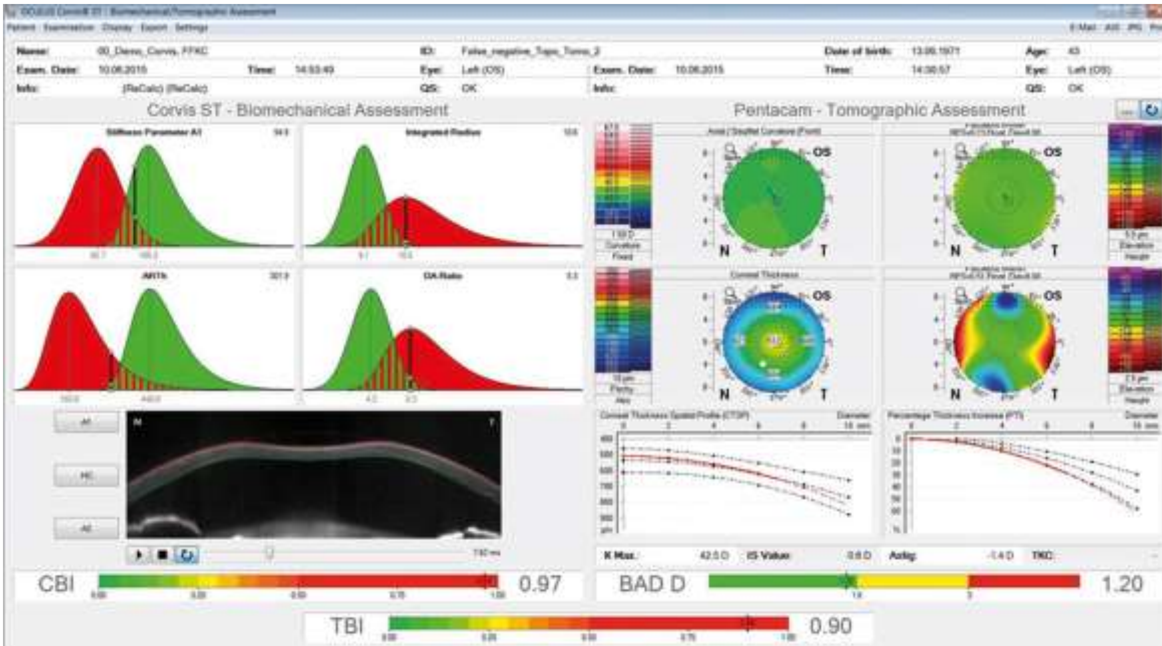

OCULUS Corvis® ST - Vinciguerra Screening Report

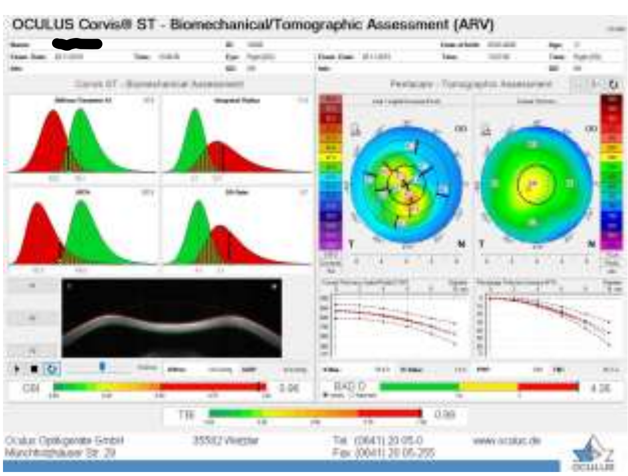


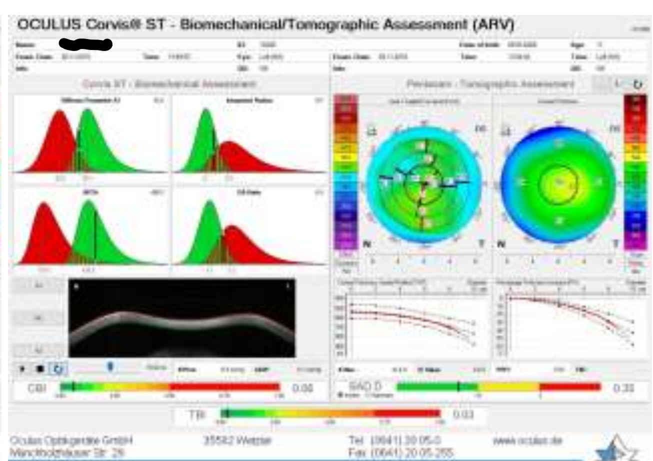
BEST Display: Homburg Biomechanical E-STaging Display
Changes over time

Integration of Tomography and Biomechanics

- **Integration of Scheimpflug-Based Corneal Tomography and Biomechanical Assessments for Enhancing Ectasia Detection**
  - Renato Ambrósio Jr, MD, PhD; Bernardo T. Lopes, MD; Fernando Faria-Correia, MD; Marcella Q. Salomão, MD; Jens Bühren, MD; Cynthia J. Roberts, PhD; Ahmed Elsheikh, PhD; Riccardo Vinciguerra, MD; Paolo Vinciguerra, MD. **Journal of Refractive Surgery. 2017;33(7):434-443**
- Tomographic and Biomechanical Index (TBI), which combines Scheimpflug based corneal tomography and biomechanics for enhancing ectasia detection.


Corvis ST - Biomechanical Assessment
Pentacam - Tomographic Assessment
CBI
0.97
BAD D
1.20
TBI
0.90


OCULUS Corvis® ST - Biomechanical/Tomographic Assessment (ARV)


OCULUS Corvis® ST - Biomechanical/Tomographic Assessment (ARV)

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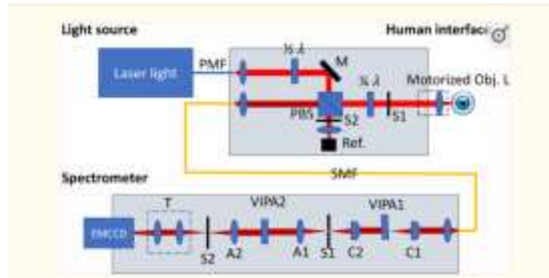
Brillouin Scattering Spectroscopy

- Since the 80s
- Interaction between PHOTONS (LIGHT) $ PHONON (wavelets from molecular vibration wz velocity proportional to biomechanical properties)
- Photons scatter.
- Brillouin doppler spectrum shift indicative of elastic modulus.



Brillouin Spectroscopy of Normal and Keratoconus Corneas

Theo G. Seiler,[1,2,3] Peng Shao,[2] Amira Eltony,[2] Theo Seiler,[1] and Seok-Hyun Yun[2]

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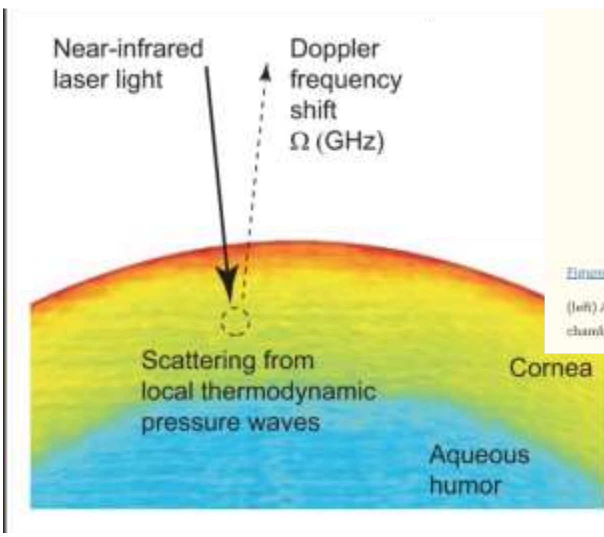


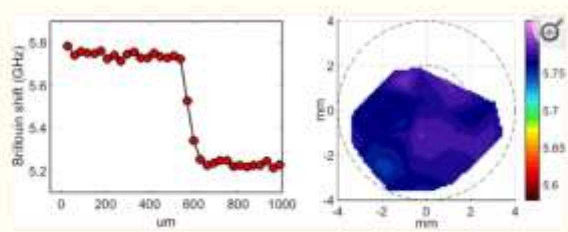


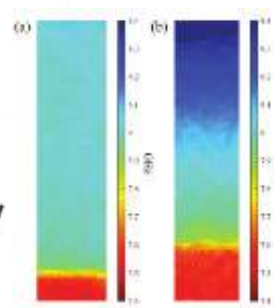
Figure 4.

(left) A representative axial (depth) scan profile of measured frequency shifts across the cornea and anterior chamber of a healthy subject and (right) a typical Brillouin frequency shift map of a healthy cornea.

DEPTH DEPENDENT variations in elastic modulus

Depth-Dependent Reduction of Biomechanical Efficacy of Contact Lens–Assisted Corneal Cross-linking Analyzed by Brillouin Microscopy

Hongyuan Zhang, PhD; Mehdi Roozbahani, MD; Andre L. Piccinini, MD; Oren Golan, MD; Farhad Hafezi, MD, PhD, FARVO; Giuliano Scarcelli, PhD; J. Bradley Randleman, MD



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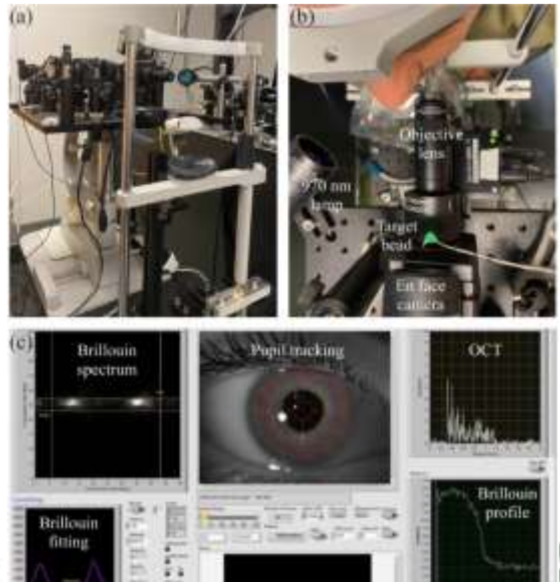
Motion tracking

A 3D motion-tracking Brillouin microscope :

- **Axial tracking** utilized optical coherence tomography (better than 3 μm).
- **Lateral tracking** achieved by tracking pupils with digital image processing (up to 10 μm).
- Depth-dependent Brillouin shift with a high spatial resolution.
- High-quality mapping even while the subject is breathing normally.



Motion-tracking Brillouin microscopy for in-vivo corneal biomechanics mapping

Hongyuan Zhang [1], Lara Asroui [1], J Bradley Randleman [1,2], Giuliano Scarcelli [3]

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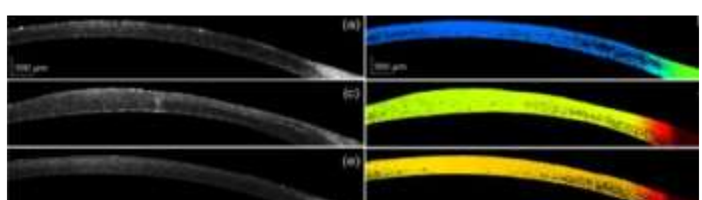
optical coherence elastography

- **OCT based**
- air puff, acoustic radiation force, or laser pulse.
- Elastic wave -> phase shift- > phase resolved color doppler.
- More accurate
- ***In depth measurements.***



In vivo evaluation of corneal biomechanical properties by optical coherence elastography at different cross-linking irradiances

Yuheng Zhou, Yuanyuan Wang, Meixiao Shen, Zi Jin, Yihong Chen, Yue Zhou, Jia Qu, and Dexi Zhu*

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To Summarize

- Corneal Biomechanics measurements are crucial in Refractive practice and for screening of population.
- Up till now, Corvis-ST is the most clinically used apparatus with ongoing hardware and software updates.
- The need for In-Depth analysis mandated the development of other methods like Brillion spectroscopy and OC Elastography.

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