TECHNIQUE

Inducing fibrogenesis and new interfibrillary bonds in post-laser in situ keratomileusis keratectasia

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Flap creation weakens the cornea and is a risk factor for keratectasia after laser in situ keratomileusis (LASIK). We describe a new technique to halt the progression of keratectasia by mechanically reintegrating the flap into the residual stroma. Deep stromal vertical puncturing is performed in the 4.0 to 9.0 mm paracentral corneal zone at a depth of 350 to 420 μm. The puncturing is applied in circumferential rows using a 25-gauge needle or a diamond blade, with denser puncturing at the level of the cone. In 5 eyes with worsening post-LASIK keratectasia, improved uncorrected and corrected visual acuities, corneal flattening, and a hyperopic shift were observed. There was no progression of keratectasia on serial topographies. New collagen fibrogenesis was documented by optical coherence tomography. The technique seems to be promising to halt the progression of post-LASIK keratectasia. More clinical data and longer follow-up are needed for validation.

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Corneal ectasia is a rare but serious complication of laser in situ keratomileusis (LASIK), with an estimated prevalence between 0.04% and 0.6%.[1] It is characterized by a degenerative deformation of the cornea with a cone-like progressive steepening and thinning of the stroma. Because the one-third anterior region of the corneal stroma has the greatest cohesive tensile strength, removing it through flap creation might induce corneal biomechanical weakening.[2–4] The following mathematic formula supports this: Percentage of tissue altered = (flap thickness + ablation depth)/central corneal thickness.[5–7] This formula provides a better understanding of the factors involved in the risk for ectasia after LASIK.

Conventional management of keratectasia is largely based on algorithms for the management of keratoconus, a disease that has similar characteristics. Management strategies have 2 major goals; that is, stabilization of the disease process and refractive rehabilitation. At present, corneal crosslinking (CXL) with ultraviolet light is the prevalent strategy used to halt the progression of ectasia. Its goal is to stiffen the anterior corneal stroma by creating strong covalent bonds between collagen fibrils.[8,9] However, CXL does not reintegrate the biomechanical adhesion of the flap to the residual stromal tissue.

In this article, we describe a technique that aims to reintegrate anatomically and biomechanically the LASIK flap into the residual stroma in ectatic corneas by restoring the interfibrillar collagen bonds through the induction of collagen fibrogenesis. This would theoretically stiffen the cornea and halt the progression of ectasia.

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The eye area is scrubbed with povidone–iodine and draped in a sterile manner. An eyelid speculum is used to hold the eyelids open. The cornea is topically anesthetized using oxybuprocaine hydrochloride 0.4% instilled 3 times at 2-minute intervals.

A bent 25-gauge needle or a diamond blade is used to vertically puncture the corneal stroma. The procedure is topographically guided so that 100 μm of deep stroma is left unpunctured up from the thinnest point in the cone area (puncture depth = thinnest point at the area of ectasia minus 100 μm). The treatment area involves 4.0 to 9.0 mm of the paracentral corneal stroma, sparing the central visual axis. It is extended 360 degrees in circumferential rows, with denser puncturing at the level of the corneal steep area or cone.

After the procedure, topical antibiotics and steroids are prescribed and slowly tapered over 1 month.

Results

Five eyes of 3 patients (1 woman, 2 men) with post-LASIK keratectasia had deep stromal puncturing. The age of the patients ranged from 34 to 38 years. The experimental nature of the procedure was explained to the patients, who signed an informed consent form before the study. All procedures were performed at the Beirut Eye and ENT Specialist Hospital by the same surgeon (E.J.).

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Table 1. Refractive and topographic outcomes of stromal puncturing in keratectasia.

Exam/Eye	UDVA	CDVA	Sph	Cyl	Ax	Kmax	K1	K2	TCT
Patient 1									
Preop									
Right eye	NA	20/25	−2.50	1.50	135	48.0	41.2	43.1	438
Left eye	NA	20/30	−1.50	4.00	25	46.9	38.0	42.1	397
13 mo postop									
Right eye	NA	20/20	−0.25	2.25	175	37.9	39.2	41.9	428
Left eye	NA	20/22	0.00	4.75	40	46.9	35.8	40.2	396
Patient 2									
Preop									
Right eye	20/400	20/200	−4.00	1.50	155	54.0	41.0	47.0	397
Left eye	20/400	20/200	−2.00	0.00	0	52.0	41.0	48.0	NA
6 mo postop									
Right eye	20/100	20/30	−2.00	2.00	90	50.0	38.0	43.0	396
Left eye	20/100	20/30	−1.50	1.25	180	49.5	39.5	43.0	NA
Patient 3									
Preop									
Right eye	20/50	20/25	−1.00	3.25	180	57.5	36.1	36.8	390
3 mo postop									
Right eye	20/50	20/20	0.00	3.00	15	55.2	35.2	36.0	397

Ax = axis (degrees); CDVA = corrected distance visual acuity (decimal scale); Cyl = cylinder (D); K1 = flat keratometry (D); K2 = steep keratometry (D); NA = not assessed; Sph = sphere (D); TCT = thinnest corneal thickness (μm); UDVA = uncorrected distance visual acuity (decimal scale)

A complete ophthalmic examination, including along corneal topography and anterior segment optical coherence tomography (AS-OCT), was performed preoperatively and at every postoperative visit. Table 1 shows each patient's refractive and topographic outcomes preoperatively and at their most recent postoperative visit. All patients had improved in uncorrected and corrected distance visual acuities and a hyperopic shift. No significant postoperative complications occurred in any eye. Significant flattening was observed on serial corneal topographies performed during follow-up visits (Figure 1). Preoperatively, the mean spherical equivalent (SE) was −1.17 diopters (D) (range −3.25 to +0.62 D), the mean flat keratometry (K1) was 39.46 D (range 36.1 to 41.2 D), the mean steep K (K2) was 43.4 D (range 36.8 to 48.0 D), and the maximum K was 51.68 D (range 46.9 to 57.5 D). At the last follow-up visit, the respective values were 0.57 D (range −1.00 to +2.37 D), 37.54 D (range 35.2 to 39.5 D), 40.82 D (range 36.0 to 43.0 D), and 47.9 D (range 37.9 to 55.2 D). New corneal collagen fibrogenetic load was documented on AS-OCT (Figure 2).

DISCUSSION

Anterior stromal puncturing has proved to be an effective treatment for several pathologic processes in which the loose attachment between the corneal epithelium and Bowman layer results in recurrent painful erosions. As an example, it is widely used in eyes with recurrent corneal erosions.[10–12] It is also a treatment option in bullous keratopathy[13] and has been used with success in a few eyes with contact lens intolerance and keratoconus in which the intolerance was related to subepithelial nodules at the apex of the cone with a sloughed epithelium.[14] In all cases, the anterior stromal puncturing resulted in localized subepithelial fibrosis that increased the adhesion of the epithelium to the underlying Bowman layer, preventing further erosions and pain.

In our practice, we found that deeper stromal puncturing, as performed for suture placement in LASIK flaps, makes it extremely difficult to lift the flap at the area of the suturing. This is because of a significant increase in the bonding of the flap to the underlying residual stroma in this area, which has been attributed to the formation of new vertical collagen fibers induced by the needle pass. Flap suturing has been used to tighten adherence between the flap and the residual stroma in cases of traumatic flap displacement, recurrent epithelial ingrowth, and

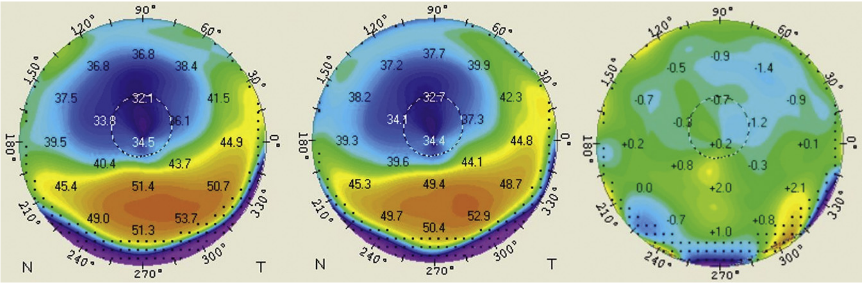

Figure 1. Preoperative (*left*), postoperative (*middle*), and differential (*right*) corneal topography maps of the right eye patient 3 show significant flattening of the ectasia with a corresponding hyperopic shift in refraction. After surgery, the maximum K, K1, and K2 values decreased. The SE refraction changed from +0.62 D preoperatively to +1.50 D postoperatively, reflecting the amount of corneal flattening induced by the puncturing (K = keratometry; K1 = flat keratometry; K2 = steep keratometry; SE = spherical equivalent).