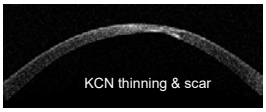
Advanced diagnostic technologies in Keratoconus and Corneal Ectatic Disease… Part 2:

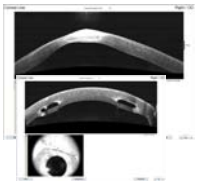
S. Barry Eiden, OD, FAAO

- Anterior segment OCT
- High frequency ultrasonography
- Corneal Biomechanics
- Aberrometry

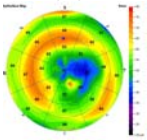
International Keratoconus Academy
Of Eye Care Professionals

Anterior Segment OCT in KCN

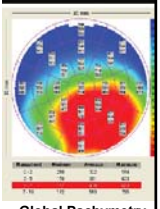




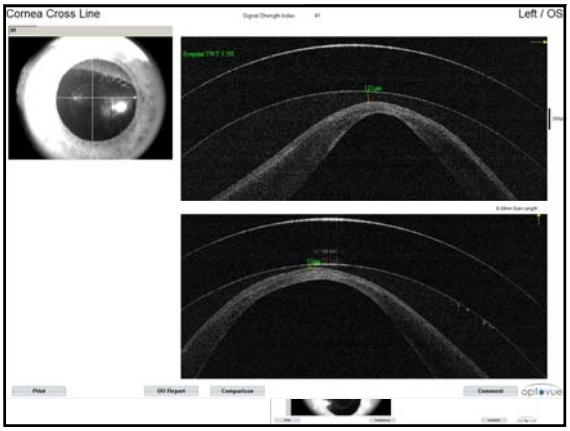
Corneal Imaging



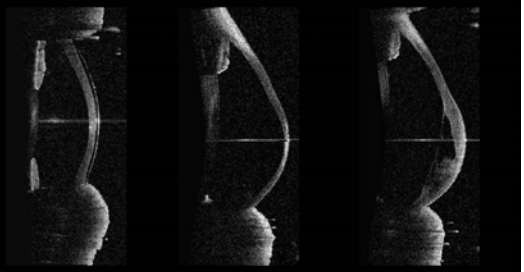
Epithelial thickness



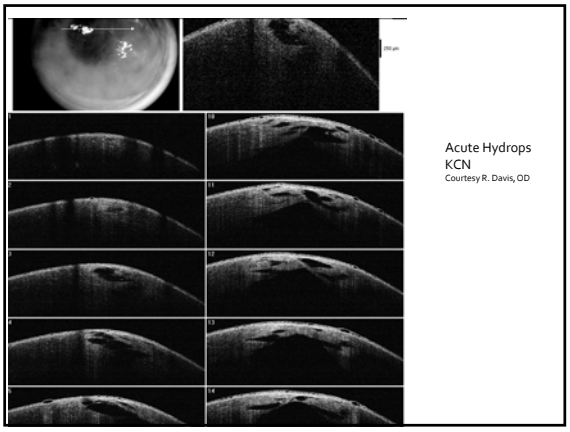
Global Pachymetry



Anterior Segment OCT: Evolution of KCN: Ectasia to Hydrops

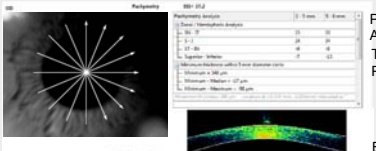


Courtesy: L.SCLAFANI, OD

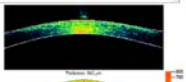


Acute Hydrops
KCN
Courtesy R. Davis, OD

Pachymetry Maps
(Radial Scans)



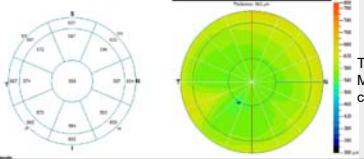
Pachymetry Analysis Thickness Parameters



B-Scans

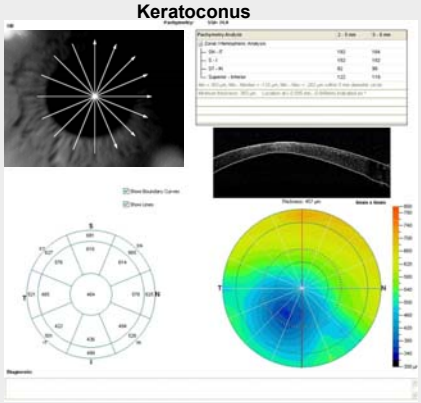
6 mm diameter average thickness values by region

Central circle 0-2mm
Middle circle 2-5 mm
Outer circle 5-6 mm



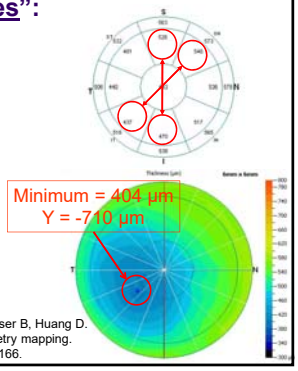
Thickness Map color coded

Keratoconus



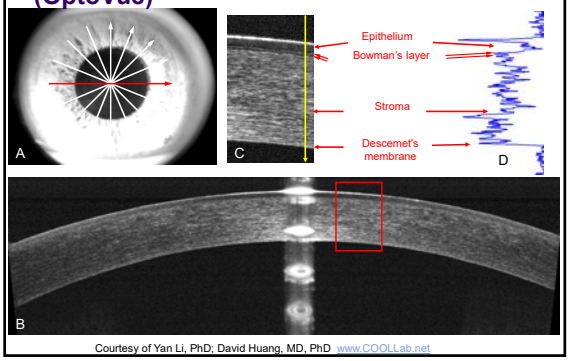
Detecting Keratoconic Thinning with OCT "Pachymetric Indices":

- **General thinning**
  - Median
- **Focal thinning**
  - Minimum – median (w/in 5mm zone)
- **Asymmetric thinning**
  - I-S
  - IT-SN
  - Y location of the Min



Li Y, Meisler M, Tang M, Lu A, Thakrar V, Reiser B, Huang D. Keratoconus diagnosis with OCT pachymetry mapping. *Ophthalmology* 2008;115:2159-2166.

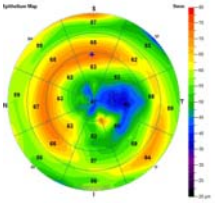
Corneal Epithelial Imaging with FD-OCT (OptoVue)



Courtesy of Yan Li, PhD; David Huang, MD, PhD www.COOLLab.net

Epithelial Thickness Mapping*

- 6mm epithelial thickness map
- Measures epithelial thickness from corneal surface to Bowman's membrane

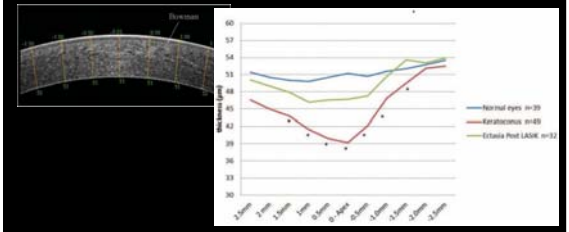


Identify Keratoconus Earlier
Enhance Preoperative Planning for Refractive Surgery
Monitor Quality of Vision in Refractive and Cataract Surgeries

*ETM requires regulatory clearance and is not yet available commercially available in the United States.

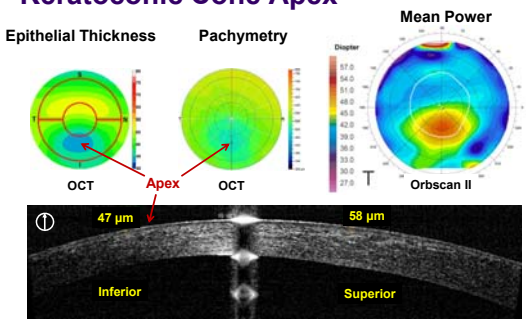
Epithelial Thickness in KCN via ASOCT

J Refract Surg. 2013 Mar;29(3) SD-OCT analysis of regional epithelial thickness profiles in keratoconus, postoperative corneal ectasia, and normal eyes



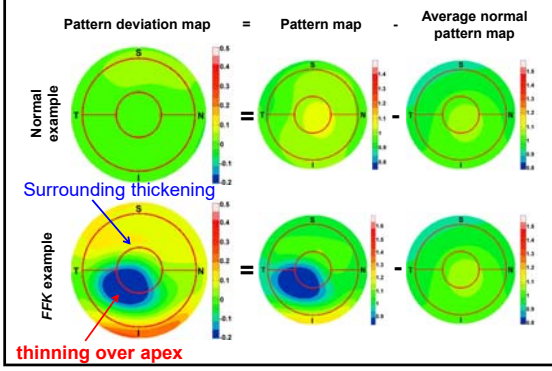
"Apical epithelial thickness was significantly thinner in eyes with keratoconus (P < .0001) and ectasia (P = .0007) than in controls."

Epithelial Thinning over Keratoconic Cone Apex



Courtesy of David Huang, MD, PhD www.COOLLab.net

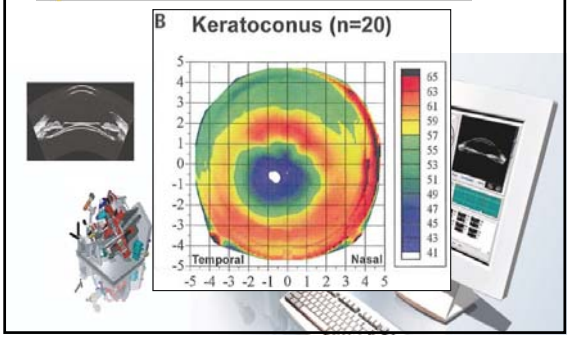
Pattern Deviation Map Examples



Epithelial Thickness Mapping:

- OCT epithelial thickness mapping may provide early detection of KCN
- This may be synergistic with other technologies that help KCN early diagnosis

Artemis (high freq. ultrasound) Epith. Thickness in keratoconus



Corneal Biomechanical Properties in Keratoconus / Keratectasia

Ocular Response Analyzer
By Reichert

Corvis
By Oculus

A New Instrument for Measuring IOP and Corneal Deformation

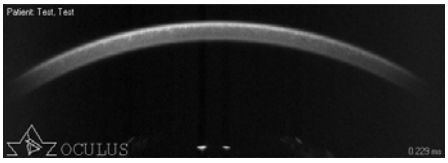
The OCULUS **Corvis ST**

Corneal Visualization Scheimpflug Technology

What is the Corvis ST?

- Ultra High-Speed (UHS ST) Scheimpflug Technology: 4,330 frames/sec
- 8mm horizontal coverage
- Non Contact Tonometer symmetrically metered air pulse

➡ Captures 140 images in the 31 ms after air pulse



What Influences Deformation?

- **Intraocular Pressure!**
- **Corneal Biomechanical Properties**
- **Corneal Thickness**
- Corneal Curvature

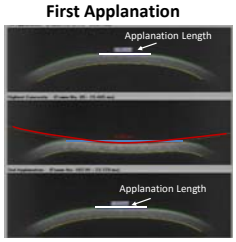
Why are Corneal Biomechanics Important?

Examples for applications

- **Identify patients at risk for Ectasia**
- Accurate measurement of IOP
- Identify risk factors for glaucoma
- Medical treatment for glaucoma
- Measuring the effect of corneal crosslinking
- Improved prediction of refractive outcomes
- Response to CL Corneal Reshaping? Etc…

Parameter Definitions

First Applanation



Second Applanation

Highest Concavity

KCN to NL comparison

Matched IOPcc; n=66 in each group

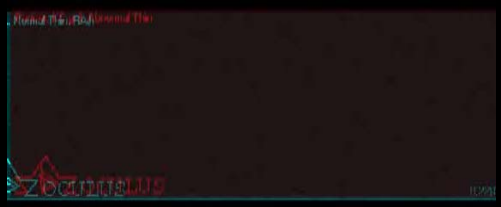
	Keratoconus	Normal	
IOPcc	14.4 ± 2.2mmHg	14.4 ± 2.5mmHg	p = .927
Da	1.13 ± .12 mm	1.04 ± .10 mm	p < .0001
Stiffness	40.6 ± 4.0 mmHg/mm	44.4 ± 4.3 mmHg/mm	p < .0001
Pachymetry*	475 ± 38 µ	520 ± 25 µ	p < .0001
rad-curve-hc*	8.66 ± 1.82 mm	11.47 ± 2.60 mm	p < .0001
Waist*	4.82 ± .24 mm	4.82 ± .26 mm	p = .9572
Vin*	.23 ± .04 mm/ms	.21 ± .03 mm/ms	p = .135
Vout*	-.36 ± .07 mm/ms	-.32 ± .05 mm/ms	p = .034
app-length1	1.73 ± .45 mm	1.99 ± .38 mm	p = .0008
app-length2*	1.84 ± .43 mm	2.31 ± .38 mm	p < .0001
app-time1*	7.9 ± .4 ms	8.4 ± .5 ms	p < .0001
app-time2*	24.1 ± .6 ms	23.8 ± .6 ms	p = .0024

*significant relationship with "stiffness"

Biomedical Engineering

Cynthia J. Roberts, Ph.D.

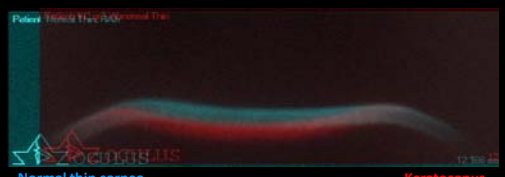
Direct Comparison of Normal eye and Keratoconic eye



Normal thin cornea Keratoconus

Data provided by Renato Ambrosio, MD, PhD

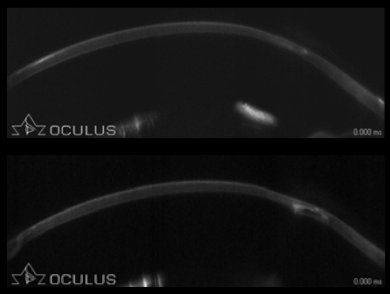
Significant Changes of biomechanical properties in ectactic corneas



Normal thin cornea Keratoconus

- Significant increase in deformation amplitude
- Significant increase of oscillation of the cornea after the air pulse

Biomechanics of Corneal Rings



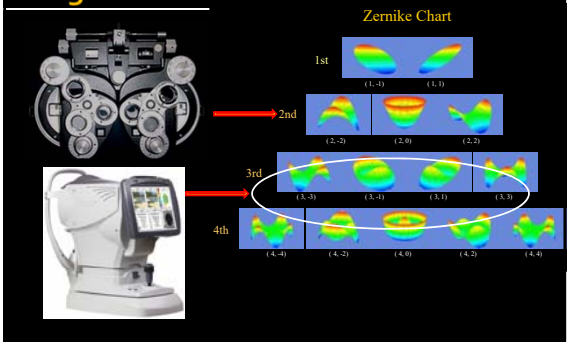
Pre Op:

Def. Ampl.: 1,35 mm

Post Op:

Def. Ampl.: 1,15 mm

Corneal Irregularity Induces High Order Aberrations



"Higher Order Aberration"

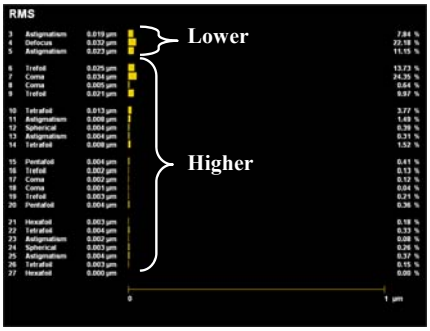
- ***Defined as:***

  Any refractive error that cannot be corrected by sphero-cylindrical lens combinations

  - *Examples include coma, trefoil, spherical aberration, chromatic aberration, etc.*
- *Higher order aberrations make up approximately* ***17% of the total aberrations of normal eyes***

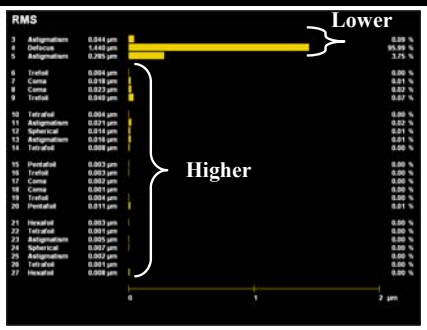
20/10 UNCORRECTED PATIENT

Ref +0.04 + 0.16 X 110



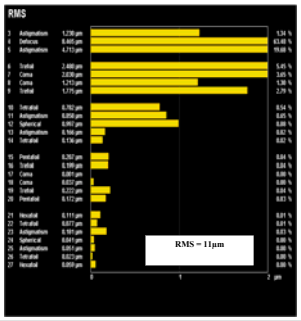
Simple Refractive Error

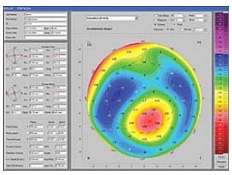
99% OF TOTAL ABBERATION IS LOWER ORDER ABERRATIONS

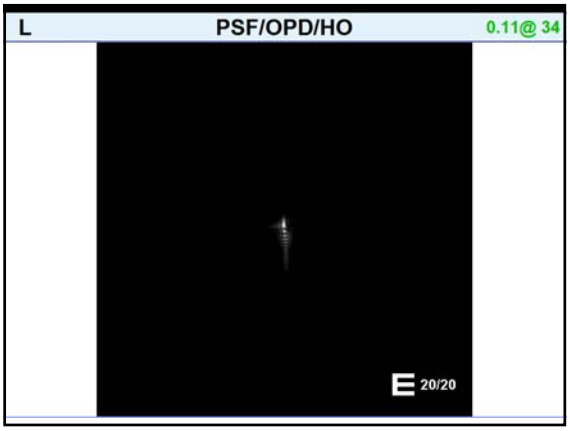


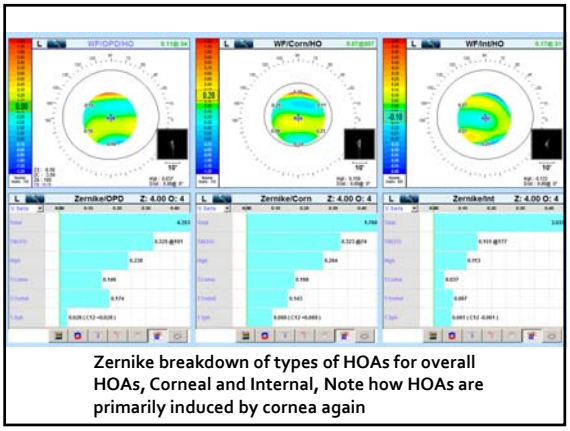
Keratoconus

WITH SIGNIFICANT LOW & HIGH ORDER ABERRATIONS









Zernike breakdown of types of HOAs for overall HOAs, Corneal and Internal, Note how HOAs are primarily induced by cornea again

Summary: Early Detection of Keratoconus and other Keratoectasias

- **Critically important in light of technologies that can halt progression**
- **Detection Methods / Technologies:**
  - **"Low Tech":** history, symptoms, refraction, Ks, slitlamp examination (be sensitive & refer)
  - **"High Tech":** placido topography, corneal tomography, ASOCT, high frequency ultrasound, corneal biomechanics, & aberrometry

Conquering the Keratoconus Contact Lens Challenge

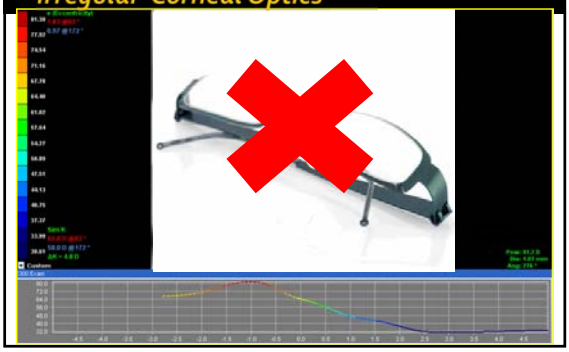
Clark Y. Chang, OD, MSA, MSc, FAAO
Director, Specialty Contact Lens Service
The Corneal and Laser Eye Institute – Hersh Vision Group
Center for Keratoconus
Adjunct Faculty, Salus University-PCO

International Keratoconus Academy
Of Eye Care Professionals

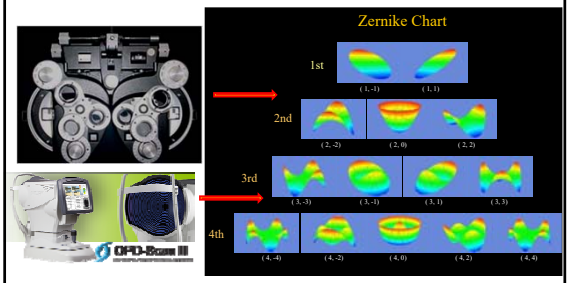
Karatoconus Challenge
Expanding Mx Spectrum

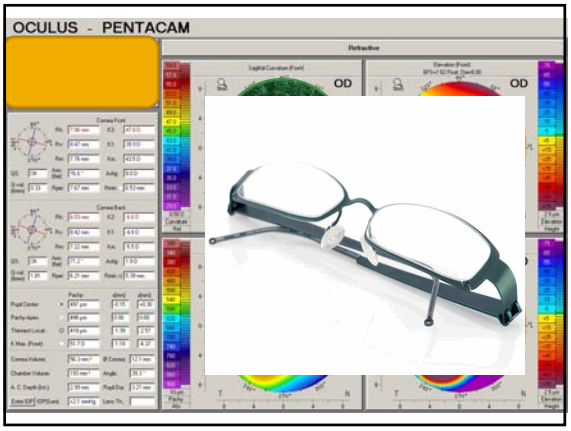
- **Glasses**
- **Contact Lenses**
- **Keratoplasty**
- **Cross-linking (CXL/CXL-Plus)**
- **ICRS (ie, Intacs)**
- **Others …**

Karatoconus Challenge
Irregular Corneal Optics



Karatoconus Challenge
Irregular Corneal Optics: HOAs

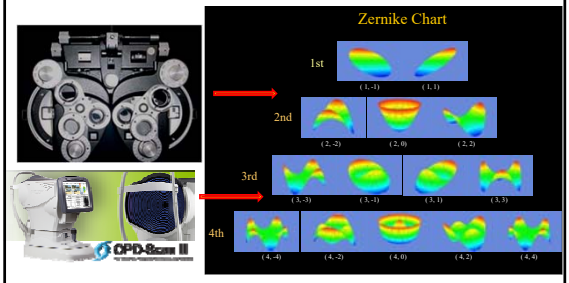




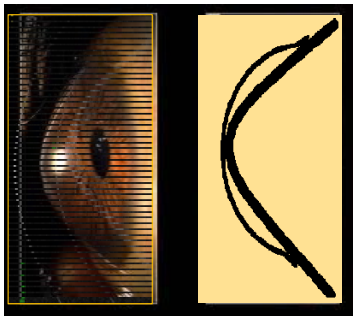
Karatoconus Challenge
Irregular Corneal Optics: Spectacles!

- ***Progression = Frequent Rx Changes !!***
- ***Impact of HOAs***
  - ***Patient characteristics, activity, environment***
- ***Significant Difference Between Eyes***
  - ***Anisometropia***
  - ***Anisekonic symptoms***
  - ***Cylinder power/axis adaptation***
    - ***Reversing neuro-compensation***

Karatoconus Challenge
Irregular Corneal Optics: HOAs

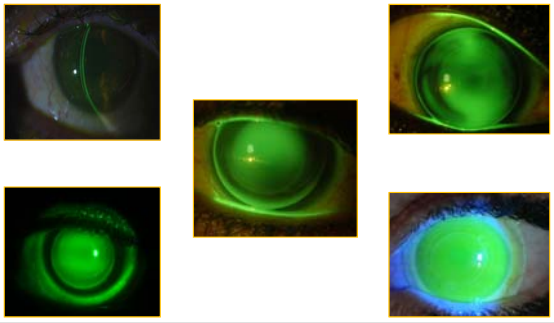


Karatoconus Challenge
Irregular Corneal Optics: Contact Lenses!



<u>Contact lenses:</u>
Still the primary vision correction tools in Mx keratoectasia & other causes of irregular cornea

Karatoconus Challenge
Contact Lens Options

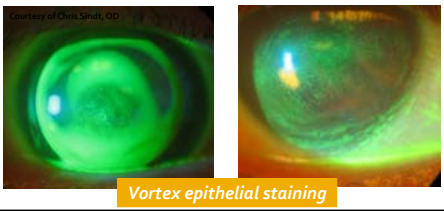


Karatoconus Challenge
Contact Lens Options

- ***Standard Soft Lenses***
- ***Custom Keratoconic Soft Lenses***
- ***Corneal Gas Permeable Lenses***
- ***Intra-Limbal Gas Permeable Lenses***
- ***Piggyback and Recess Systems***
- ***Scleral Gas Permeable Lenses***
- ***Hybrid Lenses***

Karatoconus Challenge
CL Options: General KC Fitting Principles

- Vision
- Comfort
- Other physiological Responses
  - Short & Long Term



Vortex epithelial staining

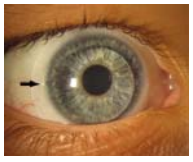
Karatoconus Challenge
CL Options: General KC Fitting Principles

- Collaborative Longitudinal Evaluation of Keratoconus (CLEK) study showed 87% of RCL subjects entered wearing flat fitting GP lenses
- By the end of the CLEK study, eight years after it began, just **9%** of those patients who were fit steep for **apical clearance developed corneal scarring**, vs. **31% of those fit flat for apical touch**. Along with lens discomfort, flatter fits "were associated with an increased likelihood of PK."

Karatoconus Challenge
CL Options: General KC Fitting Principles

- Proper Selection of Lens Design
  - HOA symptoms/testing guides design selection
  - Corneal/Scleral profile guides SAG & lens geometry
  - OAD/OZ Size
  - Lens centration & stability
  - Vaulting influences
- Avoid hypoxic corneal stress
- Avoid mechanical bearing on ocular surface
- Optimize long term outcome factors

Soft Contact Lens Fitting In Irregular Corneas

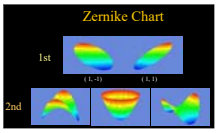


Karatoconus Challenge
CL Options: Soft Lenses

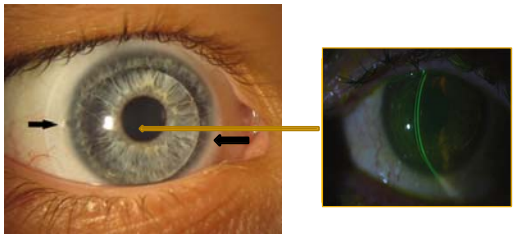
- ***Advantages:***
  - *Comfort*
  - *Centration (draping)*
  - *Corneal Protection*
- ***Limitations:***
  - *Vision (due to draping effect)*
  - *Dehydration*
  - *Hypoxia /microbial contamination*

Karatoconus Challenge
CL Options: Standard Soft Lenses

- *Used when minimal optical distortion and adequate vision with glasses*
- ***Disposable Molded Soft Lenses***
- ***Conventional Lathe Cut Soft Lenses***
- *Predictability issues RE: Power/Axis*



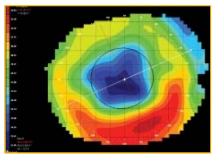
Karatoconus Challenge
CL Options: Custom Soft KC Lenses



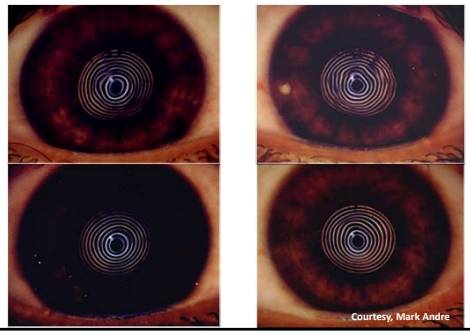
Reverse Geometry Soft Contact Lenses for Irregular Corneas

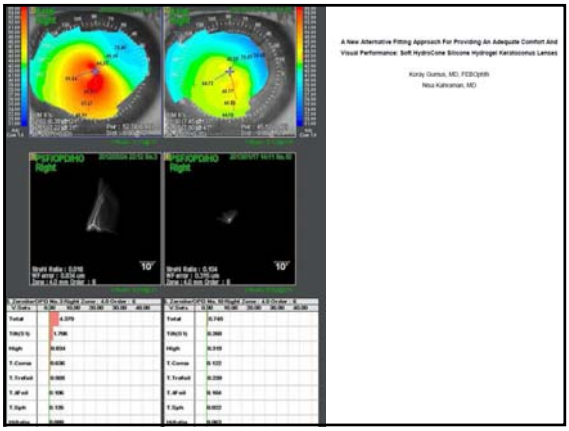
Karatoconus Challenge
CL Options: Custom Soft KC Lenses

- ***Clinical application of Reverse Geometry***
  - ***Oblate Corneas***
    - ***Post Refractive Surgery*** *(LASIK, PRK RK)*
    - ***Post PK***
    - ***Post Trauma***
    - ***Other Oblate Topographies***



Karatoconus Challenge
CL Options: Custom Soft KC Lenses

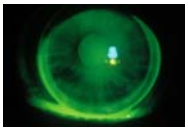




Karatoconus Challenge
CL Options: Custom Soft KC Lenses

- **Hydrokone** (Visionary Optics)
- **NovaKone** (Alden)
- **Kerasoft** (dist. By B&L)
- **Soft K** (Acculens & Advanced Vision, & SLIC Labs)
- **Continental Kone** (Continental)
- **Keratoconus lens** (Gelflex)
- **Soflex** (Marietta)
- **Ocu-Flex K** (Ocu-Ease, Optech)
- **UCL -55** (United)
- **Flexlens Keratoconus** (X-Cell)
- **+++ Others**

Corneal Gas Permeable Contact Lens Fitting In Irregular Corneas



Karatoconus Challenge
CL Options: Corneal GP

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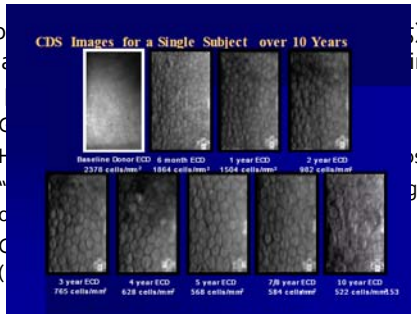


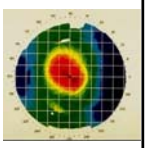
Karatoconus Challenge
CL Options: Corneal GP Fitting Goals

- ***"Avoid Apical Bearing!"***
- ***Match the periphery of the cornea*** *(if normal)*
- ***"Size Matters":*** *larger more decentered areas of irregularity require larger lenses & OZ*
- ***Address Vision Needs:*** *irregularity, astigmatism, presbyopia*

Karatoconus Challenge
CL Options: Corneal GP Selections

Small Central Cone :

- ***Small diameter multicurve designs*****
  - ***OAD < 9.0mm, OZ < 7.0***
  - *1st Dx = apx. mid + to steep Sim-K*
    - *Ie, Rose K 2, Dyna Cone, McGuire , + custom*

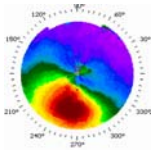


** Can consider larger diam. aspheric & others in mild kcns cases – if advanced will need to be steep over non-ectatic area due to large OZ's of these designs. Start with BC apx to 4mm temporal.

Karatoconus Challenge
CL Options: Corneal GP Selections

Moderately Decentered Oval cone :

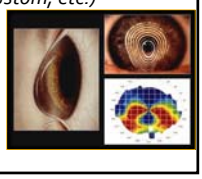
- ***Medium diameter corneal designs***
- ***OAD > 9.2 / < 11.0mm, OZ > 7.2 to 9.0+***
  - ***Ie, Ikone, KBA, + custom designs***



Karatoconus Challenge
CL Options: Corneal GP Selections

Larger & More Decentered Oval Cones

- ***Include PMD, Post-PKs*****
- ***"Intralimbal designs"***
  - ***OAD 11.0 - 12.2mm, OZ 9.0+***
  - *Dyna Z intralimbal, Rose K2 IC, custom, etc.)*
  - *Use of*
    "Asymmetric Technology" Or
    "Quadrant-Specific Curves"



** Beware of harsh limbal bearing, esp post-PK
** Reverse Geometry

Quadrant Specific Technology

End Session 3: Break