Keratectasia After Laser in Situ Keratomileusis (LASIK)

Farid Karimian M.D
Associate Professor of Ophthalmology
Labbafinejad Medical Center

November 2006
Case Presentation

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
Thickness OD 410 µ
OS plano 20/20
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
Background

*Keratectasia is also reported after:*

* Myopic Keratomileusis
* Hyperopic ALK (62%): “Controlled Ectasia
  * Radial keratotomy
  * Hexagonal Keratotomy
  - LASIK, and…PRK (1)

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 (wks) to months after LASIK generally within 2 yrs
- Peak: 6-10 months

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

Positive History; 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
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 Stromal Thickness

- Posterior cornea is unable to withstand normal IOP
Pathophysiology...

1- PPLK as Chronic Disease

Is PPLK Similar to KCN??

- Collagenase and Gelatinase activity
- Increased IL-1 and PGN activity
- Rearrangement and altered adhesion of lamellae

These are NOT proven for PPLK but:

- Loss of Keratocytes in anterior flap and interface
- Anterior flap metabolic alterations due to Neurotrophic Keratectomy
Pathophysiology ... cont

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
**B- Corneal Strain Redistribution after LASIK**

- 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)
  \( V = \text{transverse strain} / \text{longitudinal strain} \)
D - Corneal Resistance to Fatigue

Cornea has Continuous Resistance to:

- IOP
- Deforming Forces of Eyelids
- Keep stable focusing of Light on Retina

Repeated Microtrauma e.g. Eye Rubbing

Dynamic Fatigue \rightarrow Ectasia
3- Combined process of Fatigue and Proteolysis

Static & Dynamic fatigue process of Cornea

Mechanical failure

Enzymatic Proteolysis

Subclinical 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</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>
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
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) =
  Cornial 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
Direct RST Measurement

- Is NOT accurate
- Laser ablation dehydrates stroma
- Overestimation of actual tissue removal
- Under-estimation of RST
- Anterior bowing of the posterior cornea occurs after LASIK
- For Enhancement: RST must be determined after flap removal because of:
  - Inaccurate flap thickness
  - Epithelial hyperplasia
Minimum RST to prevent Keratectasia

- Variable Thickness reported: 200-320 µ
- >18% corneal thickness ablation: increases risk

- Postop Corneal Thickness must be 55-60% preop thickness but not less than 475-500 µ

- RST safety index:
  * > 300 microns: Safe zone
  * 250-300 microns: Borderline zone
  * < 250 microns: “Danger zone”
3 - Enhancement Procedures

- Cornea tissue ablation will decrease RST

- 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
4 - Preoperative Corneal Thickness

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

(Even without ablation!!)
6- Laser Corneal Tissue Resection

- Corneal tissue removed by the excimer laser
- Inaccurate immediate post-Laser intraoperative pachymetry
- Laser resection is variable with laser type and algorithms
- Munnerlyn’s formula: resected thickness depends on diameter, ablation profile (optical zone) and diopters
7- Attempted Refractive Correction

- 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
8- Diameter of the Ablation Zone

- 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!!”

- The larger the diameter of ablation, the more tissue is removed

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

Prevention is simpler than Treatment

1- Corneal Topography & Orbscan

- Is Mandatory preop to detect FFKN and KCN
- Standardized map is more accurate than absolute scale topography

Always Consider Corneal Warpage as unstable and unreliable evaluation
Prevention

KCN diagnosis:
- Central Pachymetry Difference: >20 microns
- Decrease in midperipheral Corneal Thickness
- Abnormal Posterior Corneal Elevation (>40 microns) in Orbscan

2- Family history

Presence of history of KCN or FFKN in family: “May be an Alarming sign”!
Intraoperative Preventive Measures

- Measurement of 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
- Planning enhancement procedures with suspicions and caution
Postoperative Measures for Prevention

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

Depends on the Severity and Type of Keratectasia:

- **Glasses**
  - May be helpful in early Stages of Central type
  - Patient Not completely 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 (DALK)
- New modality
- Needs more Surgical experience
- Prolonged Visual Rehabilitation

Penetrating Keratoplasty (PKP)
- May need future Refractive Surgeries
- Will have its specific problems
Conclusion

Post-LASIK Keratectasia is a Serious Complication of LASIK

There are Multiple Risk Factors which Most of them can be Screened and Diagnosed before and Intraoperatively

Management of this condition is Difficult, Try to Prevent its Occurrence !!
THANK YOU FOR YOUR KIND ATTENTION!!

Questions...?