Controversies in Identifying Risk Factors for Post-LASIK Ectasia

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I have no financial interest in this topic.

Traditional Risk Factors

- Corneal Thickness
- Manifest Refraction Spherical Equivalent
- Topography Patterns
- Age
- Gender
- Predicted Residual Stromal Bed (RSB)
What Determines Corneal Form?

Tissue Properties = Material Properties

Corneal Biomechanics
Basic Elasticity Example

- Tissue A (stiff)
- Tissue B
- Tissue C (limp)
- Applied force (stress)
- Shape change (strain)

Many Paths to Biomechanics

- Biomechanics:
  - Viscoelasticity
  - Compressibility
  - Hysteresis
  - Shear Strength
  - Cohesive Strength
  - Etc.

- Tissue Properties
- Applied Force
- Corneal Form (Shape & Thickness)
- Optical Aberrations
- Image Blur

We want to think mainly in terms of bending forces in vivo.
Corneal refraction is highly sensitive to bending.

- Biomechanics:
  - Viscoelasticity
  - Compressibility
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  - Cohesive Strength
  - Etc.

- Tissue Properties
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- IOP
- Eyelid force
- Eye rubbing
- Air puff
- Contact lens
Shape is not a Tissue Property

PLASTIC
ALUMINUM
STEEL

Fast performance, structurally weak.
Fast performance, structurally strong.
Slow performance, structurally strong.

Thickness is not a Tissue Property

However, tissue properties are closely linked to thickness, just as force is closely linked to shape.
Corneal Tissue Properties...

- Vary with location in the cornea.
- Normally don't vary between fellow eyes.
  - Genetic rule for bilateral symmetry.
- May vary among individuals.
  - Epigenetic rule for variable gene expression.
- Are changed by disease state or other trauma.
  - Includes LASIK flap creation.

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Cohesive Strength Profiles of Fellow Corneas (vertical meridian)

There is a high degree of bilateral symmetry in the interlamellar cohesive strength of fellow eye corneas. Each pair of corneas has a unique pattern of cohesive strength. Corneal collagen organization may be complex, but the data suggests it follows some genetically determined pattern.

Patterns in (static) topography maps show us corneal form information by way of curvature, but the maps can also tell us something about Applied Forces and Tissue Properties.

- Bilateral Asymmetry
- Asymmetrical Steepening OD
- Compensatory Peripheral Flattening OD

- Hydration
- Collagen density
- Collagen crosslinking
- Collagen interweaving
- PG/GAG, etc.

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**Applied Tissue LASIK Procedure**

**Direct Shape Change**

- **Δ Corneal Form (Shape change)**
- **Tissue Properties**
- **Applied Force**

**Applied**

**Δ Corneal Form (Shape change)**

**Force Properties**

**Δ Applied Force**

**Δ Applied Force**

**Δ Corneal Form (Shape change)**

- **Tensile force increases** because the same IOP-induced stress is applied across a smaller tissue cross-section.

**Force Multiplier**

**Δ Tissue Properties**

**Δ Corneal Form (Shape change)**
Keratoconus

Stress ($\sigma$) is increased by thinning, but reduced by steepening.

$\sigma = \frac{P r}{2t}$

Normal

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LASIK Procedure

Current Risk Factors don't fully address the importance of Tissue Properties

Force Multiplier

RSB

Δ Tissue Properties

Δ Applied Force

Δ Corneal Form (Shape change)

Topography Patterns

MRSE (Indirectly)

Corneal Thickness
Weaknesses of Traditional RFs

- Age and Gender alone are inadequate descriptors of corneal Tissue Properties.
- RSB is complicates the action of applied force by IOP.
- Suspicious Topography Patterns are subject to interpretation without objective metrics.
  - The ability to discern atypical, asymmetrical patterns still remains the key factor to avoiding post-LASIK ectasia because it relates information about hidden tissue properties.
  - Traditional RFs don’t include atypical patterns of pachymetry and posterior shape.

Summary

- **For now**, static corneal shape analysis is a critically important standard for assessing the biomechanical integrity of the cornea.
- Preoperative asymmetrical shape patterns are often indicative of abnormal material properties or a history of abnormal forces that have induced tissue property changes.

Summary

- **In the future**, preoperative screening based on dynamic corneal shape change might be used to “back out” information about the corneal material properties via biomechanical models.
- The criteria for defining biomechanically “normal” versus “abnormal” corneas by way of in vivo testing requires further research.