Basics Concepts in Elevation, Selected Topics in Pachymetry
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How is Elevation Data Displayed
• “RAW” elevation maps are rarely used

Reference Surface
• The most commonly used and intuitive reference surface is a Best-Fit-Sphere

How are Topographic Maps Displayed?
The most common method is to compare the data against a suitable reference surface.

How Elevation is Displayed
• The steep profile falls below the reference surface.
• The flat profile rises above the reference surface.
Astigmatism vs. Keratoconus

Keratoconus

We look for central or para-central “Positive Islands of Elevation”

Derivation of Keratoconus Pattern

But What is the Best Reference Surface?

Best Fit Sphere

Best Fit Toric Ellipse
But What is the **REALLY** Best Reference Surface?

A TRUE “Best Reference Shape” would better approximate the normal cornea and accentuate the abnormal cone.

The “Best Fit Shape” below is essentially an average of the high and low elevations of the cornea.

“AVERAGE” Best Fit Shape
But We Can Do Better!!

“BEST” Reference Shape

“BEST” Elevation reference shape is calculated using only data outside the cone.
3.5 mm diameter circle centered on point with smallest radius of curvature.

All elevation data within the red circle is excluded.

“BEST” Elevation reference shape is calculated using only data outside the red circle.

Methods

Keratoconus fit with Best Fit Sphere VS Keratoconus fit with New Reference Shape

Normal fit with Best Fit Sphere VS Normal fit with new Reference Shape

Before & After Exclusion Software

Keratoconus – Before / After

Normal Eye – Before / After

Results

• Comparing the BFS to the modified reference shape
  – Normal eyes showed an avg change in anterior apex and maximum elevation of 1.86±1.9µm and 1.63±1.4µm.
  – Keratoconus eyes showed anterior apex and maximum elevation changes of 20.4±23.1µm and 20.9±21.9µm.
    • (P<.0001).
  – Posteriorly, normal eyes showed an average change in apex and maximum elevation of 2.86±1.9µm and 2.27±1.1µm.
  – Keratoconus eyes showed posterior apex and maximum elevation changes of 39.9±38.1µm and 45.7±35.9µm.
    • (P<.0001).
Conclusion

- The modified reference shape is based on the normal portion of the cornea.
- We eliminate the abnormal portion of the cornea from the best reference shape calculation.
- This significantly enhances the identification of topographic elevation abnormalities in patients with keratoconus.
- This new reference shape may enhance the detection of subclinical ectatic disease.

Ocular Symmetry

- We commonly consider “normal” parameters “abnormal” if there is a significant amount of asymmetry. (IOP, CDR, Refractive error)
- While normal values for corneal thickness are well established, little is known about the variation between an individual’s eyes


Symmetry

- Establish the normal distribution for intra-subject (OD/OS) pachymetry in a refractive surgery population.
- Compare pachymetry readings at corneal apex, pupil center and thinnest region of each cornea to establish normal levels of variance between those points.

OD/OS Pachymetry Variance

<table>
<thead>
<tr>
<th></th>
<th>Thinnest Point</th>
<th>Corneal Apex</th>
<th>Pupil Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. OD/OS Difference</td>
<td>9.0µm (SD 8.3)</td>
<td>8.8µm (SD 7.2)</td>
<td>8.9µm (SD 8.3)</td>
</tr>
<tr>
<td>Range</td>
<td>0-105µm</td>
<td>0-59µm</td>
<td>0-105µm</td>
</tr>
<tr>
<td>2SD/3SD</td>
<td>25.6/33.9</td>
<td>23.2/30.4</td>
<td>25.5/33.8</td>
</tr>
</tbody>
</table>

N=724
Symmetry Values

- Individuals with a $>25\mu m$ difference in CCT represent $<5\%$ of the population.

- Individuals with a $>34\mu m$ difference in CCT represent $<0.5\%$ of the population.

Corneal Thickness Map

- Multiple papers compare different instruments measuring corneal thickness
  - Ultrasound, Optical Pachymetry, Scheimpflug, OCT, Confocal, etc.

- We assume they're all measuring the same thing and concentrate on machine variability
  - Ultrasound, Optical Pachymetry, Scheimpflug, OCT, Confocal, etc.

How Thick is the Cornea at Point A

Multiple ways to measure Thickness
Normal to the Surface Tangent

This is what most of us think is being measured.

Parallel Vertical Cuts

Searching for Minimal Thickness

**GREEN** is how you currently do it by taking the normal to the surface.

**RED** by looking for the closest posterior point regardless of orientation.

Ophthalmic Analogy

- Translational femtosecond laser
  - Ziemer LDV

Minimal Distance vs Normal to Tangent
ICR Surgical Planning
Channel Depth

Minimal Distance Method

As much as a 35 micron difference between Minimal & Standard Methods

Thickness from 1 fixed central point
This will vary based on the distance from the Apex

Ophthalmic Analogy
• Non-applanating femtosecond laser
  – FLEX / ReLEx posterior stromal ablation

Distance set by the focal length of the Delivery System
40 microns  30 microns  20 microns  10 microns
Thank You