Comparison of Residual Stromal Bed Thickness and Flap Thickness at LASIK and Post-LASIK Enhancement in Femtosecond Laser-Created Flaps

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The authors have no financial interests to disclose.
Background

• Laser in situ keratomileusis (LASIK) is a popular surgical technique for correction of refractive errors
  – flap creation: bladed microkeratome or femtosecond laser; corneal stroma ablation: excimer laser
• LASIK complications: undercorrection and overcorrection
• Corneal flap thickness important in LASIK planning
  – too-thin flaps: flap slippage, astigmatism, buttonholes, free caps, corneal haze
  – too-thick flaps: increased risk for biomechanical corneal changes
  – determines amount of initial ablation and if enhancement can be performed later
• Enhancement after LASIK
  – re-lift original flap or create a new flap for further ablation of corneal stroma
• LASIK flap thickness (FT) affects how much residual stromal thickness (RSB) available for enhancement
• LASIK enhancement complications: corneal ectasia
• Final RSB should be at least 250um
• Predicting FT and RSB is critical when planning enhancement
• Flanagan & Binder (2003)**1:  
  – retrospective comparative case study of 6235 eyes  
  – different methods for calculating residual stromal bed thickness were compared statistically  
  – found that pre-op pachy minus post-op pachy is a good estimate of ablation depth  

• Muallem et al (2004)**2:  
  – retrospective non-comparative case study of 57 eyes evaluating changes in flap thickness after primary LASIK  
  – found that calculated flap thickness was thicker at enhancement than at primary LASIK  
  – found that there was no difference in residual stromal bed thickness measured at enhancement versus calculated from primary LASIK  

• Das and Sullivan (2006)**3:  
  – retrospective comparative case study of 46 eyes comparing change in residual stromal thickness and flap thickness between primary LASIK and enhancement  
  – found that calculated flap thickness was thicker at enhancement than at primary LASIK  
  – found that measured stromal bed at retreatment was thinner than calculated stromal bed at primary LASIK  

**all studies performed with microkeratome flap creation
Purpose and Methods

• **Purpose:** To compare the changes in calculated flap thickness and calculated and measured residual stromal bed thickness between initial LASIK and post-LASIK enhancement in myopic patients with LASIK flaps created by femtosecond laser.

• **Setting:** The 20/20 Institute in Indianapolis, Indiana, USA.

• **Methods:**
  – flap creation: Ziemer Femto LDV femtosecond laser (110um or 90um flap thickness)
  – corneal stromal ablation: Alcon Wavelight Allegretto excimer laser
  – flap thickness calculated using subtraction pachymetry formula (total cornea thickness minus stromal bed thickness)
  – Pre-op LASIK measurements: visual acuity, manifest refraction, cycloplegic refraction, in-office ultrasound pachymetry, Pentacam corneal tomography, slit-lamp exam, dilated fundus exam
  – intra-op LASIK measurements: ultrasound pachymetry before flap cut, ultrasound pachymetry of stromal bed thickness after flap cut
  – pre-op enhancement measurements: visual acuity, manifest refraction, cycloplegic refraction, in-office ultrasound pachymetry, Pentacam corneal tomography, slit-lamp exam
  – intraop enhancement measurements: ultrasound pachymetry before flap lift, ultrasound pachymetry of stromal bed thickness after enhancement
Purpose and Methods Cont’d

• Inclusion criteria:
  – ages 18-65
  – initial LASIK and enhancement requiring ablation
  – enhancement performed by re-lifting primary flap
  – initial myopic refraction

• Exclusion criteria:
  – complications during first LASIK procedure
  – enhancement not requiring ablation (flap lift only)
  – initial hyperopic refraction

• Main outcome measures:
  – comparison of calculated residual stromal bed thickness (RSB) between initial LASIK and measured RSB at time of LASIK enhancement
  – comparison of calculated flap thickness (FT) between initial LASIK and calculated FT at time of LASIK enhancement
## Results

### Table 1. Demographics

<table>
<thead>
<tr>
<th></th>
<th>Patients (35 total)</th>
<th>Eyes (37 total)</th>
<th>Mean age, years</th>
<th>Pre-op spherical equivalent, D</th>
<th>Planned flap thickness (110um or 90um)</th>
<th>Time to enhancement (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13 male (37%)</td>
<td>22 female (63%)</td>
<td>40 ± 12 (range 18 to 56)</td>
<td>-4.71 ± 2</td>
<td>31 eyes (110um)</td>
<td>16 ± 13 (range 4 to 53)</td>
</tr>
<tr>
<td></td>
<td>23 right eyes (59%)</td>
<td>14 left eyes (38%)</td>
<td></td>
<td></td>
<td>6 eyes (90um)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2.

<table>
<thead>
<tr>
<th></th>
<th>In-office pachymetry</th>
<th>Intra-operative pachymetry</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial LASIK</td>
<td>556 ± 40um</td>
<td>559 ± 36um</td>
<td>0.74</td>
</tr>
<tr>
<td>Enhancement</td>
<td>498 ± 44um</td>
<td>492 ± 43um</td>
<td>0.56</td>
</tr>
</tbody>
</table>

- No significant difference between in-office and intraoperative pachymetry (pachy)
Results Cont’d

- Formulas for calculating Residual Stromal Bed (RSB)
  - $RSB-1 = \text{pre-ablation bed} - (\text{in-office pachy} - \text{in-office enhancement pachy})$ 
  - $RSB-2 = \text{pre-ablation bed} - (\text{initial intra-op pachy} - \text{enhancement intra-op pachy})$ 
  - $RSB-3 = \text{pre-ablation bed} - \text{central ablation depth}$
  - Measured RSB = residual stromal bed measured intra-operatively with ultrasound pachymeter

<table>
<thead>
<tr>
<th>Table 3.</th>
<th>RSB-1 (calculated)</th>
<th>RSB-2 (calculated)</th>
<th>RSB-3 (calculated)</th>
<th>Measured RSB</th>
<th>P value (one-way ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>412 ± 43um</td>
<td>403 ± 44um</td>
<td>402 ± 44um</td>
<td>385 ± 46um</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

- Statistically significant differences between RSB-1, RSB-2, RSB-3, and Measured RSB.
Results Cont’d

<table>
<thead>
<tr>
<th>Table 4. Comparisons</th>
<th>P value (Tukey HSD test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSB-1 (412 ± 43um) vs measured RSB (385 ± 46um)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>RSB-2 (403 ± 44um) vs measured RSB (385 ± 46um)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>RSB-3 (402 ± 44um) vs measured RSB (385 ± 46um)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>RSB-1 (412 ± 43um) vs RSB-2 (403 ± 44um)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>RSB-1 (412 ± 43um) vs RSB-3 (402 ± 44um)</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>RSB-2 (403 ± 44um) vs RSB-3 (402 ± 44um)</td>
<td>non-significant</td>
</tr>
</tbody>
</table>

- RSB-2 and RSB-3 formulas showed no differences
- all other comparisons of formulas for calculating residual stromal bed thickness were statistically significant

RSB-1: uses evaluation pachy to estimate ablation depth; RSB-2: uses intra-op pachy to estimate ablation depth; RSB-3: uses ablation depth from laser printout
Results Cont’d

Table 5. Mean decrease in residual stromal bed thickness (±SD)

<table>
<thead>
<tr>
<th>RSB-1</th>
<th>-27 ± 17um in measured RSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSB-2</td>
<td>-18 ± 13um in measured RSB</td>
</tr>
<tr>
<td>RSB-3</td>
<td>-17 ± 17um in measured RSB</td>
</tr>
</tbody>
</table>

- Using planned ablation depth to calculate RSB (RSB-3) is not accurate.
- Measured RSB is significantly thinner than all forms of calculated RSB

Table 6. Initial LASIK Enhancement P value

<table>
<thead>
<tr>
<th>Calculated intra-operative FT (110um)</th>
<th>90 ± 9um</th>
<th>110 ± 11um</th>
<th>&lt; 0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculated intra-operative FT (90um)</td>
<td>81 ± 9um</td>
<td>99 ± 9um</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Mean increase in FT (±SD)</td>
<td></td>
<td>20 ± 10um</td>
<td></td>
</tr>
</tbody>
</table>

- Calculated FT is significantly thicker at day of enhancement

RSB-1: uses evaluation pachy to estimate ablation depth; RSB-2: uses intra-op pachy to estimate ablation depth; RSB-3: uses ablation depth from laser printout; FT=flap thickness
Discussion

• results similar to Das and Sullivan study; no major difference with femtosecond vs microkeratome flap creation; RSB is still artifactually thickened

• highlights importance of measuring RSB intra-operatively during enhancement surgery, prior to repeat ablation to ensure sufficient RSB

• be conservative about estimating RSB (choose cut-off thicker than 250um)

• Causes for artifactually thicker stromal bed calculated during initial LASIK
  – mechanical trauma of suction ring during flap creation causes increase in intraocular pressure and fluid shift into stroma
  – at enhancement, no suction or lubrication applied prior to flap re-lift, thus less likely to have stromal hydration (i.e., more accurate RSB measurement at enhancement surgery)

• Causes for thicker flaps calculated at enhancement
  – FT is calculated using measured stromal bed, so thinner actual RSB results in thicker true flap calculations
  – possible epithelial hyperplasia (could also account for treatment regression)

• Limitations of our study: small sample size, retrospective study
Future Directions

• determine the relationship between initial stromal bed thickness and accuracy of residual stromal bed thickness estimates prior to enhancement

• larger sample size to determine an accurate residual stromal bed thickness threshold to avoid corneal ectasia

• evaluate whether anterior segment OCT (AS-OCT) and high-definition ultrasound (e.g., Artemis) would yield more accurate estimates of residual stromal bed and flap thickness prior to day of enhancement surgery
References


