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

Lingo Y. Lai, MD

William G. Zeh, MD

Clark L. Springs, MD

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EUGENE AND MARILYN GLICK EYE INSTITUTE

INDIANA UNIVERSITY

School of Medicine

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

Current Literature

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

Table 2.	In-office pachymetry	Intra-operative pachymetry	P value
Initial LASIK	556 ± 40um	559 ± 36um	0.74
Enhancement	498 ± 44um	492 ± 43um	0.56

- No significant difference between in-office and intraoperative pachymetry (pachy)

Results Cont'd

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

Table 3.	RSB-1 (calculated)	RSB-2 (calculated)	RSB-3 (calculated)	Measured RSB	P value (one-way ANOVA)
	412 ± 43um	403 ± 44um	402 ± 44um	385 ± 46um	**< 0.0001**

- Statistically significant differences between RSB-1, RSB-2, RSB-3, and Measured RSB.

Results Cont'd

Table 4. Comparisons	P value (Tukey HSD test)
RSB-1 (412 ± 43um) vs **measured RSB** (385 ± 46um)	**< 0.01**
RSB-2 (403 ± 44um) vs **measured RSB** (385 ± 46um)	**< 0.01**
RSB-3 (402 ± 44um) vs **measured RSB** (385 ± 46um)	**< 0.01**
RSB-1 (412 ± 43um) vs **RSB-2** (403 ± 44um)	**< 0.01**
RSB-1 (412 ± 43um) vs **RSB-3** (402 ± 44um)	**< 0.01**
RSB-2 (403 ± 44um) vs **RSB-3** (402 ± 44um)	**non-significant**

- 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)
RSB-1	-27 ± 17um in measured RSB
RSB-2	-18 ± 13um in measured RSB
RSB-3	-17 ± 17um in measured RSB

- 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
Calculated intra-operative FT (110um)	90 ± 9um	110 ± 11um	**< 0.001**
Calculated intra-operative FT (90um)	81 ± 9um	99 ± 9um	**< 0.01**
Mean increase in FT (±SD)	20 ± 10um		

- 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

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