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Incidence, management, and visual outcomes of buttonholed laser in situ keratomileusis flaps

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PURPOSE: To describe the incidence, management, and visual outcomes of buttonholed laser in situ keratomileusis (LASIK) flaps.

SETTING: Private practice, Riyadh, Saudi Arabia.

METHODS: This retrospective review identified eyes that developed buttonholed flaps during LASIK. Preoperative, intraoperative, and postoperative data were obtained to identify factors predictive of this complication.

RESULTS: Of 4250 primary LASIK procedures, 17 eyes (0.4%) with buttonholed flaps were identified. Buttonholes occurred with the Hansatome microkeratome in 64.7% of eyes and with the Moria microkeratome in 35.3% of eyes, the incidence of buttonholed flaps was 0.62% and 0.19%, respectively ($P = .03$). Laser ablation was performed at the same time as buttonhole formation in 8 eyes (47.1%) and was aborted in the other eyes. Retreatment was performed in 10 eyes (58.8%); of retreated eyes, 6 had repeat LASIK and 3 had surface ablation. The final spherical equivalent refraction was -0.38 diopter $\pm$ 0.79 (SD). Two eyes had a final loss of more than 2 lines of best corrected visual acuity (BCVA). The mean loss of BCVA lines was 0.72 in eyes that had complete LASIK, 0.62 in eyes that had aborted LASIK followed by retreatment with repeat LASIK, and 0.80 in eyes that had aborted LASIK followed by retreatment with surface ablation.

CONCLUSIONS: Buttonholed flaps occurred more frequently in the second of 2 consecutively treated eyes. Microkeratomes that produce a larger diameter flap were more likely to produce flap buttonholes. The least loss of BCVA was achieved when LASIK was aborted and then repeated after refractive stability.

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Some surgeons suggest that laser in situ keratomileusis (LASIK) is the procedure of choice for virtually all myopia and astigmatism as well as for low to moderate hyperopia.[1,2] Its advantages include fast, painless recovery of vision and a low incidence of subepithelial haze. However, LASIK exposes the eye to the risks associated with creating a corneal flap with a microkeratome. Poor keratectomy during LASIK may cause the most worrisome complications facing refractive surgeons. These complications include the creation of buttonholes; free caps; and thin, incomplete, or irregular flaps. In extreme cases, laceration of the cornea can result in damage to the iris and the lens.[3]

A buttonholed or a doughnut-shaped LASIK flap, which has been reported in 0.04% to 2.60% of cases, is one of the most serious flap abnormalities.[4–10] Although most flap complications, such as free caps and incomplete flaps, usually do not cause long-term loss of vision, buttonhole formation is the flap complication most likely to result in glare and substantial loss of best corrected visual acuity (BCVA).[7,11] The management of a buttonholed flap represents a therapeutic dilemma because subepithelial stromal scars may form in the visual axis and induce irregular astigmatism.[7] In

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addition, epithelial ingrowth after the formation of a buttonholed flap can initiate stromal melting and increase the stromal scarring, thereby causing a further decrease in the BCVA.[12,13]

In this study, we retrospectively reviewed the incidence, management, and visual outcomes of buttonholed LASIK flaps. We also discuss possible etiopathogenic mechanisms associated with this complication.

PATIENTS AND METHODS

This retrospective study identified all cases of buttonholed LASIK flaps during microkeratome flap creation between June 1999 and May 2008 at Eye Consultants Center, Riyadh, Saudi Arabia. All patients were 18 years of age or older and had a stable refraction for at least 1 year. Patients who were pregnant, with a history of ocular pathology (eg, glaucoma, retinal disease) or corneal disease (eg, subclinical or clinical keratoconus), previous ocular surgery including refractive corneal surgery, or contact lens wear for the 2 weeks before surgery were excluded.

Because of the relatively large number of surgeons involved, no uniform surgical technique was used. However, the standard LASIK technique was generally used. Simultaneous bilateral surgery was performed, with the right eye always having the initial treatment. The LASIK flaps were created using a Hansatome microkeratome (Bausch & Lomb) with a 160 or 180 μm plate or a Moria microkeratome (Moria Corp.) with a 130 μm plate. Trained staff followed specific criteria when inspecting the suction rings and the microkeratomes. The microkeratomes were serviced regularly in accordance with manufacturer recommendations or when difficulties or abnormalities with the microkeratome were noted. The same blade was used for microkeratome translation in both eyes of the same patient. Ablations were performed with an EC-5000 excimer laser (Nidek Co., Ltd.). Some eyes in which the procedure was aborted had repeat LASIK with a new microkeratome pass or surface ablation later. Postoperative care varied by surgeon.

Data collected from the files included patient age and sex; preoperative refraction, BCVA, and mean keratometry and pachymetry values; date of initial LASIK treatment; date and type of subsequent treatment; and refraction, BCVA, and slitlamp biomicroscopic findings after the initial LASIK treatment. Finally, BCVA, refraction, and slitlamp biomicroscopic findings at the last follow-up visit were recorded. The variables that were tested for their influence on the occurrence of buttonholed LASIK flaps included preoperative refraction, keratometry, pachymetry, right eye versus left eye, and type of microkeratome (Hansatome versus Moria).

The association between 2 categorical variables was evaluated using the Fisher exact test. The Student *t* test was used to compare the difference between 2 proportions from the same sample. A *P* value less than 0.05 was considered statistically significant.

RESULTS

During the study period, 4250 primary LASIK procedures were performed by 8 experienced LASIK surgeons. Review of the procedures identified 17 eyes (0.4%) of 15 patients with buttonholed flaps. Of the patients, 10 were men and 5 were women. The mean age of the patients was 32.6 years ± 10.3 (SD) (range 18 to 53 years). Table 1 shows the preoperative clinical characteristics of each patient. The mean preoperative spherical equivalent (SE) refraction in all eyes was −4.16 ± 2.75 diopters (D) (range +4.25 to −9.00 D); the mean keratometry, 43.70 ± 1.36 D (range 41.50 to 46.00 D); and the mean pachymetry, 584.0 ± 42.5 μm (range 473.0 to 624.0 μm). There were no statistically significant differences between right eyes and left

Table 1. Preoperative clinical findings in eyes with buttonholed flaps.

Pt	Age/Sex	Eye	Preoperative Refraction	Initial BSCVA	Mean Keratometry (D)	Pachymetry (μm)
1	42/M	Right	−0.50−1.25 × 80	20/16	45.25	509.0
2	23/M	Left	−8.50 sphere	20/20	44.70	509.0
3	39/F	Left	−2.00−0.50 × 70	20/20	45.50	473.0
4	42/F	Left	−5.25−4.25 × 05	20/30	46.00	534.0
5	43/M	Right	−3.50−0.50 × 95	20/16	43.50	544.0
6	53/M	Left	+4.25 sphere	20/20	43.00	594.0
7	28/F	Left	−2.00−1.00 × 17	20/20	44.00	511.0
8	34/M	Left	−4.50 sphere	20/16	43.50	520.0
9	36/M	Left	−9.00 sphere	20/50	45.75	544.0
10A	18/M	Right	−1.25−1.75 × 15	20/16	42.30	607.0
10B	18/M	Left	−1.50−2.00 × 180	20/16	42.50	613.0
11	35/F	Left	−6.25−0.75 × 30	20/20	44.50	624.0
12	23/M	Right	−4.00 sphere	20/20	42.20	574.0
13	21/M	Right	−3.00 + 0.25 × 95	20/16	42.50	521.0
14	33/F	Left	−1.75−0.75 × 15	20/20	41.50	525.0
15A	19/M	Right	−3.00−0.50 × 130	20/16	43.00	565.0
15B	19/M	Left	−3.50 sphere	20/16	43.50	554.0

BCVA = best-spectacle corrected visual acuity; Pt = patient

eyes in preoperative refraction, keratometry, or pachymetry ($P > .05$).

Intraoperative flap buttonholes occurred in 6 right eyes and 11 left eyes (2 bilateral cases). The flap buttonhole was central in all eyes and occupied approximately 10% to 20% of the flap's surface area. Buttonholed flaps occurred in 11 eyes (64.7%) of 10 patients with the Hansatome microkeratome and 6 eyes (35.3%) of 5 patients with the Moria microkeratome. Of buttonholed flaps that occurred with the Hansatome microkeratome, 6 were with the 180 μm plate and 5 with the 160 μm plate. Primary LASIK was performed using the Hansatome microkeratome in 1611 patients (37.9%) and with the Moria microkeratome in 2639 patients (62.1%); thus, the incidence of buttonholed LASIK flap was 0.62% (10/1611) and 0.19% (5/2639), respectively ($P = .03$, Fisher exact test).

Laser ablation was performed at the same time as buttonhole formation in 8 eyes (47.1%); the procedure was aborted in the other 9 eyes (52.8%). Of the eyes that had laser ablation at the same time as buttonhole formation, 3 eyes (case 6 and cases 10A and B) had extremely thin flaps (incomplete buttonhole) in which the central epithelium was left in the corneal flaps. In these cases, the surgeon proceeded with laser ablation; in other cases, the surgeon scraped the central island of corneal epithelium before laser ablation.

Table 2 shows the intraoperative and postoperative data for each patient with a buttonholed flap. Retreatment was performed in 10 eyes (59%). Of these, 6 eyes had repeat LASIK, 3 had laser-assisted subepithelial keratectomy (LASEK) with mitomycin-C (MMC), and 1 had photorefractive keratectomy (PRK). There were no intraoperative complications during retreatment. However, in case 1, 2 attempts were made to perform LASEK with MMC. The mean SE refraction just before retreatment was −4.65 ± 3.14 D (range +0.25 to −8.75 D), and the mean loss of BCVA was 0.66 lines (case 12 lost 6 lines of BCVA and case 4, 4 lines). Following aborted LASIK but just prior to retreatment, refraction showed an SE shift (mean 0.50 ± 0.50 D) toward myopia in 4 eyes and toward hyperopia (mean 0.66 ± 0.34 D) in 6 eyes. The mean time to retreatment was 20 ± 14 weeks (range 3.0 to 47.1 weeks). The final mean SE refraction was −0.38 ± 0.79 D (range +0.75 to −2.13 D) after a mean follow-up of 31.7 ± 30.4 weeks (range 3.0 to 101.4 weeks).

Finally, a loss of more than 2 lines of BCVA occurred in 2 (11.8%) of the 17 eyes; 14 eyes (82.3%) retained a BCVA better than 20/40. Of the eyes that lost more than 2 lines of BCVA, 1 (case 9) lost 6 lines of BCVA because of a significant central corneal scar despite attempted phototherapeutic keratectomy (PTK) to reduce the scar density. In eyes in which the LASIK procedure was completed, the mean loss of BCVA was 0.73 lines. However, the mean loss of BCVA was 0.60 lines in the group with aborted LASIK. In this group, eyes that had repeat LASIK had a mean loss of 0.60 lines of BCVA and eyes that had surface ablation, a mean loss of 0.80 lines (Table 2). Of the 10 eyes that had retreatment, 4 had a loss of 2 or more lines of BCVA. Of these eyes, 2 (case 4 and case 9) had a poor outcome related to irregular astigmatism, which was documented by corneal topography (Figure 1).

Epithelial ingrowth was not reported during primary LASIK or after retreatment. No eye had complications during recreation of the LASIK flap.

DISCUSSION

Buttonholes in LASIK flaps occur when the microkeratome blade exits through the epithelium during the mid incision and then reenters to complete the flap. It has been suggested that the etiology of buttonholed flaps is multifactorial and may include a steep cornea, a small corneal diameter, a deep eye socket, loss of suction ring pressure, and conjunctival incarceration in the suction port, which can lead to loss of suction during flap creation.[6] Factors related to the microkeratome include blunted blades, microflaws of blades, poor oscillation,[11] and perhaps other unrecognized causes.

Gimbel et al.[6] hypothesize that buttonholed flaps occur in steep corneas as a result of the microkeratome footplate compressing excess tissue beyond applanation, causing the central cornea to buckle in a posterior direction during microkeratome translation. Thus, although the microkeratome makes a complete pass and produces a normal-sized flap, the central area is extremely thinned or buttonholed. However, Leung et al.[11] suggest that reduced power of the microkeratome motor allows the blade to move forward without a synchronized blade oscillation, which leads to displacement of corneal tissue centrally in front of the blade and causes the device to pass across the cornea faster than it can cut, skimming the blade over the corneal tissue and resulting in the formation of a central buttonholed flap. In our study, the mean keratometric value in the 17 eyes with buttonholed flaps was 43.7 ± 1.36 D. Only 4 eyes (23.5%) had a mean keratometry greater than 45.00 D. This finding is not consistent with the theory that steep corneas are more prone to buttonholed flaps.[6] In agreement with more recent reports,[10,14–16] we believe that corneal steepening alone may not explain the existence of flap buttonholes.

Tham and Maloney[17] found that flap buttonholes were significantly more prevalent when a Hansatome microkeratome was used. They speculate that this was probably a result of the relatively larger flap made by this microkeratome, which subsequently flattens

a greater area of the corneal surface and produces dimpling centrally. If intraocular pressure is inadequate, a flap buttonhole may result. In agreement with this observation, our study found that buttonholed flaps were statistically significantly more prevalent with the Hansatome microkeratome than with the Moria microkeratome ($P = .03$).

It has been reported that corneal flaps are thinner in the second eye when the same microkeratome blade is used in bilateral, consecutive, same-session LASIK (A. Wallerstein, MD, et al. "Thin Button Hole Flaps in Hansatome LASIK Surgery," presented at the ASCRS Symposium on Cataract, IOL and Refractive Surgery, San Francisco, California, USA, April 2001; D.Z. Reinstein, MD, et al. "Hansatome Flap Consistency Analysis by 3D VHF Ultrasound Pachymetric Topography," presented at the ASCRS Symposium on Cataract, IOL and Refractive Surgery, Boston, Massachusetts, USA, May 2000).[18–20] Lichter et al.[16] report 5 patients with buttonholed flaps; in all cases, the buttonholed flaps occurred in the second of 2 consecutively treated eyes of the same patient. Similarly, our study showed that in the 13 cases of unilateral buttonholes (13 eyes), 9 eyes (69.2% of cases) had buttonholes in the left eye in bilateral, consecutive, same-session treatment in which the right eye had the initial treatment. We agree with the recommendation of Lichter et al.[16] that the microkeratome blade should be changed when a thin flap is noticed in the first eye when both eyes of a patient are treated consecutively in the same session.

In the present series, 2 cases developed bilateral buttonholed flaps. We believe that the etiology of the complication in these cases was related to dysfunction of the microkeratome or secondary to a blade manufacturing problem, especially because the keratometry readings in these 4 eyes were 43.50 D or less and corneal steepening was probably not an etiological factor. In addition to the suggested etiologic factors in the bilateral cases, we agree with Kwok and Coroneo's hypothesis that reduced corneal biomechanical integrity might be a predisposing factor in the formation of buttonholes (Kwok L, Coroneo MT. IOVS 1999; 40:ARVO Abstract 4713). Hence, these corneas might be more elastic than usual and tend to buckle more easily during microkeratome translation. Other possible etiological causes of buttonholes include corneal dissection,[15] previous corneal surgery,[7] and surgeon inexperience.[21] On the other hand, flap buttonholes have been reported with nonmechanical methods of creating corneal flaps. Srinivasan and Herzig[22] and Seider et al.[23] found subepithelial gas breakthrough during femtosecond laser flap creation for LASIK. Although 2 of our cases developed bilateral buttonholed flaps, we agree with the proponents of same-session bilateral simultaneous LASIK who argue that the risk–benefit ratio is favorable.[24] However, it cannot be overemphasized that

Table 2. Intraoperative and postoperative data in eyes with buttonholed flaps.

Pt	Eye	Microkeratome	LASIK Completed	BCVA	Change in BCVA (Lines)
1	Right	Hansatome	–	20/20	−1
2	Left	Hansatome	–	20/20	0
3	Left	Hansatome	+	20/16	+1
4	Left	Hansatome	–	20/70	−4
5	Right	Hansatome	–	20/16	0
6	Left	Hansatome	+	—	—
7	Left	Hansatome	–	20/20	0
8	Left	Hansatome	–	20/16	0
9	Left	Hansatome	–	20/80	−2
10A	Right	Hansatome	+	—	—
10B	Left	Hansatome	+	—	—
11	Left	Moria	–	20/20	0
12	Right	Moria	–	20/80	−6
13	Right	Moria	+	—	—
14	Left	Moria	+	—	—
15A	Right	Moria	+	—	—
15B	Left		+	—	—

BCVA = best corrected visual acuity; LASEK = laser-assisted subepithelial keratectomy; LASIK = laser in situ keratomileusis; MMC = mitomycin-C; PRK = photorefractive keratectomy; Pt = patient

surgery in the second eye must be canceled or postponed if a substantial complication occurs in the first eye.

The management of flap buttonholes is challenging and presents a therapeutic dilemma. The conventional approach involves centrally reapproximating the flap with the stromal bed but without performing laser ablation at the time of buttonhole formation. Successful results have been reported by creating a new LASIK flap after 3 to 6 months. However, in cases in which the etiology of the buttonhole is unknown, a second keratectomy may lead to the development of a second buttonhole or other flap abnormality.[25]

Another reported useful approach is surface ablation PRK/PTK techniques, with or without the use of prophylactic MMC, after previously aborted LASIK.[12,13,25,26] However, when flap buttonholes develop fibrosis at the site of perforation through Bowman membrane, this approach should not be used because of the unpredictability of excimer ablation through the scar and the high likelihood of subsequent irregular astigmatism and loss of the BCVA. Thus, it has been suggested that these methods be used before the onset of scarring.[13,27–29]

The timing of management of flap buttonholes is critical because immediate laser ablation has been associated with severe haze.[27] Waiting at least 2 weeks may allow the activated stromal keratocytes to stabilize and the epithelium to remodel and normalize the corneal surface.[12] Stulting et al.[7] recommend abandoning laser ablation in eyes with irregular flaps, such as those with buttonholes, because they noticed a trend toward loss of BCVA when the ablation was performed at the same time as surgery. In contrast, eyes seemed to do well (ie, returned to the preoperative state) when ablation was abandoned. However, their recommendation for management of intraoperative flap complications was not supported in a formal study of flap-management techniques. Moreover, several studies caution against laser ablation immediately after buttonhole formation and conclude that it is prudent to delay retreatment (Kwok L, Coroneo MT. IOVS 1999; 40:ARVO Abstract 4713).[16,30] Other studies[10,15] report excellent outcomes when patients were retreated after the eye was allowed to settle. Leung et al.[11] showed that flap buttonholes can produce alterations in refraction and recommend that retreatment is best performed after the refractive error has stabilized. In addition, Lichter et al.[16] found that the buttonhole flap itself caused a myopic spherical change of −0.50 D as well as 0.70 D of astigmatism. In our study, although the 8 eyes (47.1% of cases) that had complete LASIK as scheduled did not have the worst loss of BCVA, the least loss of BCVA was achieved when LASIK was aborted and then repeated after refractive stability. We are not sure that proceeding with LASIK as scheduled is

Table 2 (Cont.)

Refraction After Buttonhole, Just Before Retreatment	Reoperation	Period Between 2 Surgeries (Wk)	Final		
			Refraction	BCVA	Change in BCVA (Lines)
−0.50 +1.50 × 90	LASEK+MMC 2×	47.1	+0.75 −1.50 × 90	20/25	−2
−8.75 −0.25 × 92	Repeat LASIK	3.0	−1.75 −0.75 × 10	20/25	−1
−1.00 −0.50 × 60	Repeat LASIK	11.0	+0.25 −1.00 × 72	20/20	0
−7.50 −2.00 × 180	PRK	38.0	−1.25 −1.00 × 14	20/40	−2
−2.75 −0.25 × 125	Repeat LASIK	10.0	−0.25 −0.50 × 95	20/20	−1
—	—	—	+2.75 −4.75 × 72	20/40	−3
−1.75 −2.00 × 05	Repeat LASIK	28.0	+1.25 −1.00 × 61	20/25	−1
−4.75 −0.25 × 51	Repeat LASIK	12.0	−0.50 −0.50 × 81	20/20	−1
−8.00 sphere	Repeat LASIK	10.0	+2.75 −4.75 × 130	20/200	−6
—	—	—	−0.75 −0.50 × 15	20/28	−2
—	—	—	−0.50 sphere	20/28	−2
−5.75 −1.25 × 30	LASEK+MMC	29.0	−0.75 −1.25 × 90	20/20	0
−2.75 −2.00 × 90	LASEK+MMC	14.0	+0.50 −0.25 × 30	20/25	−1
—	—	—	+0.75 −0.75 × 50	20/25	−2
—	—	—	+0.25 −0.50 × 175	20/28	−1
—	—	—	+0.25 −0.75 × 175	20/16	0
—	—	—	+0.25 −1.00 × 170	20/20	−1

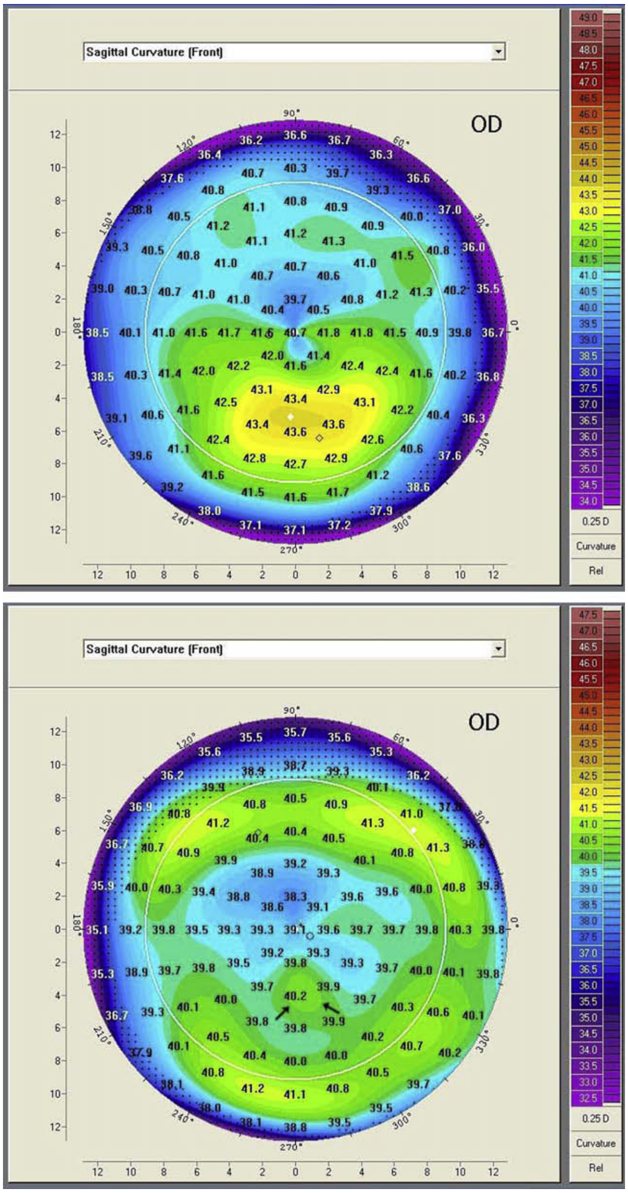

Figure 1. Corneal topography (Pentacam, Oculus) of the right eye (case 4). *Top*: After a LASIK buttonholed flap but just before retreatment (PRK). *Bottom*: Six months after PRK. The arrowheads indicate the paracentral elevation.

a safe approach in the management of buttonholed LASIK flaps.

In the present study, the mean loss of BCVA in the 3 groups of eyes that had complete LASIK, aborted LASIK followed by retreatment with repeat LASIK, and aborted LASIK followed by retreatment with surface ablation was 0.72 lines, 0.62 lines, and 0.80 lines, respectively. Although the least loss of mean BCVA was in eyes that had aborted LASIK and were retreated later with repeat LASIK, it might be argued that the differences between the 3 groups are not clinically significant. Surprisingly, the group of eyes that had aborted LASIK and then had retreatment with surface ablation (3 LASEK with MMC and 1 PRK only) tended to have the worst mean loss of BCVA. This outcome probably occurred because in our series, the ablation was performed after the formation of a significant scar (mean period 8 months), which is considered late. As previously discussed, ablation through a corneal scar is unpredictable and might increase the likelihood of subsequent irregular astigmatism and loss of BCVA. In agreement with a report by Harissi-Dagher et al.,[10] we believe that an observation period of at least 12 weeks might be appropriate before considering surface ablation with or without MMC. This period might allow corneal epithelial hyperplasia to smooth the optical surface and ensure refractive stability before the occurrence of a significant corneal scar that might reduce laser ablation predictability.

The eyes (cases 4, 9, and 12) with the largest shift in refraction after aborted LASIK had the worst final outcomes in our study. A large change in refraction might therefore be a warning sign of a bad outcome of a secondary procedure.

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