Re-treatment in LASIK: To Flap Lift or Perform Surface Ablation

Colin Chan, MBBS, FRANZCO; Michael Lawless, MBBS, FRANZCO, FRACS; Gerard Sutton, MBBS, MD, FRANZCO; Chris Hodge, BAppSc, PhD

ABSTRACT

PURPOSE: To review safety and efficacy outcomes following re-treatment for residual refractive errors in eyes with prior laser in situ keratomileusis (LASIK) and determine the most appropriate course of action for patients.

METHODS: A review of all patients undergoing LASIK enhancement at a single refractive surgery center between 2012 and 2017 was undertaken. Refraction and biomicroscopy results before and after enhancement were collated and analyzed according to the method of enhancement (flap lift or surface ablation).

RESULTS: A total of 108 eyes were included in the analysis; 58 eyes underwent flap lift and 50 underwent surface ablation re-treatment with mean times to enhancement of 22.3 and 53.2 months, respectively. The mean spherical equivalent prior to enhancement was -0.43 ± 0.69 and -1.03 ± 1.01 diopters (D) for the flap lift and surface ablation groups, respectively. The absolute difference from intended refraction was statistically significant (lift 0.16 ± 0.24 versus surface ablation 0.31 ± 0.35 D; P = .01). The difference was more pronounced for eyes with prior hyperopia (P = .041). The incidence of haze following re-treatment was 3.4% in the flap lift group versus 10.0% in the surface ablation group, and 8.6% of the flap lift group had evidence of epithelial ingrowth, with 1 eye requiring washout. There was no correlation between time to enhancement, refraction, and incidence of complications following the enhancement procedure.

CONCLUSIONS: There has been a trend toward treating residual LASIK refractive error through surface ablation. This review suggests that flap lift may result in a more accurate refractive outcome, albeit with an expected greater risk of epithelial ingrowth.

study, we retrospectively analyzed a large cohort of patients proceeding to enhancement surgery to compare the efficacy of technique and identify potential risk factors for reduced performance.

**PATIENTS AND METHODS**

This study represents a retrospective review of all patients who underwent a refractive laser enhancement procedure between 2012 and 2017 at a single private laser refractive surgery center in Sydney, Australia. The procedures were performed by three physicians (CC, GS, and ML). Patients receiving an enhancement procedure following the original LASIK procedure were identified for further analysis. Enhancement procedures were completed by one of two techniques: lifting the original LASIK flap or surface ablation (photorefractive keratectomy) over the flap with the addition of mitomycin C to minimize the risk of haze formation.

Institutional review confirmed the study as low or negligible risk and was exempt from full Human Research Ethics Committee review. All patient information was collected retrospectively and de-identified prior to analysis. The study adhered to the tenets of the Declaration of Helsinki.

The standard criterion for an enhancement procedure was a stable refraction with no documented change for 3 months. Minimum residual refractive sphere or cylinder was 0.50 diopters (D) and/or a minimum of two lines of improvement in uncorrected distance visual acuity (UDVA) with refraction. Patients seeking increased independence for near work due to progressive presbyopia underwent a contact lens trial prior to surgery to define the appropriate refractive end-point.

The examination before enhancement included manifest refraction, UDVA and CDVA, slit-lamp biomicroscopy, corneal topography and tomography assessment, corneal aberration, and puff tonometry. Standard follow-up was at 1 day, 3 weeks, and 3 months. Patients were then discharged to referring clinicians and seen as required. Manifest refraction, visual acuity, and slit-lamp biomicroscopy were performed at each postoperative visit.

Primary laser procedures were performed with one of several excimer lasers, including the Summit Apex Laser (Alcon Laboratories, Inc., Fort Worth, TX), Alcon LADARWave and WaveLight Allegretto (Alcon Laboratories, Inc., Fort Worth, TX), or Schwind Amaris (SCHWIND eye-tech-solutions, Kleinostheim, Germany). LASIK flaps were created with a manual microkeratome (SKBM; Alcon Laboratories, Inc.) or femtosecond laser (IntraLase iFS; Abbott Medical Optics, Inc., Santa Ana, CA).

Surgeon preference determined the type of enhancement procedure, although exclusion criteria for flap lift were epithelial surface irregularity or insufficient residual stromal bed. All patients with preexisting ocular surface disease were treated prior to the enhancement procedure. Although corneal thickness did influence the decision to perform surface ablation, ocular surface disease did not.

Data were collated and transferred to SPSS software (version 25.0; IBM Corporation, Armonk, NY) for analysis. Normality of data samples was evaluated by the Kolmogorov–Smirnov test. When normal conditions were assumed, a paired Student’s t test was used to compare data before and after enhancement. If standard parametric analysis was not available, the Wilcoxon rank-sum and Mann–Whitney tests were applied in place of paired t tests. The independent t test was used to compare enhancement procedures (eg, flap lift versus surface ablation). Multiple logistic regression analysis was performed in an attempt to determine predictors of final refractive outcomes. A P value of .05 was considered statistically significant.

**RESULTS**

A total of 169 eyes of 4,628 patients underwent a laser enhancement procedure following either LASIK, photorefractive keratectomy, or SMILE surgeries. Of the enhancement cohort, 108 eyes had previously undergone LASIK surgery. The mean age of patients who had prior LASIK at the time of enhancement was 39.0 ± 11.0 years (range: 19 to 73 years). The mean time to enhancement was 27.4 ± 41.7 months (range: 4 to 196 months).

**Refractive and Vision**

Refractive and visual outcomes are shown in Figures A-B (available in the online version of this article). The mean spherical equivalent was -2.53 ± 3.20 D (range: -10.25 to 4.88 D) prior to the initial surgery and -0.71 ± 0.90 D (range: -3.50 to 1.75 D) prior to enhancement. The breakdown of the broader LASIK cohort is listed in Table 1.

Of the 108 LASIK procedures that had further enhancement, 58 eyes were treated by relifting the existing flap and 50 eyes were treated by surface ablation and mitomycin C. The refraction data for the separate groups are listed in Table 2. The mean absolute difference from intended spherical equivalent refraction for the flap lift and surface ablation groups was 0.16 ± 0.24 D (range: 0.00 to 1.38 D) and 0.32 ± 0.35 D (range: 0.00 to 1.50 D), respectively, which represented a statistically significant difference (P = .008).

A further breakdown by preoperative refractive error was undertaken (Table 3). Patients undergoing surface
Ablation had significantly greater residual myopia prior to surgery, but refractive cylinder levels were equivalent. There was no statistical difference in previously hyperopic patients prior to enhancement surgery. Previously myopic patients achieved a mean absolute difference from a target of 0.13 ± 0.18 and 0.27 ± 0.33 D for the flap lift and surface ablation groups, respectively (P = .035). Similarly, for patients with previous hyperopia, the mean absolute difference from intended spherical equivalent target was 0.14 ± 0.21 and 0.59 ± 0.46 D for the flap lift and surface ablation groups, respectively (P = .041). A total of 91.5% of the flap lift group obtained UDVA of 20/20 or better following surgery compared to 72.5% of the surface ablation group (Figure 1).

**SAFETY**

All flaps were lifted without incident. There were no intraoperative complications for either group.

Trace or mild haze was seen in 3.4% of the flap lift group at 3 weeks postoperatively. Epithelial cells under the LASIK flap were seen in 8.6% of eyes in the same group (1 flap had previously been created with the manual microkeratome and 4 created with the femtosecond laser). No patient lost visual acuity, but one eye required postoperative washout for epithelial ingrowth and 10% of the surface ablation group experienced mild haze following surgery, which resolved by 2 months in all cases. There was no significant correlation between the time to enhancement or level of spherical equivalent before enhancement and the presence of haze or epithelial ingrowth.

One eye (2%) in the surface ablation group lost two lines of CDVA (from 20/15 to 20/25) following the enhancement procedure but returned to 20/20 at 12 months. A total of 25.9% of the flap lift group and 20% of the surface ablation group gained one or more lines.

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**TABLE 1**

Refractive Parameters of LASIK Surgery Patients

<table>
<thead>
<tr>
<th>Original Refractive Error</th>
<th>Myopia (n = 77)</th>
<th>Hyperopia (n = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sphere (D)</td>
<td>Cylinder (D)</td>
</tr>
<tr>
<td>Preoperative</td>
<td>-3.70 ± 2.16</td>
<td>-0.88 ± 0.93</td>
</tr>
<tr>
<td>Before enhancement</td>
<td>-0.60 ± 0.77</td>
<td>-0.62 ± 0.54</td>
</tr>
<tr>
<td>After enhancement</td>
<td>0.07 ± 0.46</td>
<td>-0.17 ± 0.21</td>
</tr>
</tbody>
</table>

LASIK = laser in situ keratomileusis; D = diopters; SE = spherical equivalent

*Values are presented as mean ± standard deviation.

**TABLE 2**

Refractive Breakdown for LASIK Flap Lift and Surface Ablation Re-treatment Groups

<table>
<thead>
<tr>
<th>Original Refractive Error</th>
<th>Flap Lift (n = 58)</th>
<th>Surface Ablation (n = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sphere (D)</td>
<td>Cylinder (D)</td>
</tr>
<tr>
<td>Preoperative</td>
<td>-1.78 ± 3.11</td>
<td>-0.75 ± 0.93</td>
</tr>
<tr>
<td>Before enhancement</td>
<td>-0.09 ± 0.70</td>
<td>-0.68 ± 0.61</td>
</tr>
<tr>
<td>After enhancement</td>
<td>-0.16 ± 0.60</td>
<td>-0.17 ± 0.20</td>
</tr>
</tbody>
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LASIK = laser in situ keratomileusis; D = diopters; SE = spherical equivalent

*Values are presented as mean ± standard deviation.

**TABLE 3**

Refractive Breakdown for LASIK Flap Lift and Surface Ablation Re-treatment Groups

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</thead>
<tbody>
<tr>
<td></td>
<td>Flap Lift</td>
<td>Surface Ablation</td>
</tr>
<tr>
<td>Before enhancement sphere</td>
<td>-0.26 ± 0.53</td>
<td>-0.91 ± 0.83b</td>
</tr>
<tr>
<td>Before enhancement cylinder</td>
<td>-0.66 ± 0.67</td>
<td>-0.59 ± 0.38</td>
</tr>
<tr>
<td>Before enhancement SE (D)</td>
<td>-0.59 ± 0.51</td>
<td>-1.20 ± 0.78b</td>
</tr>
</tbody>
</table>

LASIK = laser in situ keratomileusis; D = diopters; SE = spherical equivalent

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P < .001.
of CDVA postoperatively. This was not significantly different between groups (Figure 2).

There were no recorded cases of corneal ectasia following any re-treatment procedure at the time of final review (mean follow-up: 7.18 months; range: 1 to 72 months).

**Multivariate Analysis**

The time to enhancement represented the most significant contributing factor to the final mean absolute difference in the flap lift group (adjusted $r^2 = 0.239$). The refractive cylinder before enhancement represented the single significant contributing factor to postoperative mean absolute difference in the surface ablation group (adjusted $r^2 = 0.271$). The initial spherical equivalent represented a significant factor to the final spherical equivalent outcome for both previously myopic and hyperopic eyes (adjusted $r^2 = 0.329$ and 0.419, respectively), but spherical equivalent refraction before enhancement was also significant within the hyperopic group (adjusted $r^2 = 0.408$).

**Discussion**

The positive outcomes of laser refractive procedures significantly outweigh the negative association with regression, thereby presenting one of the most consistent, successful surgical procedures available. Despite technological advances, increasing experience, and surgical technique refinement, regression remains a consideration for refractive surgeons. Risk factors for regression include preoperative refractive error, age, and the presence of intraoperative and postoperative surgical complications. Although enhancement rates within the literature have been reported to be as high as 29.4%, an overall re-treatment rate of 2.55%, found in a significant prospective clinical audit of LASIK outcomes, represents a more reasonable representation of the refractive success of laser surgery.

The mechanism of regression is not well understood. Multiple researchers have identified epithelial hyperplasia as the potential cause of regression. However, because epithelial changes remain relatively consistent following LASIK, this suggests that the interplay between additional factors includes, but is not limited to, forward shift of anterior and posterior corneal surfaces. A combination of these variables may affect the refractive outcomes following re-treatment. We found that lifting the LASIK flap achieved outcomes significantly closer to the desired refractive target and with less variation compared to the patients undergoing surface ablation over the existing flap. This was exaggerated in patients with hyperopic residual error undergoing surface re-treatment. This makes sense if epithelial hyperplasia is considered as a primary factor in postoperative refractive variation.

Frings et al. suggested peripheral epithelial proliferation in combination with an increase in corneal aberrations may contribute to the higher level of enhancements in hyperopic patients who have LASIK, although whether this makes a further impact on enhancement outcomes is difficult to conclude without additional information. The level of refractive astigmatism was similar in both groups. Although the difference in outcomes may not represent a clinically significant impact, this remains at odds with the existing literature, which suggests equivalence. Ortega-Usobiaga et al. found no difference in visual outcomes in a study incorporating 5,468 enhancement procedures, whereas Schallhorn et al. found both techniques equally effective and predictable in a cohort of 290 patients. Because LASIK epithelial changes tend to settle faster than those of surface ablation, consideration of enhancement outcomes at a longer timeframe following the procedure may provide more equivalent outcomes, although this in itself suggests a relative disadvantage in choosing the surface tech-
nique over flap lift. Of note, the percentage of patients achieving UDVA of 20/20 or better was increased in our flap lift group, which may also reflect better overall quality of vision in this cohort.

In multivariate analysis, we found the most significant contributing factor to final refractive outcome in the flap lift cohort was time to enhancement. Although time to flap lift enhancement has been considered as an increased risk factor for epithelial ingrowth, the impact on refractive outcomes has not been considered previously. Of note, the majority of longer-term flap lift procedures occurred in LASIK flaps created by manual microkeratomes rather than femtosecond laser procedures. Our results may reflect the consistency of the LASIK flap and/or difficulty in lifting the flap, although no lift procedure led to flap complications, suggesting the former may represent a more dominant contributing risk factor. Of note, despite the significantly greater residual myopia in the surface ablation group, the most significant factor contributing to decreased refractive outcome in patients who had surface re-treatment was refractive cylinder before enhancement. This may again reflect the relative inconsistencies of epithelial remodeling following surgery.

In terms of initial refraction, the preoperative level of both myopia and hyperopia appears to affect the success of the enhancement procedure regardless of technique. Additionally, the degree of residual hyperopia represents a factor in final refractive outcome. These findings may reflect the broader impact of biomechanical forces following surgery. That our outcomes suggest poorer performance in previously hyperopic patients, particularly in higher errors, indicates that patients must be counseled appropriately prior to further surgery as to potential outcomes.

The creation of the LASIK flap induces corneal nerve damage, which remains a variable in wound healing. Neira-Zalentein et al. suggested this may be exaggerated following surface ablation re-treatment in eyes with prior LASIK, leading to the increased appearance of corneal haze. In accordance with the literature, we found an increased incidence of corneal haze following surface re-treatment compared to primary procedures, although all cases resolved within several months without further intervention or loss of corrected visual acuity. Epithelial ingrowth was present in 8.6% of cases. This was equivalent with previous literature, which indicates an incidence between 2.3% and 22% across LASIK enhancement cohort studies. The use of a microkeratome to cut the initial LASIK flap has been proposed as a risk factor for increased epithelial ingrowth against flaps generated by femtosecond laser due to differences in flap edge geometry and adhesion, but we found no correlation between method, time to enhancement, or preoperative refractive error. This suggests that, in the absence of existing corneal scarring or abnormalities, intraoperative surgeon technique may be key to avoiding flap edge or epithelial defects likely to lead to ingrowth.

Enhancement following original LASIK surgery generally represents a safe and accurate procedure. Patients with previous hyperopia and patients with residual astigmatism, particularly in cases requiring surface ablation, may not be as successful compared to flap lift techniques. Patient counseling is key to optimizing both objective clinical and subjective perceived benefits of enhancement surgery.

**AUTHOR CONTRIBUTIONS**

Study concept and design (CC, ML, GS, CH); data collection (CH); analysis and interpretation of data (CC, ML, GS, CH); writing the manuscript (CC, ML, GS, CH); critical revision of the manuscript (CC, ML, GS, CH); statistical expertise (CH); supervision (CC, ML, GS, CH)

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Figure A. Refractive outcomes in the prior myopia group. UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; D = diopters.
Figure B. Refractive outcomes in the prior hyperopia group. UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; D = diopters.