

Effect of Hinge Position on Corneal Sensation and Dry Eye Parameters After Femtosecond Laser-assisted LASIK

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ABSTRACT

PURPOSE: To evaluate the effect of superior- versus nasal-hinged flaps on corneal sensation and dry eye after femtosecond laser-assisted LASIK.

METHODS: A total of 43 patients who had undergone bilateral femtosecond laser-assisted LASIK for myopia were evaluated in a prospective, nonrandomized, contralateral eye study to compare the difference between different hinges on corneal sensation and dry eye. Corneal esthesiometry, Schirmer basic tear secretion test (BST), tear break-up time (BUT), ocular surface stainings, and the Ocular Surface Disease Index (OSDI) questionnaires were used to evaluate corneal sensation and dry eye parameters preoperatively as well as at 1 week and 1, 3, and 6 months postoperatively.

RESULTS: Corneal sensation decreased significantly in both groups 1 week after surgery ($P < .05$ in the nasal hinge group; $P < .01$ in the superior hinge group) and gradually recovered over the first 3 months. No significant change was noted in BUT after surgery in either group ($P > .05$). Significant increases were noted in BST values at 1 and 3 months ($P < .05$) and 6 months ($P < .01$) postoperatively in both groups. Corneal fluorescein staining increased significantly in both groups at 1 week ($P < .01$) and returned to baseline by 6 months. Conjunctival Rose Bengal staining decreased significantly by 6 months in the superior hinge group only ($P < .05$). The OSDI significantly increased 1 week after surgery ($P < .01$) and did not completely return to baseline by 6 months postoperatively in either group ($P < .05$). No significant differences were noted in any of the parameters between groups at any time point ($P > .05$).

CONCLUSIONS: Hinge position had no significant effect on corneal sensation or dry eye parameters. Aggressive dry eye regimens are needed for patients with preoperative dry eye. (*J Refract Surg.* 2012;28(8):625-631. doi:10.3928/1081597X-20120815-07

Laser in situ keratomileusis (LASIK) is the most commonly performed refractive surgical procedure¹ and the first choice for the correction of refractive errors in the majority of patients. However, patients who have received LASIK often present with dry eye symptoms postoperatively.² Multiple factors have been implicated in this problem, including damage to the limbal goblet cells due to suction ring pressure, altered tear-film distribution and stability due to altered corneal curvature, inflammation, effects of medications, and neurotrophic epitheliopathy.^{3,4} Laser in situ keratomileusis-induced neurotrophic epitheliopathy describes the neurotrophic component of LASIK dry eye as a result of corneal denervation from transection of corneal nerves during flap formation and stromal ablation.⁵⁻⁸

It was previously believed that the corneal nerves predominantly enter the cornea at the 3- and 9-o'clock positions. However, Muller et al⁹ performed histopathologic analysis in human corneas that showed conclusively no larger nerve trunks were present at 3 and 9 o'clock in the human cornea. Other studies⁷⁻⁹ also confirmed the equal distribution of nerve trunks around the circumference of the cornea. Thus, creating a LASIK flap with a nasal or temporal hinge provides a potential channel for corneal nerves, but may not help to preserve corneal innervation. Although previous studies on the side effects of microkeratome-assisted LASIK have found that loss of corneal sensation and presence of dry eye syndromes were less common in eyes with a nasal-hinged flap than in eyes with a superior-hinged flap,^{10,11} other studies did not report such findings.^{12,13}

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TABLE
Preoperative and Surgical Parameters

| Parameter | Hinge Position | | P Value* |
|--------------------------------|----------------|--------------|----------|
| | Superior | Nasal | |
| Preoperative SE (D) | -7.82±3.34 | -8.24±2.90 | .26 |
| Astigmatism (D) | 0.98±0.82 | 1.01±1.11 | .38 |
| Mean keratometry (D) | 42.63±4.35 | 42.71±3.73 | .46 |
| Calculated ablation depth (μm) | 103.90±30.69 | 107.46±23.82 | .23 |
| Suction time (s) | 33.11±7.51 | 33.25±7.40 | .38 |

SE = spherical equivalent refraction

*Paired two-tailed Student *t* test.

the central cornea, as well as into superior, inferior, nasal, and temporal quadrants as recommended by the National Eye Institute Industry Workshop.¹⁸

SCHIRMER BASIC SECRETION TEST

After instilling one drop of proparacaine 0.5% in each eye and drying the fornix, a sterile standardized Schirmer tear test strip (Alcon Laboratories Inc) was placed at the junction of the lateral and middle third of the inferior fornix. The length of the wet portion of the strip was measured at 5 minutes and recorded in millimeters.

SUBJECTIVE DRY EYE SYMPTOMS

Subjective symptoms were evaluated using the OSDI questionnaire, which is a reliable and validated 12-item questionnaire used to assess subjective symptoms of ocular surface diseases and their impact on visual function.¹⁹

STATISTICAL ANALYSIS

Comparisons of dry eye outcome variables between different hinge positions as well as pre- and postoperative within-eye comparisons were performed using paired Student *t* tests. Data are presented as mean±standard deviation.

RESULTS

The study population comprised 10 men and 33 women with a mean age of 29.8 years (range: 22 to 43 years). All patients (88 eyes) completed 6-month follow-up. Mean preoperative spherical equivalent refraction in the superior hinge group was -7.82±3.34 D (range: -1.00 to -16.75 D) and -8.24±2.90 D (range: -3.25 to -16.25 D) in the nasal hinge group. No significant differences were noted in mean spherical equivalent refraction, astigmatism, keratometry readings, calculated ablation depth, and suction time between the ferro-

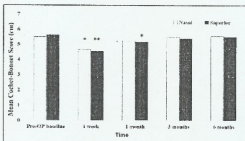


Figure 1. Central Corneal Sensation (mm) measured mean corneal sensation associated with nasal- and superior-hinged flaps. **P* < .05 and ***P* < .01 when compared with preoperative baseline within group.

second laser-created nasal hinge and superior hinge groups (Table).

Mean preoperative corneal sensation was 5.46±0.84 mm (out of 6.0 mm) in the nasal hinge group and 5.59±0.76 mm in the superior hinge group. Corneal sensation decreased significantly 1 week postoperatively in both groups (4.63±1.60 mm in the nasal hinge group [*P* < .05] and 4.52±1.53 mm in the superior hinge group [*P* < .01]) and at 1 month postoperatively in the superior hinge group (5.15±1.16 mm, *P* < .05) relative to preoperative measurements (Fig 1). Gradual recovery of corneal sensation to baseline levels was observed over time in both groups. Mean corneal sensation returned to baseline by 1 month (5.22±1.06 mm) in the nasal hinge group and by 3 months postoperatively (5.36±1.02 mm) in the superior hinge group. However, there was no difference in corneal sensation between the superior hinge group and nasal hinge group at any time point. Tear BUT decreased insignificantly at 1 week (nasal: 7.10±4.13 seconds; superior: 6.94±2.82 seconds) and at 1 month

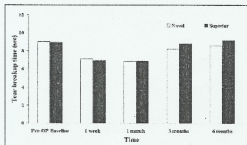


Figure 2. Tear break-up time in patients with nasal- and superior-hinged flaps.

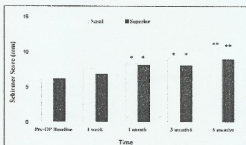


Figure 3. Schirmer test values in patients with nasal- and superior-hinged flaps. * $P < .05$ and ** $P < .01$ when compared with preoperative baseline within group.

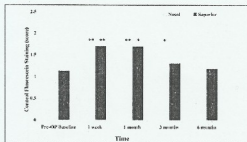


Figure 4. Corneal fluorescein staining in patients with nasal- and superior-hinged flaps. * $P < .05$ and ** $P < .01$ when compared with preoperative baseline within group.

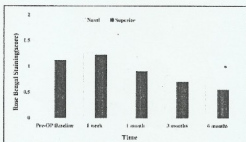


Figure 5. Rose Bengal staining values in patients with nasal- and superior-hinged flaps. * $P < .05$ when compared with preoperative baseline within group.

postoperatively (nasal: 6.85 ± 4.03 seconds; superior: 6.88 ± 3.66 seconds), but recovered by 3 months (nasal: 8.24 ± 4.95 seconds; superior: 8.82 ± 4.65 seconds) after surgery in both groups. Comparisons of postoperative values between groups and with baseline values (nasal: 9.02 ± 8.76 seconds; superior: 8.91 ± 8.07 seconds) were not statistically significant at any time point (Fig 2).

Mean preoperative BST values were 6.00 ± 3.88 mm in the nasal hinge group and 6.13 ± 5.29 mm in the superior hinge group. Because of the preoperative dry eye conditions in the patients enrolled in the study, punctal plug occlusions were performed immediately after surgery in all patients. Mean BST values increased gradually throughout postoperative follow-up and were significantly higher than baseline values 1 month after surgery (nasal: 8.22 ± 6.60 mm; superior: 8.11 ± 6.18 mm) and at 3 and 6 months postoperatively in both hinge groups. There were no differences in mean BST values between groups at any follow-up (Fig 3). The degree of corneal fluorescein staining increased significantly in both the nasal and superior hinge groups at 1 week and

1 month after surgery. In the nasal hinge group, the increase remained significant at 3 months postoperatively, whereas in the superior hinge group, no significant difference was noted between the degree of corneal fluorescein staining at 3 months postoperatively and degree of staining at baseline. A gradual trend towards recovery was noted in both groups, and no significant difference was noted between the hinge groups at any time point (Fig 4).

The degree of conjunctival Rose Bengal staining 1 week after surgery did not differ significantly from baseline scores in either group. From that point on, a gradual decrease occurred in mean scores in both groups, and at 6 months after surgery, mean staining scores in the superior hinge group were significantly lower than those at baseline (0.55 ± 0.62 , $P < .05$). There were no significant differences in mean staining scores between the groups at any time point (Fig 5).

Subjective dry eye symptoms were scored by the OSDI questionnaire (0 to 12 = normal eye, 13 to 22 = mild dry eye, 23 to 32 = moderate dry eye, 33 to 100 =

severe dry eye disease). The preoperative mean OSDI score was 14.0 in both hinge groups. The mean scores were significantly higher in both groups at 1 week (25.0; $P<.01$) after surgery and remained significantly elevated at 1 month (21.0; $P<.05$), 3 months (19.0; $P<.05$), and 6 months (19.0; $P<.05$) postoperatively despite showing a trend in reduction towards baseline values (Fig 6). No significant differences were observed in any of the subjective and objective parameters tested between eyes that received nasal-hinged flaps and eyes that received superior-hinged flaps at any time point.

DISCUSSION

Dry eye symptoms is the most common complaint after LASIK surgery, with an incidence rate ranging from 0.25% to 59%,²⁰⁻²² depending on how these symptoms are defined and evaluated and presence or absence of dry eye symptoms preoperatively. Postoperative LASIK dry eye symptoms are usually temporary and begin to recover within 3 months; however, prolonged cases of up to 18 months have been reported.²³ In our study, subjective dry eye symptoms as measured by OSDI were mild (mean OSDI=14) in both hinge groups preoperatively. The mean OSDI peaked at 1 week postoperatively (25.0) and decreased by 1 month postoperatively, although at 6 months postoperatively the scores remained significantly elevated relative to preoperative baseline values. This result differs from that reported by Mian et al,¹⁸ who showed that dry eye symptoms normalized within the first 3 months after surgery. All of our patients had mean preoperative spherical equivalent refraction in the high myopic range and had more severe mean preoperative dry eye symptoms (mean OSDI=14). Studies have shown that preexisting dry eye and high myopia are risk factors for severe postoperative dry eye²⁴; therefore, those preoperative conditions in our patients most likely played an important role in the persistence of dry eye symptoms postoperatively.

One of the major postulated mechanisms for the development of dry eye after LASIK is the decreased corneal sensation and blink reflex due to amputation of corneal afferent nerves during flap creation and stromal ablation.³ Patients included in our study had a significantly higher mean preoperative spherical equivalent refraction correction than patients in previous studies with femtosecond laser-assisted LASIK. Thus, we expected that our patients would have more severe dry eye symptoms than patients in related studies because they required greater ablation depths due to high degree of preoperative myopia. However, we found that recovery of mean central corneal sensation was faster in our patients than in the patients reported

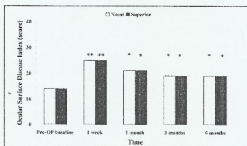


Figure 6. Ocular Surface Disease Index (scores) values in patients with nasal- and superior-hinged flaps. * $P<.05$ and ** $P<.01$ when compared with preoperative baseline within group.

by Mian et al.¹⁸ This may be partly attributed to the shorter suction time required with the 60-kHz model used in our study. Moreover, we found that our patients who received LASIK for high myopia had ongoing dry eye symptoms despite improved clinical signs of tear insufficiency and hypoesthesia, a finding that is consistent with that reported by Tuisku et al.²⁵

In our study, the BST values increased at 1 week postoperatively and became significantly higher than at baseline at 1-, 3-, and 6-month follow-up. This is probably because of the fact that punctal plug occlusions were performed in all eyes of patients enrolled in the study. The degree of corneal fluorescein staining was significantly greater than at baseline at 1 week postoperatively in both hinge groups but gradually returned to baseline 3 and 6 months after surgery. Likewise, the degree of conjunctival Rose Bengal staining increased, although not significantly, at 1-week follow-up and returned to baseline 1 month after surgery. Further reduction in conjunctival staining was noted at 3 and 6 months postoperatively. Tear BUT decreased insignificantly at 1 week postoperatively and returned to baseline by 3-month follow-up. These results are consistent with the gradual improvement of corneal sensation and increased basic tear secretion postoperatively. Therefore, postoperative punctal plug occlusions should be considered for patients who present with dry eye symptoms before LASIK.

In terms of dry eye parameters and corneal sensitivity, the results from previous studies on LASIK with a microkeratome that attempted to spare horizontally oriented corneal stromal nerves during flap preparation via making a nasal-hinged flap versus making a superior-hinged flap were inconsistent. Donnenfeld et al¹⁰ and Vroman et al²¹ reported less corneal sensitivity loss and a lower incidence of dry eye syndrome in na-

sal-hinged eyes and Lee and Joo¹¹ reported greater tear BUT and Schirmer test values in nasal-hinged eyes than in superior-hinged eyes. However, Ghoreishi et al¹² reported no differences between nasal and superior hinge flap methods in regards to signs and symptoms of dry eye after LASIK with a microkeratome. Kumano et al¹³ noted a significantly greater decrease in corneal sensitivity in patients who underwent nasal-hinged LASIK than in patients who received a superior hinge.

More recent studies have compared the effects of varying hinge positions on dry eye parameters after LASIK with a femtosecond laser. Mian et al^{15,16} compared temporal and superior hinge positions and noted no difference between the two hinge positions in corneal sensation and dry eye symptoms at any time point. In this study, we compared pre- and post-operative within-eye parameters to see whether any differences occurred in dry eye symptoms and signs between nasal- and superior-hinge flaps in patients receiving LASIK with a femtosecond laser. We found that hinge position did not have a significant effect on central corneal sensation and dry eye parameters at any time point postoperatively, a finding that suggests variation of flap hinge positions does not affect corneal innervations when performing femtosecond laser-assisted LASIK. This is consistent with the more recent human studies with in vivo confocal microscopy and Heidelberg Retinal Tomograph (HRT II; Heidelberg Engineering, Carlsbad, California) that suggest an alternative model of corneal innervation. In those studies, subbasal nerves appeared to be radially organized along the circumference and equal numbers of nerves appeared to penetrate the stroma in all quadrants.^{8-9,26,27}

In addition to hinge position, factors such as hinge width, flap diameter, and flap depth may play important roles in the health of the corneal surface. The effect of hinge width seems to have an effect on dry eye parameters. Donnenfeld et al¹⁰ showed that the loss of corneal sensation and presence of dry eye syndrome were greater in eyes with a narrow hinge (0.6 mm) flap than in eyes with a wider hinge (1.2 mm) flap. We speculate that prior studies of nasal versus superior flap sensation differences were likely confounded by differences in flap diameters between the patients with nasal and superior hinges. However, further study is needed to establish the correlation. A recent study by Mian et al¹⁵ noted that hinge angle (45° vs 90° hinge angles) and flap thickness (100 vs 130 µm) have no effect on corneal sensation or dry eye syndrome. Therefore, other factors such as damage to conjunctival goblet cells⁸ may be important contributing factors to the multifactorial nature of LASIK-induced dry eye.

In summary, femtosecond laser-assisted LASIK reduced corneal sensitivity and led to increased corneal staining postoperatively, although these parameters returned to baseline values within 6 months. We found that the subjective OSDI values increased after surgery and did not improve by 6 months postoperatively. Thus, for patients with high myopia and preoperative symptoms of dry eye, more aggressive postoperative dry eye regimens may be needed. In addition, we found that differences in hinge position in femtosecond laser-assisted LASIK had no significant effect on central corneal sensation and dry eye parameters; therefore, we suggest that selection of hinge position can be made according to the surgeon's preference. However, the low number of patients as well as the lack of flap thickness measurements are the limiting factors in our study. Therefore, future large scale study is mandatory and further evaluation of corneal nerve organization and regrowth patterns may help us understand how to minimize dry eye after LASIK.

AUTHOR CONTRIBUTIONS

Study concept and design (C.C.S., C.K.C.); data collection (Y.F.L.); analysis and interpretation of data (J.C.G.H., D.H.K.M.); drafting of the manuscript (J.C.G.H., C.C.S., Y.F.L.); critical revision of the manuscript (C.C.S., C.K.C., D.H.K.M.); statistical expertise (J.C.G.H., Y.F.L.); administrative, technical, or material support (C.C.S., D.H.K.M.)

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