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

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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).\(^2\)

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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

- Τόμος (tomas) means "slice",
- γράφω (graphia) significa "write"

3D reconstruction of the cornea
- Slit scanning
- Scheimpflug
- OCT
- VHF-US
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
“False” Pellucid Marginal Degeneration But an Inferior Keratoconus
“True” Pellucid Marginal Degeneration
Keratoconus Diagnosis with Pentacam

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

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

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

*no evidence of keratoconus on Oculus TKC and/or Nidek Corneal Navigator
Pre-LASIK Ectasia: Retrospective Study

- 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: Advanced 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)
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 na enhanced susceptibility approach.
- Any cornea may undergo ectatic progression
- Depends on the innate biomechanical predisposition and environment
- Continuous characterisation of the susceptibility with TBI
- Future role of Genetics
Managing corneal ectasia prior to keratoplasty

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Keratoconus

Progressive

Good UCVA

Good BCVA

Bad VA

Non-progressive

Good VA

Bad VA

Epi-on CXL

CXL

Clear cornea

Apical scar

Follow-up epi-on CXL

CXL

DALK PK

Contact lens ICRS phakic IOL

Low refractive error

Contact lens glasses phakic IOL RLE

Contact lens ICRS phakic IOL

High refractive error

Glasses contact lens PRK
Jan 2013
Male, 19 yo. “bad vision”

- UDVA / MRx / 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
Faria Correia
MD

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
17/01/2013: Fs-ICRS OS
Keraring SI6 210° /200µm 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
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**
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
Thank you for your attention

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