Keratectasia After Laser in Situ Keratomileusis (LASIK)

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May 2000: Mr. A.N. 34 Y/O employee had LASIK on his both eyes for -9.0 D Myopia
* LASIK OD became complicated by “incomplete flap”

Nov. 2000: Re- LASIK OD was performed. Again after 6 mo enhancement OD to correct -2 D Residual Myopia.

October 2005: Refraction OD is -7.00-4.00 x 95° with BCVA 20/120
**Background**

- **Barraquer (1980)** reported Keratectasia following Myopic Keratomileusis. **Conclusion:** the Residual stromal thickness is important to prevent Ectasia.

- **Seiler (1998)** reported first typical form of Post-LASIK Ectasia.

- Keratectasia is also reported after:
  * Keratophakia or Myopic Keratomileusis
  * Hyperopic ALK (62%): “controlled ectasia”
  * Radial keratotomy
  * Hexagonal Keratotomy

- LASIK, PRK

(1) Holland SP, Srivannaboons, Reinstein DZ: Ophthalmology 2000:18:177-184
Background

Synonyms:
- Progressive Post- LASIK Keratectasia (PPLK)
- Iatrogenic Keratectasia
- Keratectasia after LASIK

Onset:
- Immediate (weeks) to many months after LASIK generally within 2 years
- Peak: 6-10 months

Incidence:
- 0.66%, relative uncommon
- Incidence is more than reported
Presentation & Clinical Exam

- **Positive History** of Corneal Refractive Surgery

- **Corneal Findings:** Anterior & Posterior Corneal Steepening
  - Irregular astigmatism,
  - Thinning in the area of Ectasia

- **General:**
  - * Increasing myopia, Progressive Keratometric steepening
  - * Often with loss of UCVA & BCVA
  - Iron ring may be visible
  - Ectasia may appear in one eye while similar treatments in both
Presentation & Clinical Exam

Topographic findings:

- **Central Ectasia** with irregular astigmatism but good corrected acuity

- **Paracentral Ectasia** resembling Keratoconus, with irregular astigmatism and poor spectacle-corrected acuity
Pathophysiological Aspects of Post-LASIK Keratectasia
1- PPLK as Chronic Disease

Is PPLK Similar to KCN??

- Collagenase and Gelatinase activity
- Increased interleukin-1 and prostaglandin activity
- Rearrangement and altered adhesion of lamellae
- These Not proven for PPLK but:
  - Loss of Keratocytes in anterior flap and interface
  - Anterior flap metabolic alterations due to neurotrophic keratectomy

Pathophysiology...
2- Biomechanical process

A- Early effects of LASIK

- Forward movement of posterior corneal surface (usual finding after LASIK)
- Central as well as peripheral cornea is affected after central ablation (C. Roberts Theory)

- Posterior stroma after LASIK:
  * Altered Proteoglycan composition
  * Fewer Collagen cross links
  * Reduced Keratocyte Density

(Altered Stromal Remodeling and late Keratectasia)
2- Biomechanical process

- IOP is responsible for posterior lamella bulging:
- Not Proven for normal range IOP (at least in short term)
- The smaller the radius of curvature the bulging will be smaller
Cornea is weakest in bend and shear but strongest in tension due to Collagen fibers cross-linking (stress stiffening).

Cornea is under strain even in normal physiological conditions.

After ablation:

* Posterior lamellar tension is increased
* Reduced interlamellar cohesive strength in the Infero-Central Cornea (where Ectasia is common)
C - Corneal Shape Changes after LASIK

- Peripheral cornea moves outward and forward (Roberts’ Rubber-Band Theory)
- Limbus doesn’t expand
- Surface area of posterior cornea remains constant

Transverse contraction of posterior lamellae (Poisson’s ratio)
\( V = \text{transverse strain} / \text{longitudinal strain} \)

Central Corneal Movement

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D - Corneal Resistance to Fatigue

1- Resistance to IOP
2- Stable focusing of light
3- Resist Deforming Forces of Eyelids

Repeated microtrauma e.g. Eye Rubbing

Dynamic Fatigue

Ectasia
3- Combined process of Fatigue and Proteolysis

Static & Dynamic fatigue process of Cornea

↓

Mechanical failure

↓

Enzymatic Proteolysis

Subclinical interface inflammation

↓

Molecular Collagen changes
Adhesion Protein changes

↓

PPLK
### Risk factors for PPLK in LASIK

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Safe</th>
<th>Warning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young modulus</td>
<td>High</td>
<td>&lt;1MPa</td>
</tr>
<tr>
<td>Poisson Ratio</td>
<td>Low</td>
<td>(1-ν)/E &gt; 0.7MPa⁻¹</td>
</tr>
<tr>
<td>IOP</td>
<td>Low</td>
<td>&gt;20mmHg</td>
</tr>
<tr>
<td>Loading pressure /elastic parameters</td>
<td>Low</td>
<td>(1-ν)P/E &gt; 0.001</td>
</tr>
<tr>
<td>Curvature radius</td>
<td>Small</td>
<td>With irregular topography</td>
</tr>
<tr>
<td>Preop. Corneal thickness</td>
<td>Thick</td>
<td>&lt;500μ</td>
</tr>
<tr>
<td>Flap thickness</td>
<td>Thin</td>
<td>&gt;160 μ</td>
</tr>
<tr>
<td>Ablation diameter</td>
<td>Small</td>
<td>&gt;6mm</td>
</tr>
<tr>
<td>Attempted correction</td>
<td>Low</td>
<td>Depends on other parameters</td>
</tr>
<tr>
<td>Residual stromal bed</td>
<td>Large</td>
<td>Depends on other parameters</td>
</tr>
</tbody>
</table>

**Warning**

**Safe Parameter**

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Theories about the Risk Factors for Keratectasia
1- Pre-existing Keratoconus or Forme Fruste Keratoconus

- **FFKC:** *is abortive or early form of KCN
  * stable refraction and Corneal Curvature
- 30% of Keratectasia cases had preop Forme Fruste KCN (FFKC)
- Post-LASIK Ectasia topography is different:
  - Preop Normal eyes → Central steepening
  - Preop FFKCN eyes → Inferior steepening

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2-Minimum Residual Stromal Thickness

Low Residual stromal thickness is mechanically Unable to withstand the Intraocular Pressure

Subtraction Technique: Is Not Reliable

Remained stromal thickness (RST) =
Corneal thickness (Pachymetry) – (flap thickness + ablated depth)
Flap thickness: - Inaccurate with different microkeratomes
  - Thick flap doesn’t prevent ectasia even predispose to Ectasia
Ablated thickness (depth): variable with Hydration

Anterior flap does not contribute to the biomechanical stability of cornea

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Direct RST Measurement

- Inaccurate
- Laser ablation dehydrates stroma
- Overestimation of actual tissue removal
- Under-estimation of RST
- Anterior bowing of the posterior cornea occurs after LASIK
- RST must be determined after flap removal because of:
  * Inaccurate flap thickness
  * Epithelial hyperplasia
Minimum RST to prevent Keratectasia

- Variable Thickness reported: $200-320 \mu$
- $>18\%$ corneal thickness ablation: increases risk
- Postop Corneal Thickness must be $55-60\%$ preop thickness + not less than $475-500 \mu$
- RST safety index:
  - * $> 300$ microns  Safe zone
  - * $250-300$ microns  Borderline zone
  - * $< 250$ microns  “Danger zone”

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Factors affecting RST

- Preoperative Corneal Thickness
- Thickness of Corneal Flap
- Flap thickness is inaccurate: ± 80 microns
  Even thickness through one flap is variable
- Amount of tissue removed by the Excimer laser

Mr. K.F 20 Y/O student underwent bilateral LASIK for -2.00 D myopia in his both eyes, pachy OU ~ 520 µ
OD had incomplete flap and incomplete operation (No laser!) for 2 times.
OS uncomplicated operation After 10 months: RFN OD -4.25-1.50x 45° 20/30
  OS plano 20/20
  Thickness OD 410 µ

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3 - Enhancement Procedures

- Cornea tissue ablation will decrease RST

- Twenty two (22) percent of ectasia cases had at least one enhancement procedure

- Regression! of myopia with or without astigmatism may be initiation of Ectasia

- If enhancement indicated, up to 2-3 diopters can be enhanced by ablation over the flap
4- Preoperative Corneal Thickness

- Current standard for pachymetry: Ultrasound Pachymetry
- Orbscan II (Optical slit):
  * Mostly overestimates 20-30 µ
  * Only one report shows underestimation
  * Calibration Coefficient Factor: 0.92-0.96

- More unreliable in “non-virgin” Corneas

Orbscan is Not suitable for Reoperation

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Thin corneas with higher IOP may have a risk for forward shift of Posterior Corneal Surface after LASIK.

Posterior corneal surface shift is larger in those with lower preop Corneal Thickness, higher IOP and greater Myopia.
5- Thick Corneal Flap

- Same Microkeratome and same blade produce variable flap thickness

- Preoperative thin cornea → thinner flap (1)

- Thick flap → high risk for immediate Corneal Ectasia (even without ablation)

6- Laser Corneal Tissue Resection

- i.e corneal tissue removed by the excimer laser
- Inaccurate intraoperative pachymetry i.e immediate post-Laser
- Laser resection is variable with laser type and algorithms
- Munnerlyn’s formula: resected thickness depends on diameter, ablation profile (optical zone) and diopters
Regional Anatomical Differences in Normal Cornea

- Anterior 100-120 µ of the corneal stroma:
  * More highly compact than posterior
  * May be more resistant to mechanical deformation

- Hydration of Cornea and Refractive Index: changes across corneal thickness

- Posterior cornea is unable to withstand normal IOP
Most of Keratectasia have been in myopia over – 6.0D correction

Exception: Some eyes with low attempted Correction have developed Ectasia

Correction of regular Astigmatism does not increase the risk for Ectasia
The larger the diameter of ablation, the more tissue is removed

Faraj and coworkers: “An ablation diameter of 6.0 mm or greater is a risk factor”

Difficult to conclude; “diameter alone is a risk factor!!”

Increasing the ablation diameter increases the deformation of the posterior corneal surface
9-Other Risk Factors

History of Contact Lens use

- RGP contact lens wearers before LASIK need more Enhancement surgery
- Most of Keratectasia cases had no history of contact lens wearing: no direct relationship

Chronic Eye Rubbing

- May be a risk factor for development of ectasia
Prevention

Due to difficulty in management
Prevention is better than treatment

1- Corneal Topography & Orbscan

- Mandatory preop to detect FFKN, KCN
- Standardized map is more accurate than absolute scale topography
- Consider Corneal Warpage as unstable and unreliable evaluation
- Pachymetry: >20 micron decrease in midperiphery
- Abnormal Posterior Corneal Elevation (>40 microns): in KCN diagnosis
Prevention

- Pachymetry: >20 micron decrease in midperiphery
- Abnormal Posterior Corneal Elevation (>40 microns): KCN diagnosis

2- Family history

Presence of history of KCN or FFKN in family:

“May be an Alarming Sign”!
Intraoperative Preventive Measures

- Measurement of flap thickness, posterior stroma (before and after ablation)
- Reduction of flap thickness (Thin-flap LASIK)
- Change procedure to surface ablation (in borderline cases)
- Reducing optical zones as far as possible
- Change the refractive surgery plan!
- Planning enhancement procedures with suspicions and caution
Postoperative Measures for Prevention

- Advise the patient not to rub even in long term.
- Myopic regression may be due to Ectasia.
- Pre-ectasia condition must be diagnosed by topography or Orbscan.
- Topical IOP lowering medications: temporary.
- Consider myopic regression may be due to lens Nuclear Sclerotic (N.S) changes.
Treatment

 Depends on the Severity and Type of Keratectasia:

Glasses

* May be helpful in early Stages of Central type
* Patient Not complete satisfied
* May be a transient management
Treatment

Contact lenses

- **Soft Contact Lens:**
  - may temporarily improve vision
  - Can be used in those intolerated RGP

- **RGP Contact Lens:**
  - Ideal due to correction of astigmatic irregularity
  - More difficult fitting than Keratoconus patients
  - Usually patient not satisfied (previous CL-intolerant, psychological)
Treatment

Excimer Laser Customized Treatment
- Not effective, not proven
- Unpredictable, poor outcome

Intracorneal segments (ICS or ICR)
- Reduction of astigmatic irregularity and myopia
- Short term effective
- Difficulty in procedure (in comparison to KCN)
Treatment

Keratoplasty

Deep anterior lamellar keratoplasty (DLK)
- New modality
- Needs more experience
- Prolonged Visual Rehabilitation

Penetrating keratoplasty
- May need future Refractive Surgeries
- Will have its specific problems
Thank You for Your Kind Attention!!