



Scheimpflug imaging for detecting ectasia, follow up and evaluating the results of **CXL** treatment

F. Faria-Correia, MD

Financial Disclosures: None

Renato Ambrósio Jr., MD, PhD

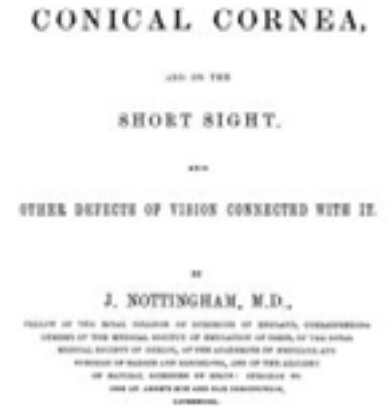
Financial Disclosures: Consultant for Oculus, Alcon, Mediphacos

Porto - Portugal



Ectasia Definitions

● **KERATOCONUS** WAS FIRST DESCRIBED OVER 150 YEARS AGO BY JOHN NOTTINGHAM AS “**CONICAL CORNEA**”



- **KERATOCONUS** is a **BILATERAL** but often **ASYMMETRIC** disease.¹
- **SECONDARY ECTASIA** may occur unilaterally (in any eye) due to mechanical process.¹
- The two-hit hypothesis proposes an underlying **GENETIC PREDISPOSITION** coupled with external **ENVIRONMENTAL FACTORS** (eye rubbing, atopy).²

1. Gomes JA, Rapuano CJ, Belin MW, Ambrósio R Jr; Panelists for the Global Delphi Panel. Global Consensus on Keratoconus Diagnosis. *Cornea*. 2015 Dec;34(12):e38-9.

2. McGhee CN, Kim BZ, Wilson PJ. Contemporary Treatment Paradigms in Keratoconus.

Cornea. 2015 Oct;34 Suppl 10:S16-23.



Concepts behind Ectasia Diagnosis

- Fundamental for **REFRACTIVE SURGERY & KERATOCONUS MANAGEMENT.**
- **SCREENING FOR ECTASIA** risk among candidates for laser vision correction goes beyond disease diagnosis into understanding the **SUSCEPTIBILITY.**
- Advances on **CORNEAL IMAGING*** allow for augmenting sensitivity and specificity, including:
 - **CORNEAL TOPOGRAPHY:** front surface curvature
 - **CORNEAL TOMOGRAPHY:** 3D reconstruction (front and back surface characterization & pachymetric mapping)
 - **SEGMENTAL OR LAYERED CORNEAL TOMOGRAPHY:** epithelial-stromal thickness mapping
 - **CORNEAL BIOMECHANICAL CHARACTERIZATION**



Corneal Tomography

- ◆ $\tau \acute{o} \mu \omicron \varsigma$ (tomos) means "slice", and $\gamma \rho \acute{\alpha} \phi \omega$ (graphia) significa "write"
- ◆ **3D reconstruction of the cornea**

- ◆ Slit scanning
- ◆ **Scheimpflug**
- ◆ OCT
- ◆ VHF-US



Renato Ambrosio Jr, MD, PhD



Michael W. Belin, MD

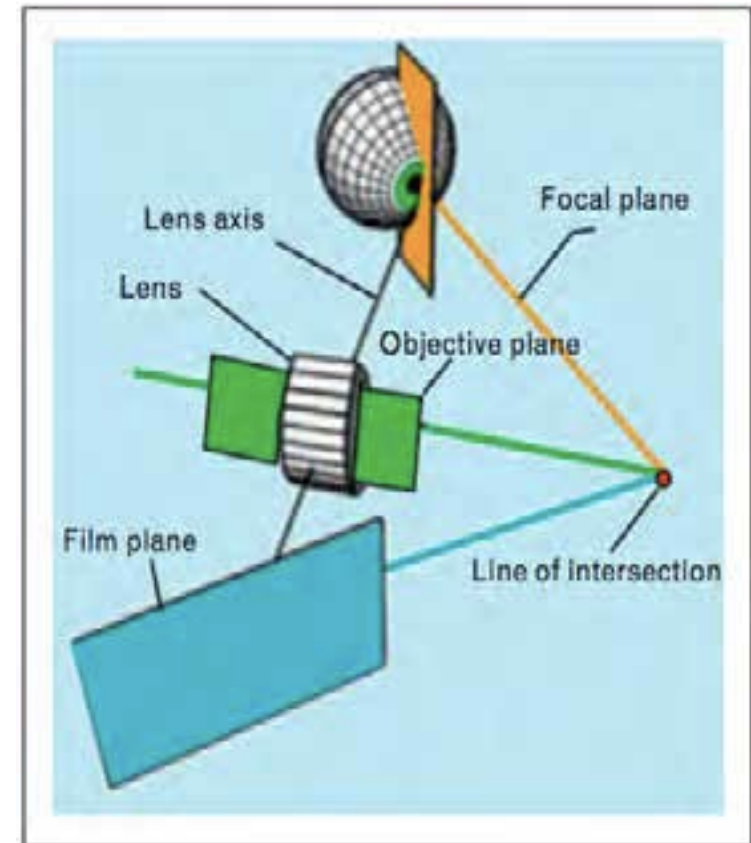
GUEST EDITORIAL

Imaging of the Cornea: Topography vs Tomography

Renato Ambrósio, Jr, MD, PhD; Michael W. Belin, MD

Scheimpflug Principle

- First described by Jules **Carpentier** in 1901, who was cited and credited in the original patent by Theodor **Scheimpflug** in 1904.
- **Three imaginary planes** – the film plane, the lens plane, and the focal plane – disposed in a **nonparallel** manner.
- The lens is tilted in a way that the resulting lens plane intersects the film plane and the plane of focus in a form of a **line** at **Scheimpflug intersection**.





Scheimpflug Principle

- **Advantages:**
 - extends the **depth of focus**
 - more **sharpness** to points of the image located at different planes
 - **minor distortion** of the image



Scheimpflug Principle

Nidek EAS 1000 (Gamagori, Japan)

- First devices incorporating Scheimpflug Principle (**horizontal scan**);
- Ability to detect **changes in lens transparency** over time



These systems, however, did **not perform tomographic three-dimensional reconstruction** of the cornea and anterior segment.



Scheimpflug Principle

PENTACAM (Oculus, Wetzlar, Germany)

- The first system that performed corneal and anterior segment tomography by **digital rotating Scheimpflug photography**, was first presented in 1999.

- **Single** rotating Scheimpflug camera measurement.

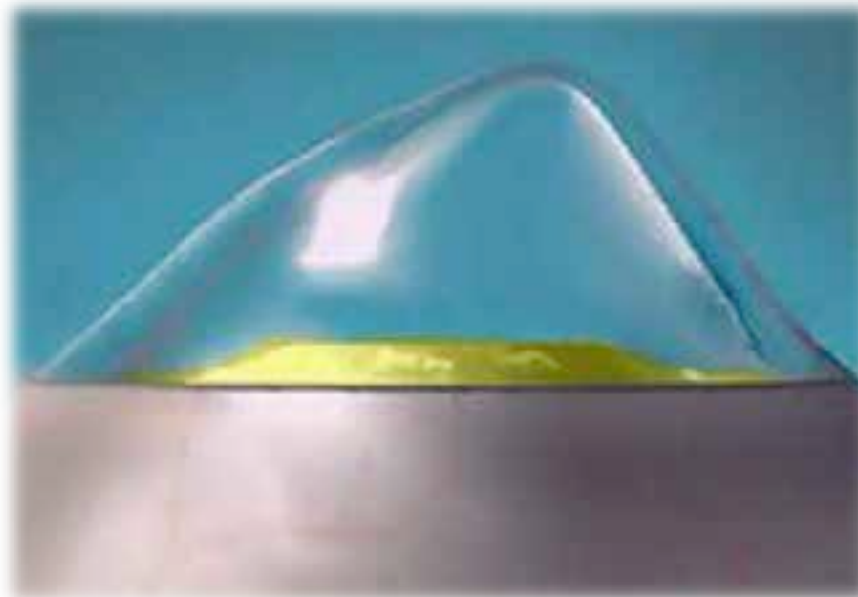
- The light source consists of **UV-free blue LEDs** with a wavelength of 475 nm.





What is Corneal Ectasia?

- Biomechanical failure with progressive non-inflammatory thinning and protrusion of the cornea, leading to irregular geometry which causes irregular astigmatism (HOAs), usually with myopia



Classic Ectatic Corneal Diseases

- Keratoconus
- Pellucid Marginal Degeneration
- Keratoglobus



Thinning Location and Pattern

Pellucid Marginal
Degeneration

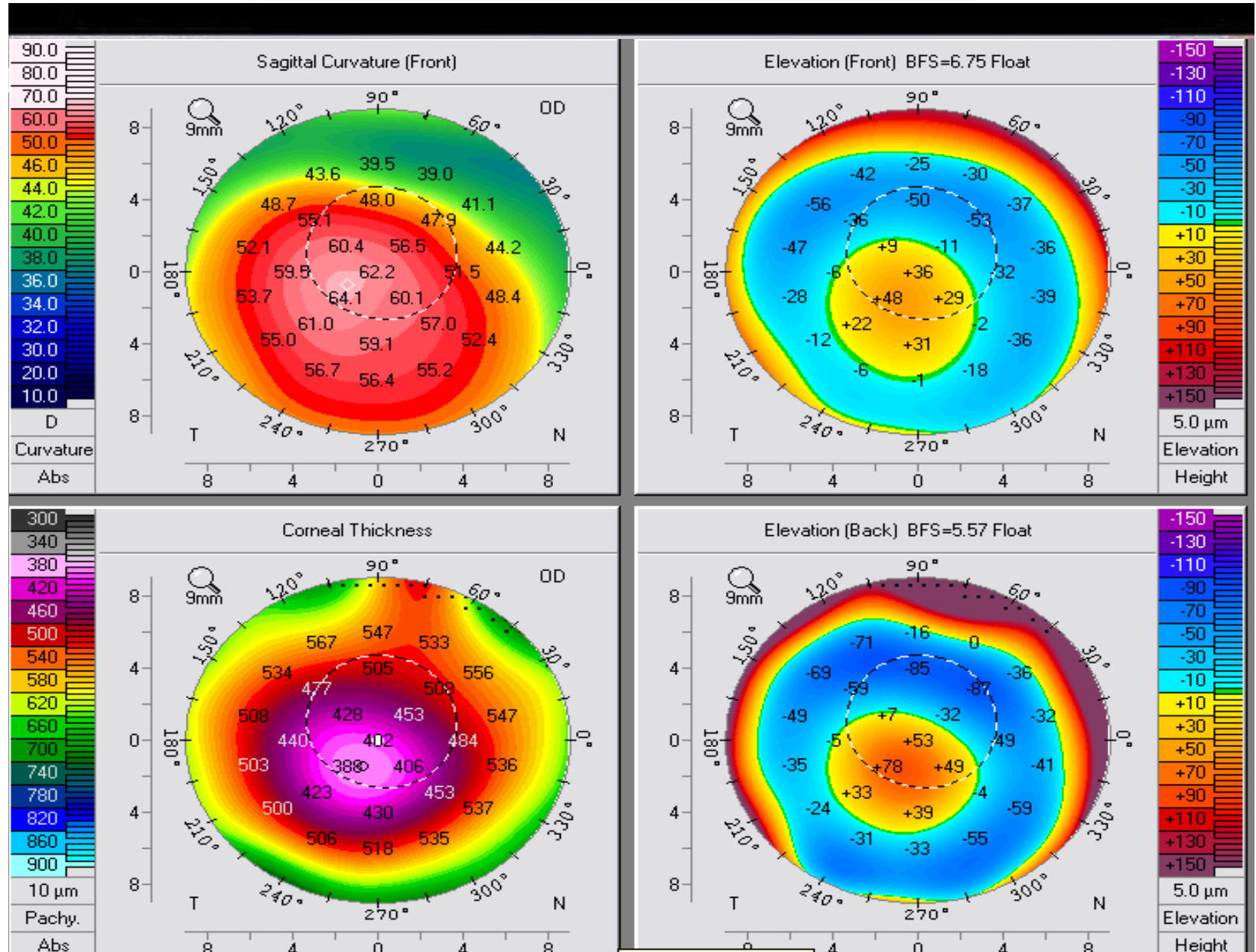


Keratoglobus



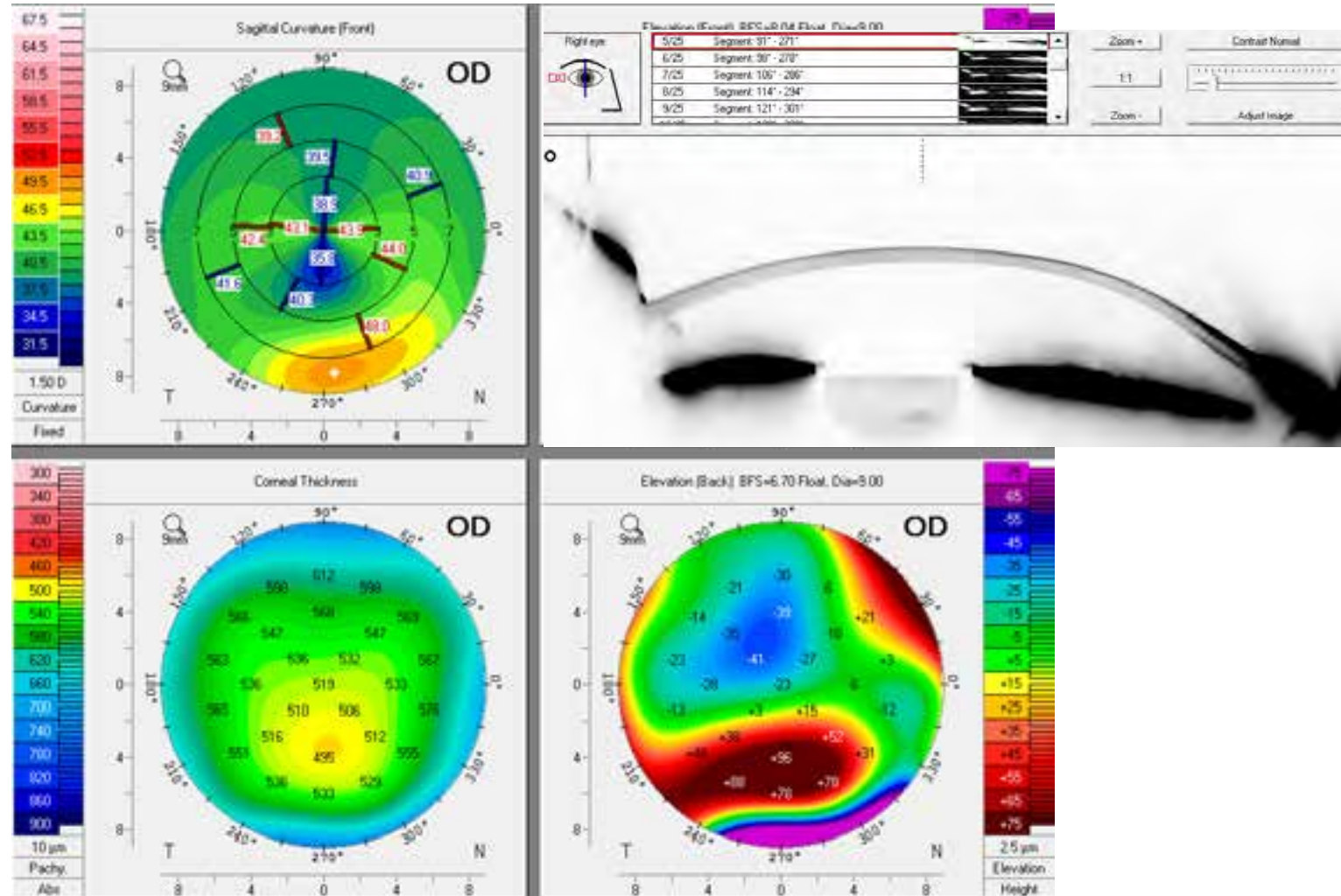
ToMography for diagnosing Keratoconus

Faria Correia
MD



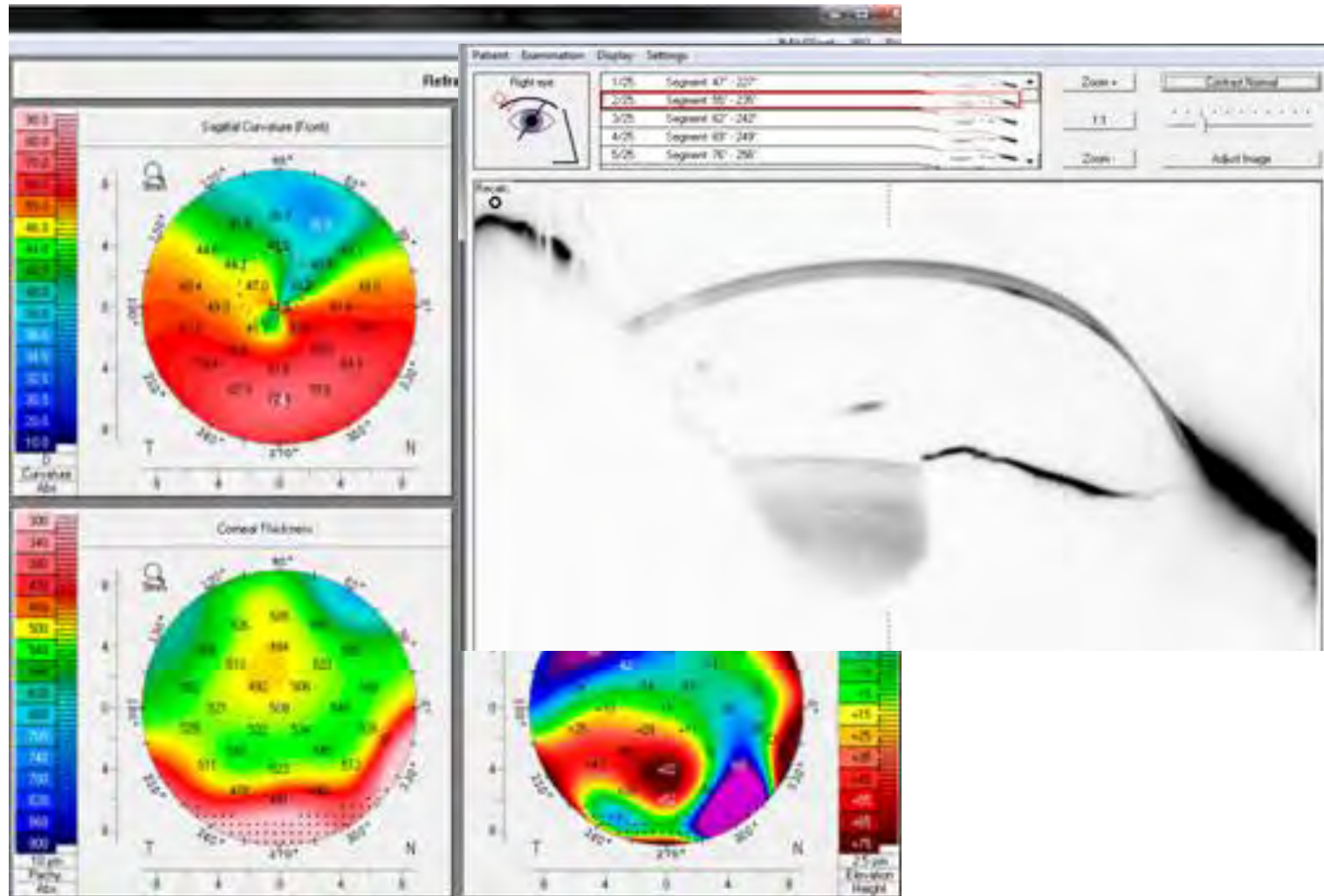


“False” Pellucid Marginal Degeneration But an Inferior Keratoconus





“True” Pellucid Marginal Degeneration



Keratoconus Diagnosis with Pentacam

Faria Correia
MD

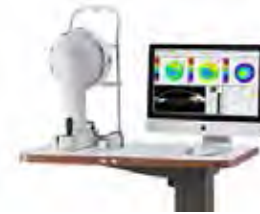


ORIGINAL ARTICLE

IJKECD

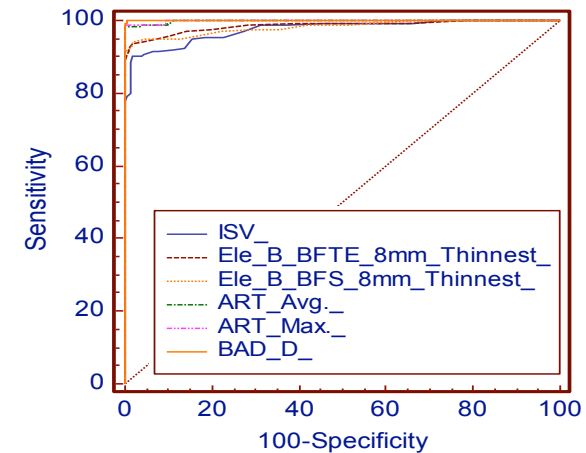
Topometric and Tomographic Indices for the Diagnosis of Keratoconus

Fernando Faria Correia, Isaac Ramos, Bernardo Lopes, Marcella Q Salomão, Allan Luz, Rosane O Correa, Michael W Belin, Renato Ambrósio Jr



Parameter	AUC	SE	95% CI
ISV	0.977	0.00617	0.956 - 0.989
IHA	0.89	0.0176	0.854 - 0.919
IVA	0.958	0.0109	0.933 - 0.976
IHD	0.973	0.0067	0.952 - 0.987
K Max	0.972	0.00901	0.949 - 0.986
K1	0.771	0.0245	0.725 - 0.812
K2	0.856	0.0167	0.807 - 0.929
Astigmatism	0.862	0.0203	0.812 - 0.896
Ele F BFS 8mm Apex	0.834	0.0213	0.793 - 0.870
Ele F BFS 8mm Max. 4mm Zone	0.957	0.011	0.932 - 0.976
Ele F BFS 8mm Thinnest	0.973	0.00672	0.952 - 0.987
Ele F BFTE 8mm Apex	0.856	0.02	0.816 - 0.889
Ele F BFTE 8mm Max. 4mm Zone	0.955	0.0113	0.929 - 0.974
Ele F BFTE 8mm Thinnest	0.967	0.00687	0.944 - 0.983
Ele B BFS 8mm Apex	0.858	0.0199	0.819 - 0.892
Ele B BFS 8mm Max. 4mm Zone	0.976	0.00827	0.955 - 0.989
Ele B BFS 8mm Thinnest	0.983	0.00697	0.964 - 0.993
Ele B BFTE 8mm Apex	0.858	0.02	0.817 - 0.890
Ele B BFTE 8mm Max. 4mm Zone	0.972	0.00893	0.950 - 0.986
Ele B BFTE 8mm Thinnest	0.987	0.00608	0.970 - 0.996
Pachy Apex	0.932	0.0133	0.902 - 0.955
Pachy Min	0.958	0.0107	0.933 - 0.974
RPI Avg	0.990	0.00355	0.982 - 0.999
RPI Max	0.996	0.00338	0.983 - 0.999
ART Avg	0.999	0.00188	0.987 - 0.999
ART Max	0.999	0.00162	0.988 - 1.000
BAD - D	1.000	0.000283	0.999 - 1.000

- Best topometric and tomographic indices AUROC comparison (DeLong method)

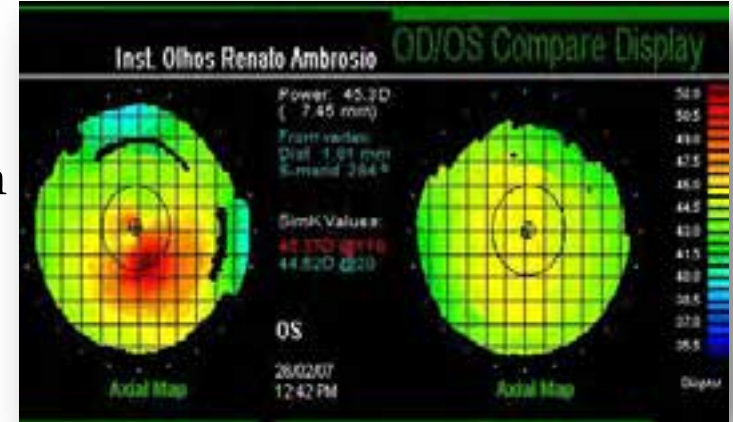


	Ele B BFS 8mm Thinnest	Ele B BFTE 8mm Thinnest	ART Max	ART Avg	BAD - D
ISV	0.994	0.277	0.912	0.91	0.993
Ele B BFS 8mm Thinnest		0.378	0.834	0.831	0.999
Ele B BFTE 8mm Thinnest			0.884	0.873	0.923
ART Max				0.796	0.235
ART Avg					0.247

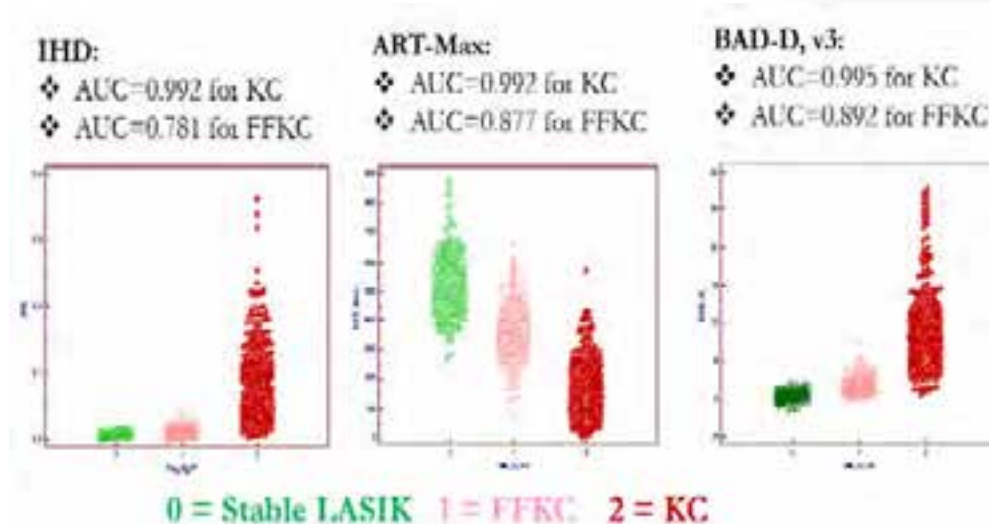


Very Asymmetric Ectasia Study

- 241 eyes with normal topography* from patients with clinical ectasia in the fellow eye.
- 439 controls (Pre stable LASIK); 364 Keratoconus (KC)



*no evidence of keratoconus on
Oculus TKC and/or Nidek
Corneal Navigator



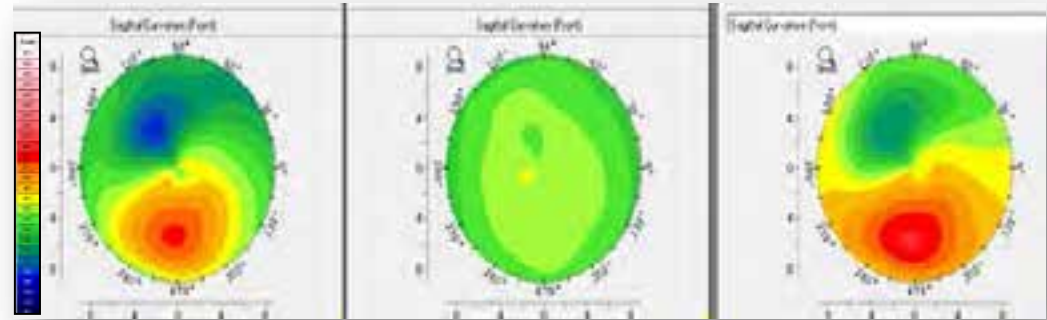
● 205/241 (85.06%) eyes with normal topography were detected by corneal tomography (Pentacam)

Pre-LASIK Ectasia: Retrospective Study

Faria Correia
MD

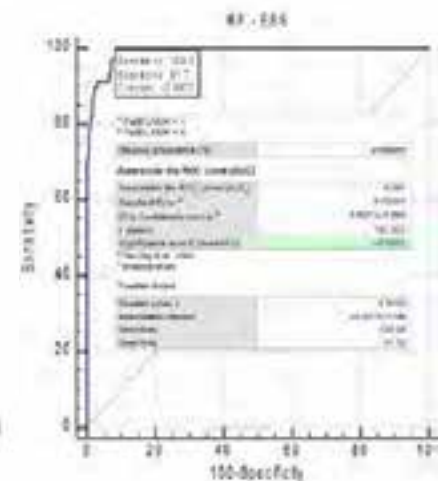
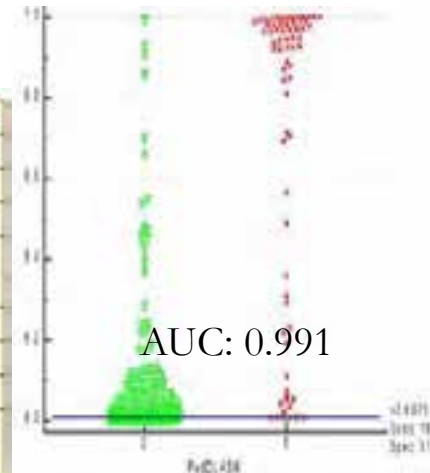
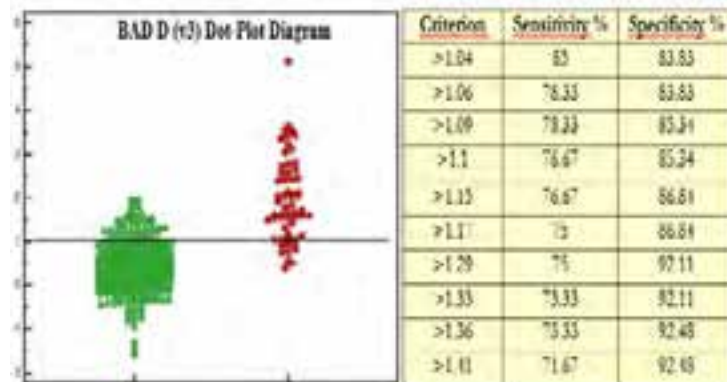


- Pre-op Pentacam from 72 eyes that developed ectasia after LASIK.



BAD-D (v3):

Best parameter, but large overlap



- 100% sensitivity to detect ectasia susceptibility by enhanced artificial intelligence method
- 8.2% of false positives (stable LASIK cases)





ECTASIA SUSCEPTIBILITY IN IDENTICAL TWINS

- Identical twin sister 2 with bilateral normal topography, whose sister (1) had clinical keratoconus in one eye and fellow eye with forme fruste disease.



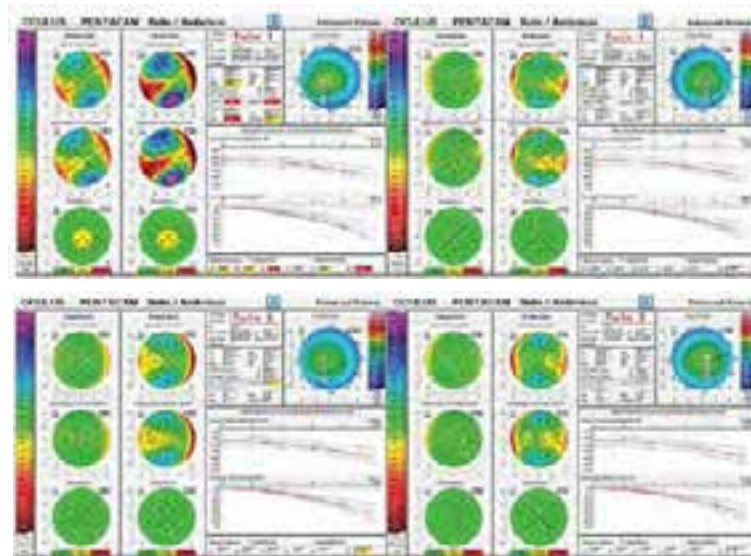
ARTmax
OD/OS

Twin 1:
209/354

Twin 2:
380/392

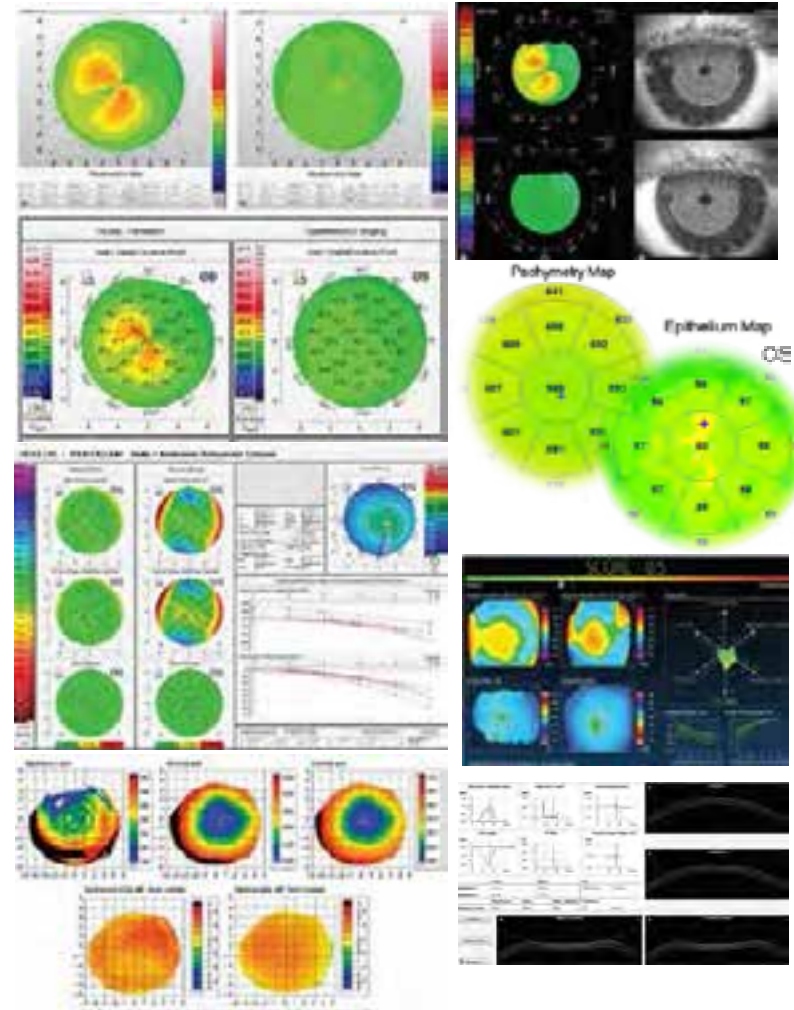
BAD-D OD/OS

Twin 1: 4.45/1.47; Twin 2: 1.70/1.35



UNILATERAL ECTASIA: ADVNCED DIAGNOSTIC CHARACTERIZATION

- OD with ectasia; OS was characterized as normal by all tests, including tomography and segmental tomography.



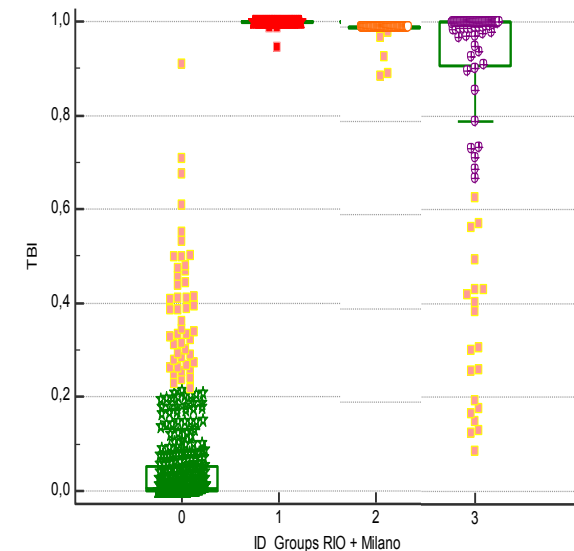


ULTIMATE ECTASIA SCREENING 2016: SCHEIMPFLUG TOMOGRAPHY & BIOMECHANICS



- Rio de Janeiro & Milano Study
- TBI: combination of Pentacam + Corvis
- Stable (0) x Frank Ectasia (1,2) x Sub-clinical (3)
- BAD-D v3 for frank ectasia (0 x 1+2): 98.9% sensitivity/99.2% specificity
Cut off=1.95 (AUC: 0.999)
- BAD-D v3 for the normal topography eye from VAE cases (0 x 3):
81.2% sensitivity/72.1% specificity; Cut off=1.07 (AUC: 0.846)
- TBI had AUC=1.0 for frank ectasia
- TBI for the normal topography eye from VAE cases (0 x 3):
90.6% sensitivity/95.2% specificity; Cut off=0.362 (AUC: 0.986)
- Significant improvement for accuracy for detecting mild forms of ectasia with normal topography and also normal tomography (BAD-D)

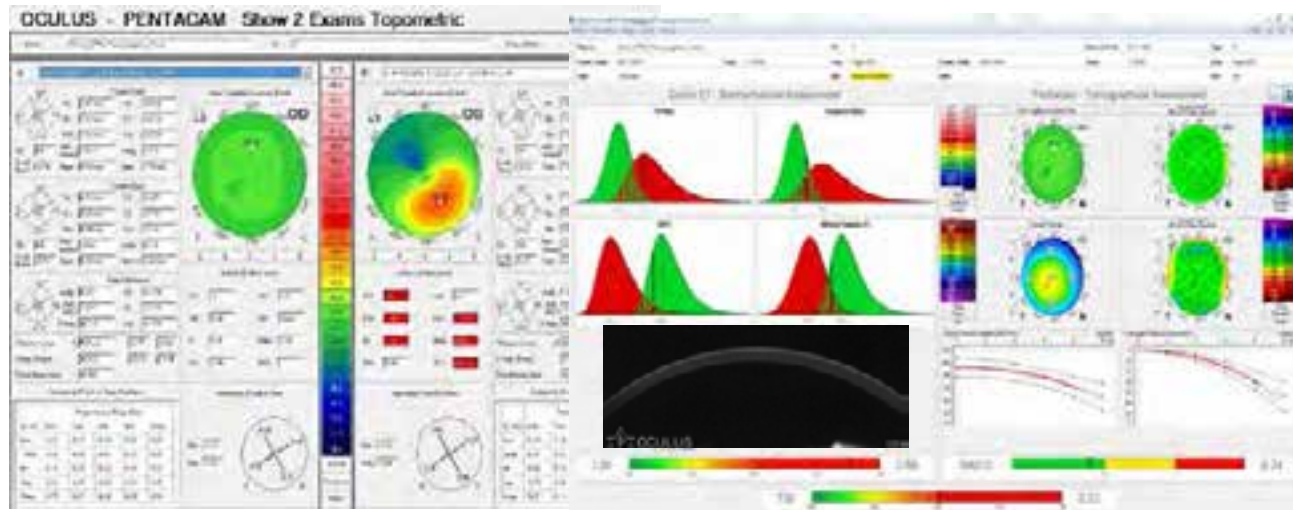
Factor	n	Groups
0	480	Normal
1	182	Keratoconus
2	96	Abnormal eye from Very Asymmetric Ectasia (VAE)
3	117	Normal Topo Eye from VAE



ARV: *Ambrosio-Roberts & Vinciguerra - Tomography and Biomechanics Report with TBI*



- OD: normal topography and tomography but abnormal TBI



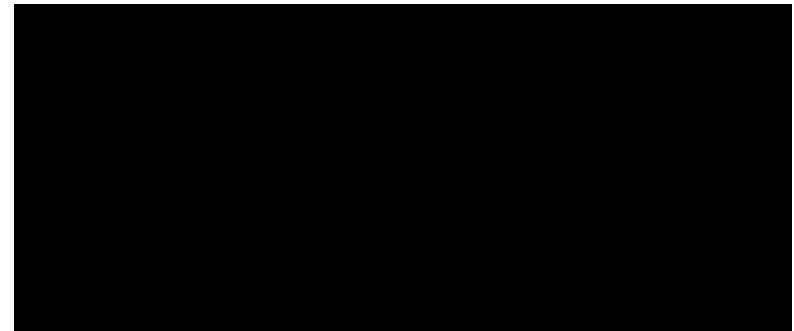
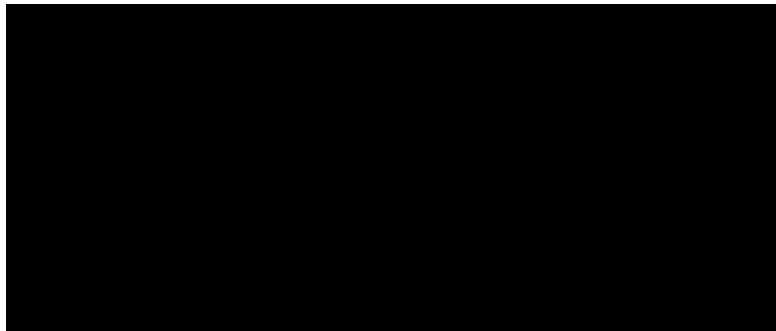
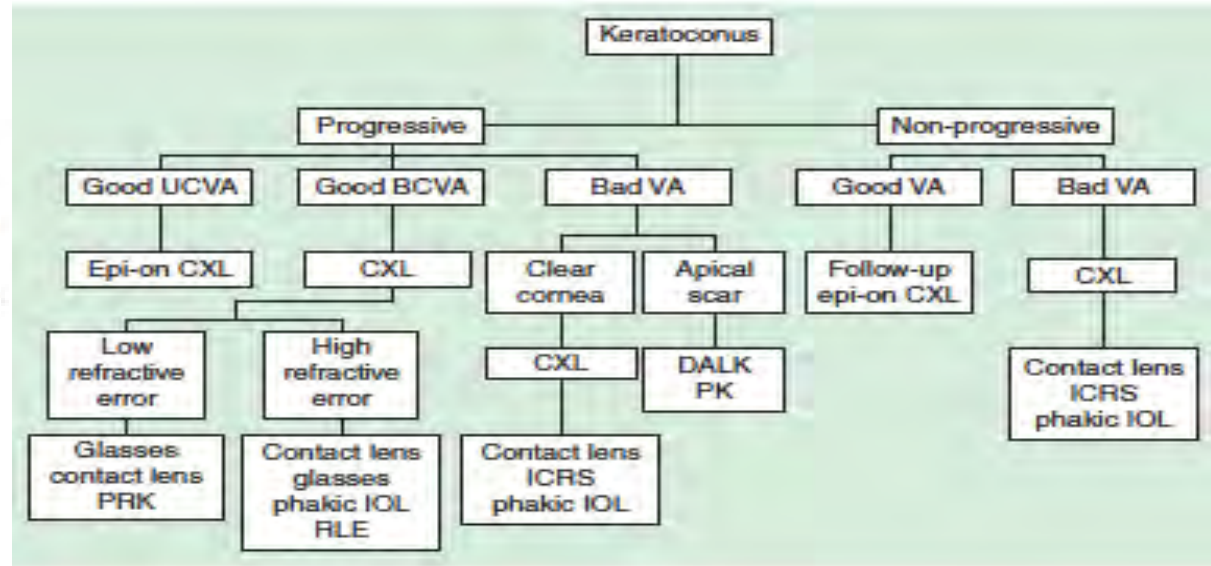
- Detected retrospectively in cases that developed ectasia after laser vision correction using an enhanced susceptibility approach.
- Any cornea may undergo ectatic progression
- Depends on the innate biomechanical predisposition and environment
- Continuous characterization of the susceptibility with TBI
- Future role of Genetics



Managing corneal ectasia prior to keratoplasty

Expert Rev. Ophthalmol. Early online, 1–16 (2014)

Fernando Faria-Correia^{1–6},
Allan Luz^{6–8} and
Renato Ambrósio Jr^{4,8–10}





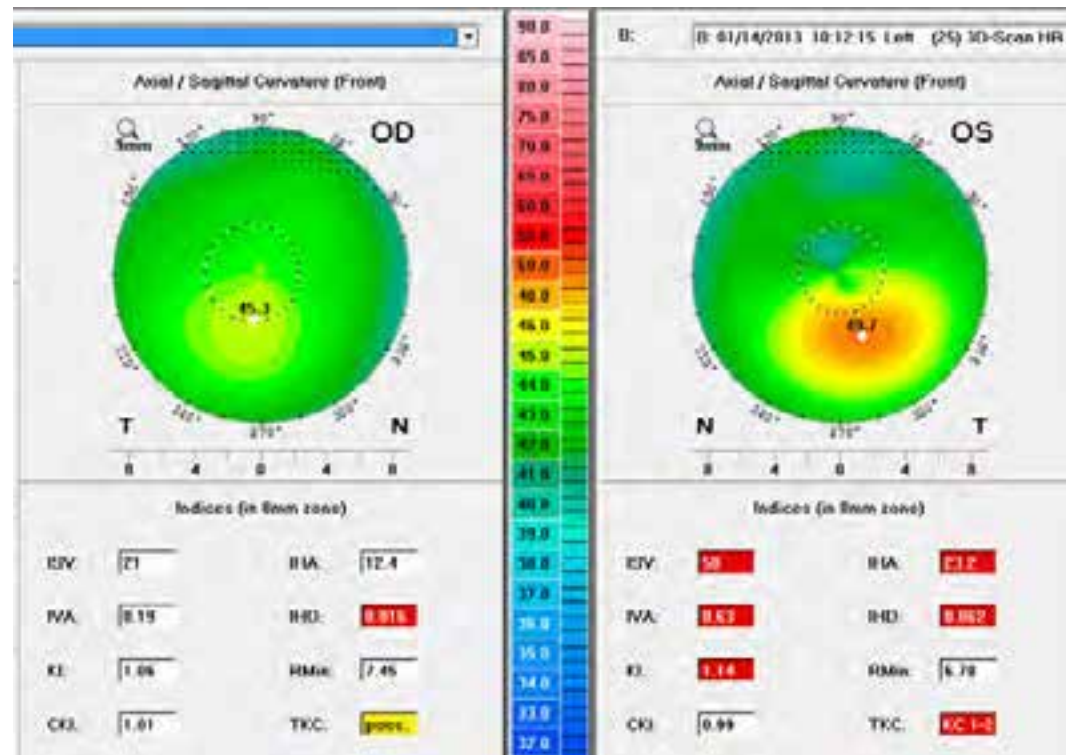
Jan 2013

Male, 19 yo. “bad vision”

- UDVA / MR_x / DCVA

20/200 -2,25 -1,50 x 118°, giving 20/20 OD

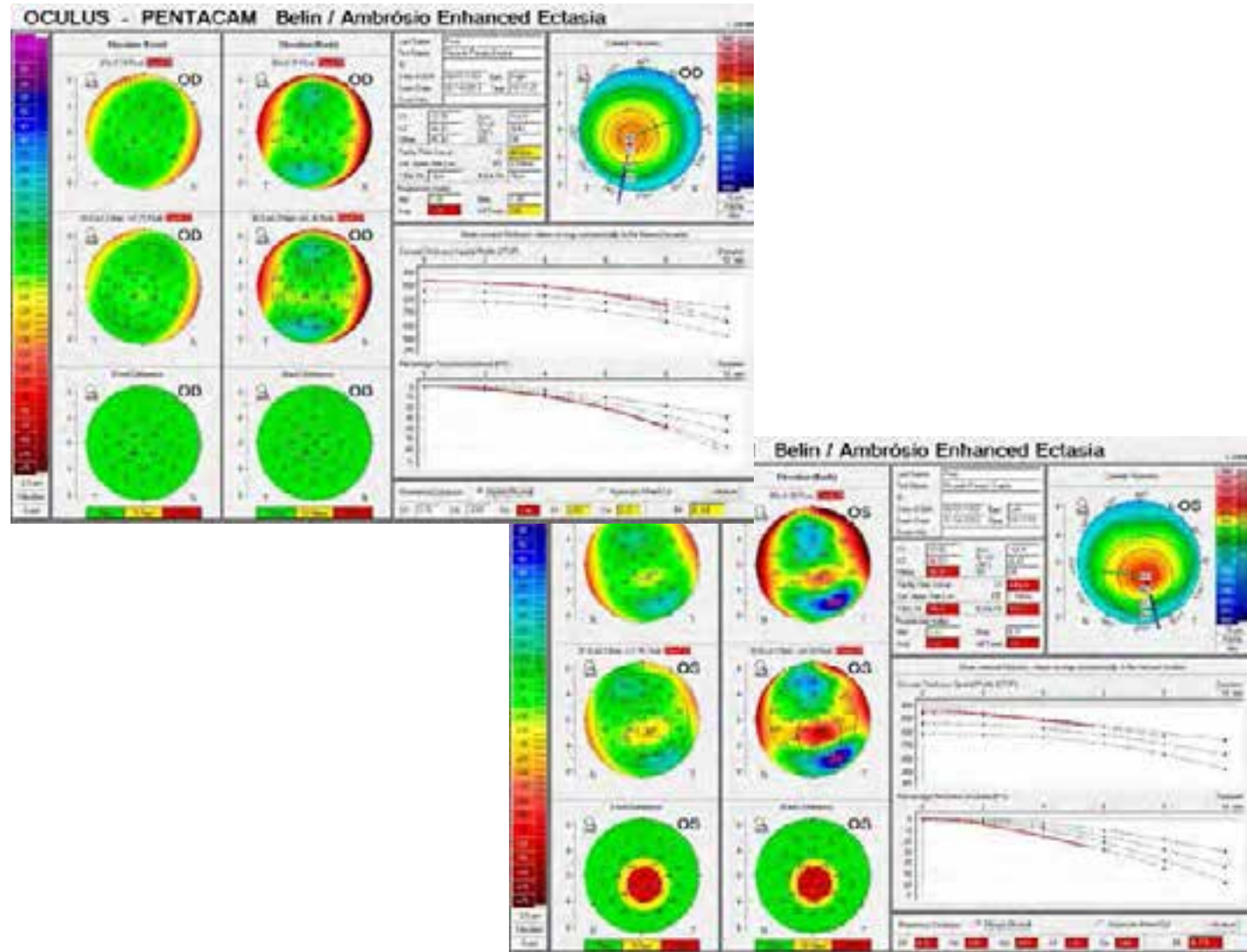
20/80 -1,75 -2,00 x 094°, giving 20/30 OS



AXL:
24,44mm OD
24,32mm OS



Tomographic Evaluation





Diagnosis and Management

- OD: very mild (“fruste”) keratoconus
- OS: moderate keratoconus with likely progression

Management

- OD: no surgery but advised against eye rubbing and for treating ocular allergy
- OS: FS-ICRS



ICVS/3B's
Portuguese
Laboratory
of Vision Research

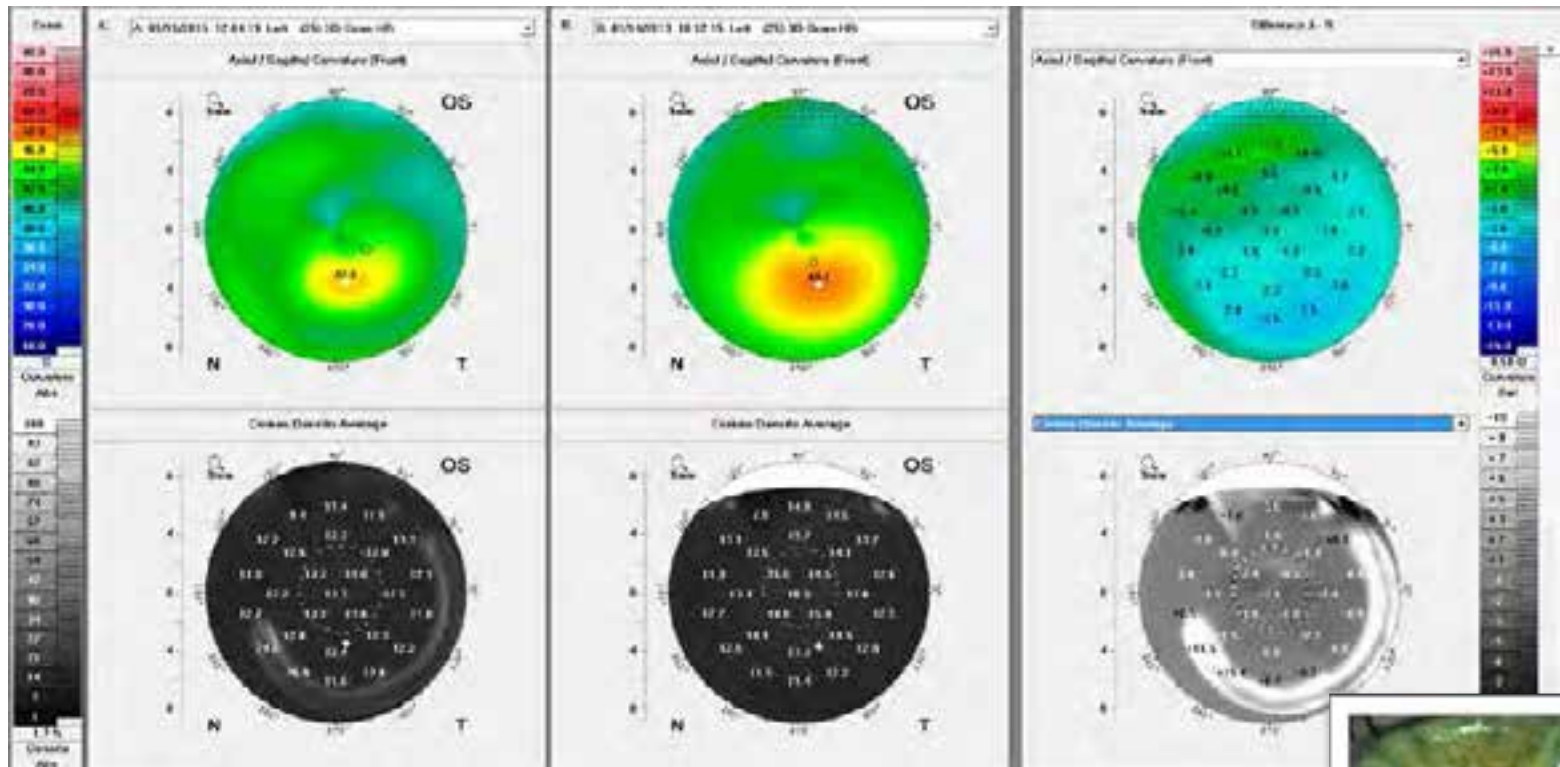


17/01/2013: Fs-ICRS OS

Keraring SI6 210° / 200 μ m with iFS (150kHz)

19/01/2015: 24Mo Post op OS

UDVA 20/80 -1,25 -1,25 x 100°, giving 20/20-1 OS

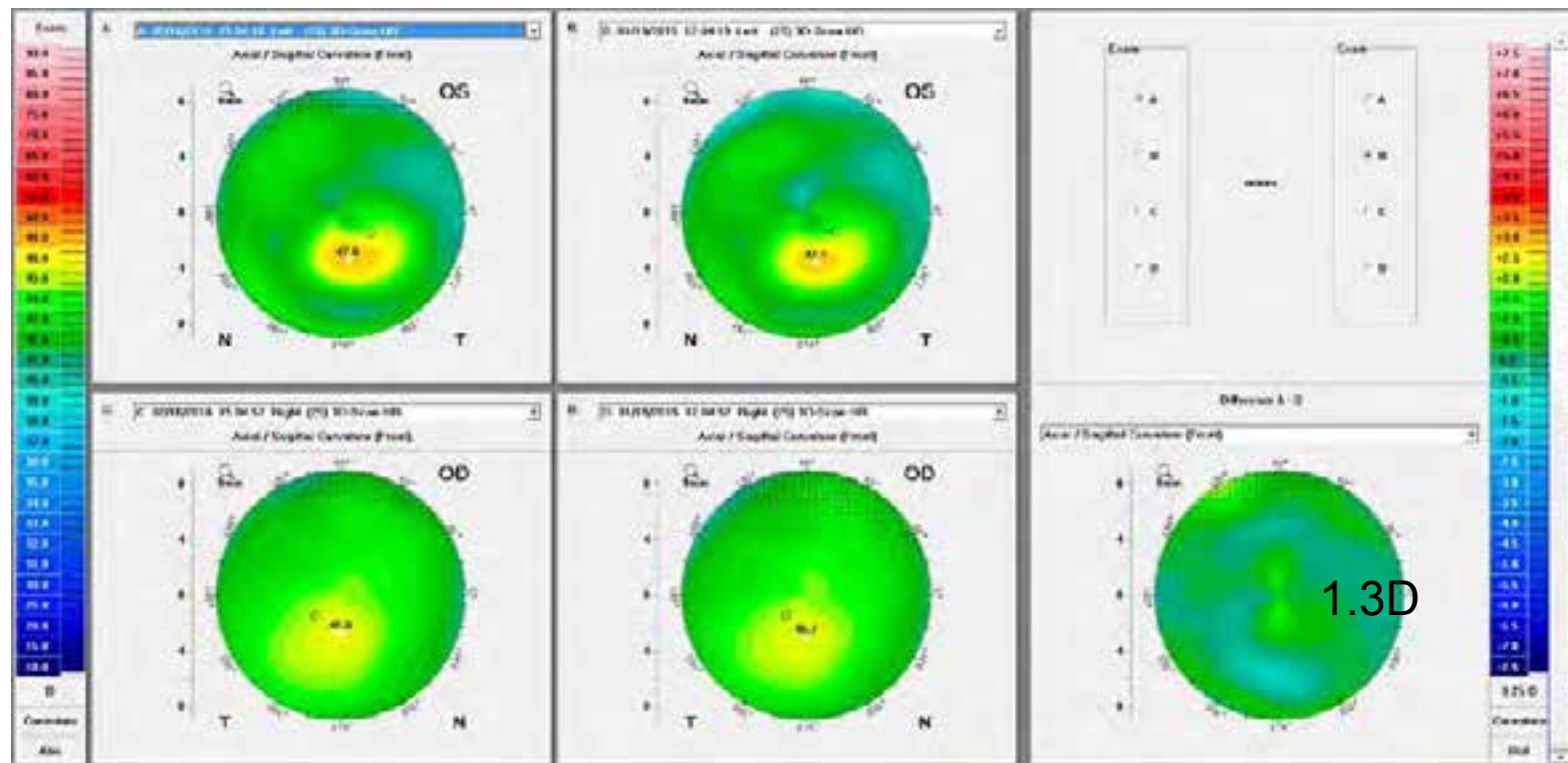


16/2/2016

OD was stable

vision got worse OS

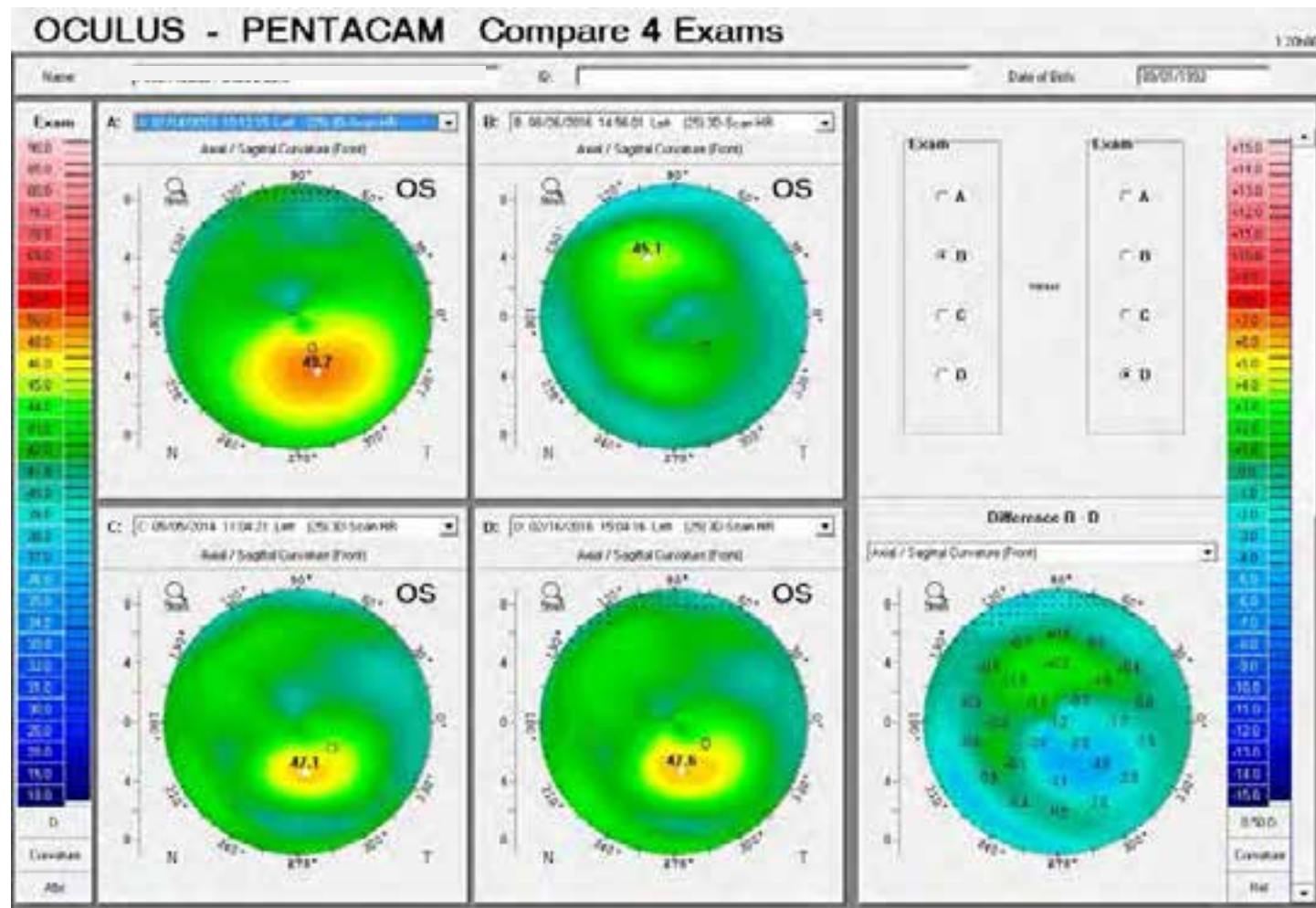
UDVA 20/100 -1,75 -2,25 x 95°, giving 20/30+1 OS



14/4/2016: Athens Protocol OS

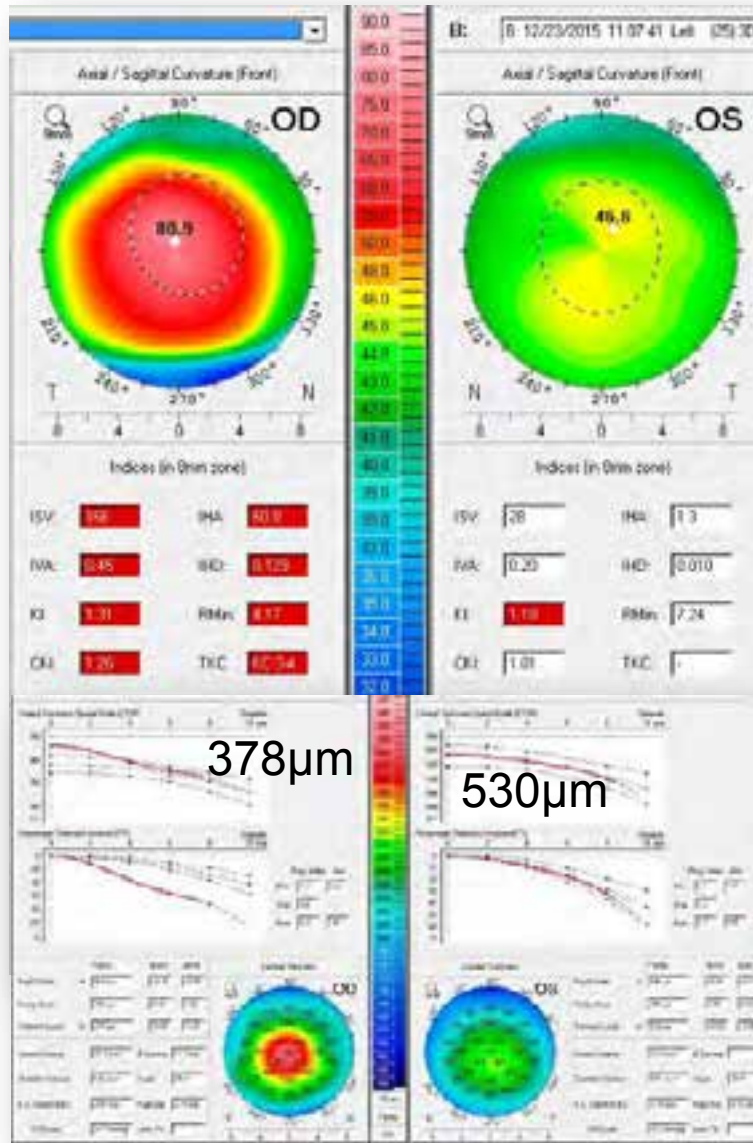
26/8/2016: 18 weeks Post Op OS

UDVA 20/60 -1,00 -1,25 x 105°, giving 20/20 OS





19 years old male with very asymmetric ectasia OD



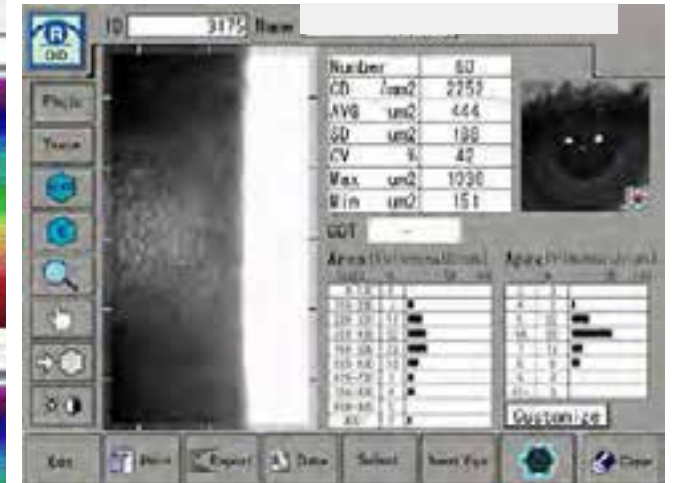
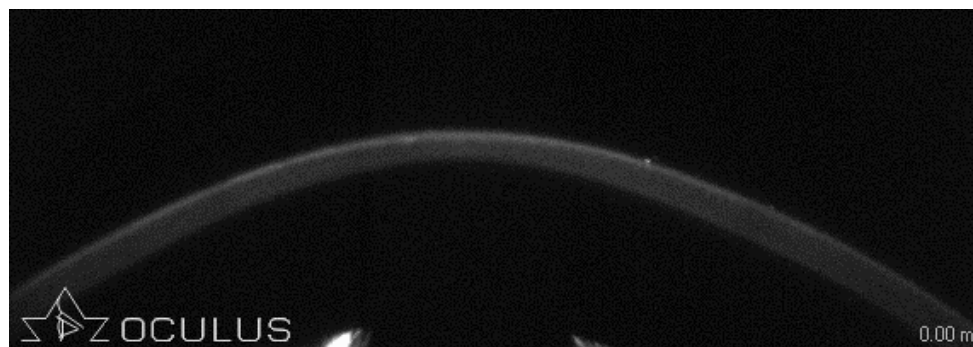
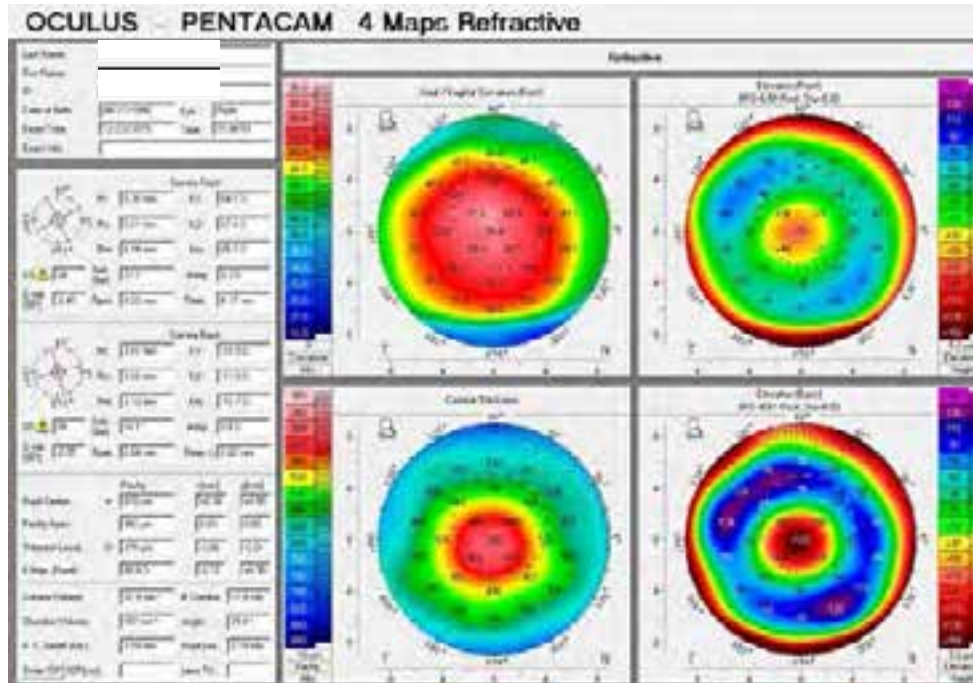
- ◆ Bad vision OD, reports good vision OS; did not tolerate CLs OU
- ◆ Confused as two doctors said he needed CXL OS; indication for transplant OS
- ◆ Intense eye rubbing (OD+)
- ◆ UDVA: CF at 2m OD, 20/20-1 OS
- ◆ MRx: -14.00 cyl-2.75 x 30, giving 20/100 OD +0.50 = -1.75 x 169, 20/15 OS



ICVS/3B's
Research Laboratory



Can we try anything before a Transplant in OD?

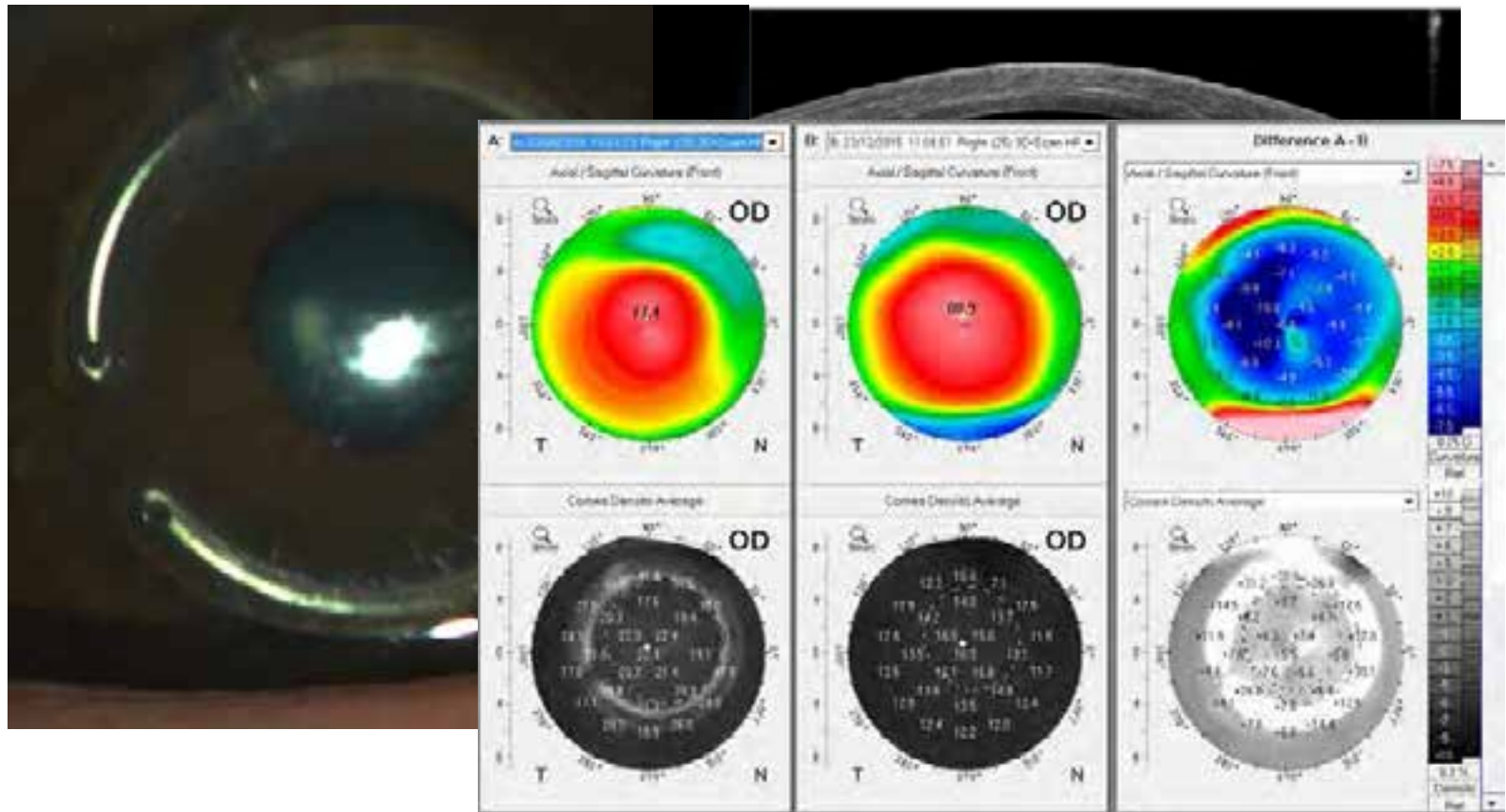




Plan: FS-ICRS + CXL OD

Patient Education and observation OS

- ◆ Surgery at 11 Feb 2016: Keraring 340°/200µm
- ◆ 6months PO: UDVA 20/200; -8.00 -1.25 x 16, 20/60
- ◆ Advised for contact lens or ICL



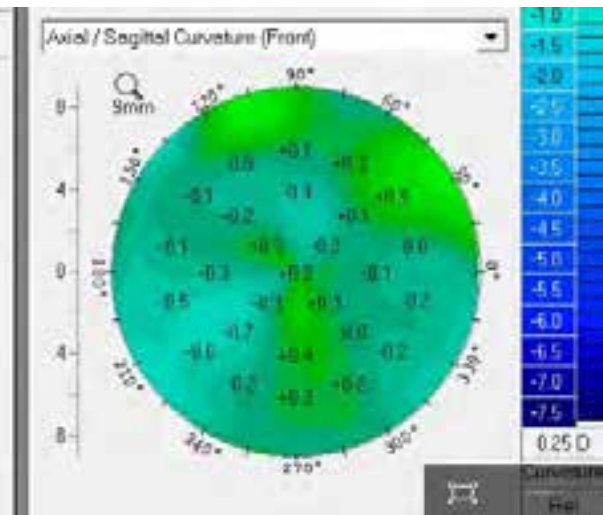
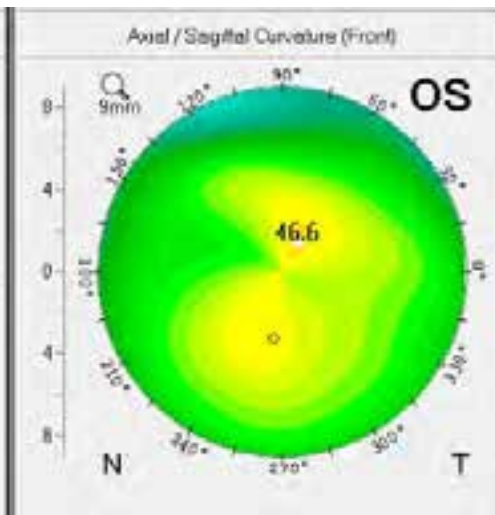
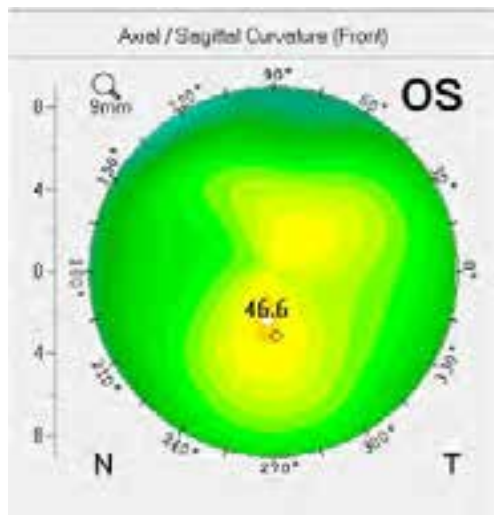
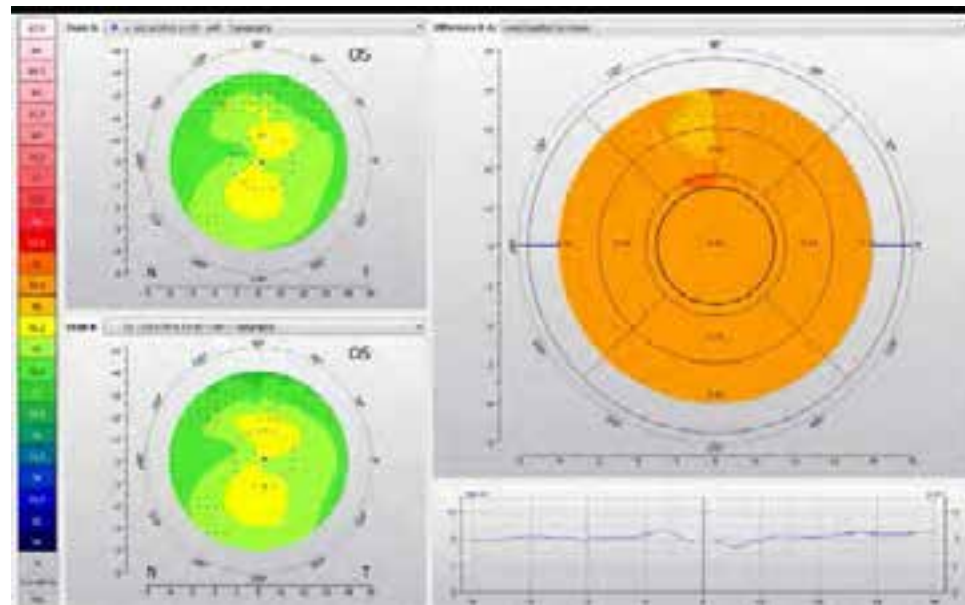


Biomechanical Change OD





OS remains stable with UDVA 20/20





Take-Home Messages

- Ectasia concepts and definitions
 - *Any cornea may undergo ectatic progression*
- Scheimpflug Imaging is essential for corneal analysis
 - Corneal 3D reconstruction
 - Corneal Deformation
- **Segmental** or Layered Corneal Tomography: epithelial-stromal thickness mapping
- Future role of **Genetics**

Artificial Intelligence improves
the diagnostic accuracy



Take-Home Messages

- **Advance Ocular Analysis** helps in ectasia management
- Patient and Family **education** is critical.
- Indication of **Cross-linking** needs to be considered based on individual patient characteristics, including UDVA, DCVA, ectasia progression and should NOT be generalized.
- **Athens Protocol** (ePTK+TCAT with MMC) or **Cretan Protocol** (ePTK) after **ICRS** are valuable options
- **Therapeutic Bioptics**: RLE or phakic IOL for residual ametropia

International
CXL
Experts' Meeting

Faria Correia
MD



Thank you for your attention



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ESCRS 2017
Lisbon - Portugal