Epithelial Removal and Phototherapeutic Keratectomy for Residual Refractive Error Following LASIK in Eyes With Corneal Epithelial Basement Membrane Degeneration

Ella G. Faktorovich, MD; Emily Nosova, BA

From Pacific Vision Institute, San Francisco, Calif.

Corneal epithelial basement membrane degeneration, also called map-dot-fingerprint dystrophy and Cogan’s microcystic dystrophy, is a diffuse, bilateral corneal pathology characterized by abnormality in the epithelial basement membrane.1 Histopathologic findings include reduplicated basement membrane with extension into the epithelium, collection of aberrant collagen and fibrous tissue in the basement membrane, fibrillar material between the epithelial basement membrane and Bowman’s layer, loosely adherent and thickened epithelium, linear structures of 50- to 100-µm height arranged in parallel below the epithelium, and cysts with a diameter between 50 and 400 µm.1-4 Patients may present with symptoms of recurrent erosion, corneal slit-lamp microscopic findings of map-dot-fingerprint changes, irregular astigmatism, and decreased uncorrected and best-corrected vision.5,6

Phototherapeutic keratectomy (PTK) has been shown to be effective in treating signs and symptoms of epithelial basement membrane degeneration.7-9 Following PTK, corneal clarity improves, epithelial attachment to basement membrane strengthens, basement membrane reduplication resolves, and epithelial thickness becomes more even and normal.10,11

Epithelial basement membrane degeneration is typically a contraindication to LASIK. However, despite careful screening, it may go undetected prior to LASIK. Asymptomatic eyes with clear corneas at preoperative evaluation may develop epithelial loosening and sloughing intraoperatively. Postoperatively, they may develop symptoms of recurrent erosions, slit-lamp microscopic findings of epithelial basement membrane degeneration, irregular astigmatism, and decreased

ABSTRACT

PURPOSE: To retrospectively evaluate the efficacy of epithelial removal followed by phototherapeutic keratectomy (PTK) for reducing residual refractive error in eyes with corneal epithelial basement membrane degeneration after LASIK.

METHODS: Eight eyes of four patients with residual refractive error and signs of epithelial basement membrane degeneration after LASIK were followed until their refractive error stabilized. Epithelium was debrided and PTK performed. Refractive error and visual acuity outcomes were analyzed.

RESULTS: In the six eyes that underwent LASIK for myopic astigmatism, mean spherical equivalent refraction after LASIK was $-1.75\pm0.62$ diopters (D) and mean astigmatism was $+0.75\pm0.59$ D. After PTK, mean spherical equivalent refraction was $-0.33\pm0.35$ D and mean astigmatism was $+0.50\pm0.27$ D. Mean logMAR uncorrected visual acuity (UCVA) improved from $0.39\pm0.31$ before PTK to $0.03\pm0.05$ after PTK. Mean Snellen UCVA improved from 20/50 before PTK to 20/20 after PTK. In two eyes that underwent LASIK for hyperopic astigmatism, mean spherical equivalent refraction after LASIK was $+4.38\pm0.35$ D and mean astigmatism was $+3.25$ D. After PTK, mean spherical equivalent refraction decreased to $+1.56\pm0.44$ D and mean astigmatism decreased to $+2.13\pm0.53$ D. Mean logMAR UCVA improved from 0.24 to 0.14. Mean Snellen UCVA improved from 20/35 to 20/27.

CONCLUSIONS: In eyes with epithelial basement membrane degeneration and refractive error after LASIK, epithelial removal followed by PTK may reduce refractive error, both myopic and hyperopic, bringing it close to emmetropia and avoiding the need for traditional stromal enhancement. [J Refract Surg. 2009;25:723-729.] doi:10.3928/1081597X-20090707-07

From Pacific Vision Institute, San Francisco, Calif.
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Correspondence: Ella G. Faktorovich, MD, Pacific Vision Institute, One Daniel Burnham Ct, San Francisco, CA 94109. Tel: 415.922.9500; Fax: 415.922.9568; E-mail: ella@pacificvision.org

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visual acuity. They may also have postoperative refractive error. Typically, a patient who is unsatisfied with the refractive error after LASIK is considered for an additional laser treatment to try to achieve the desired outcome. This retreatment involves stromal ablation—either by lifting the flap and ablating the stromal bed or by removing the epithelium and performing photorefractive keratectomy (PRK).

If a patient, however, develops signs and symptoms of epithelial basement membrane degeneration after LASIK, they may require PTK. Rojas and Manche reported PTK to be effective in treating the symptoms of recurrent erosion and improving corneal clarity in eyes that manifested signs of epithelial basement membrane degeneration after LASIK. They also noted a mean hyperopic shift after PTK. Phototherapeutic keratectomy has been reported to result in refractive change in eyes without previous refractive surgery as well. Although the effect of PTK to result in refractive error stabilized after LASIK, these eyes were treated throughout follow-up after LASIK. Once the refractive error stabilized, these eyes were treated with PTK and refractive error, uncorrected visual acuity (UCVA), and best spectacle-corrected visual acuity (BSCVA) were followed. Visual acuities were measured with Snellen and logMAR-based visual acuity charts.

**PATIENTS AND METHODS**

Eight eyes of four patients that were targeted for emmetropia with LASIK had residual postoperative refractive error and were being considered for retreatment to bring them close to emmetropia. Prior to LASIK, corneal examination was normal in these eyes, but their epithelium loosened intraoperatively, and postoperatively, they developed slit-lamp microscopic findings of map-dot-fingerprint changes consistent with epithelial basement membrane degeneration. In all eyes, the corneal findings of epithelial basement membrane degeneration were present within the optical zone of the excimer correction. The findings were consistently noted throughout follow-up after LASIK. Once the refractive error stabilized after LASIK, these eyes were treated with PTK and refractive error, uncorrected visual acuity (UCVA), and best spectacle-corrected visual acuity (BSCVA) were followed. Visual acuities were measured with Snellen and logMAR-based visual acuity charts.

**LASIK Technique**

Immediately prior to LASIK, one drop of each was administered: 0.5% topical proparacaine hydrochloride (Bausch & Lomb, Tampa, Fla), ketorolac tromethamine preservative-free (Acular PF; Allergan, Irvine, Calif), moxifloxacin hydrochloride 0.5% (Vigamox; Alcon Laboratories Inc, Ft Worth, Tex), naphazoline hydrochloride 0.025% and pheniramine maleate 0.3% (Naphcon A, Alcon Laboratories Inc), tropicamide 1% (Mydracil 1%, Alcon Laboratories Inc), and phenylephrine hydrochloride 2.5% (Mylotil 2.5%, Alcon Laboratories Inc). Limbal markings were placed at the slit lamp to allow for LADARVision4000 (Alcon Laboratories Inc) astigmatic axis alignment during excimer ablation.

**PTK Technique**

Once refraction after LASIK stabilized (mean 7.83±2.71 months after LASIK for myopic astigmatism and 12 months following LASIK for hyperopic astigmatism), PTK was performed. Prior to PTK, patients signed an informed consent. They were informed about the off-label use of PTK to treat residual refractive error after previous corneal surgery. Immediately before the procedure, a drop of each was administered: 0.5% topical proparacaine hydrochloride, ketorolac tromethamine preservative-free, moxifloxacin hydrochloride 0.5%, and naphazoline hydrochloride 0.025% and pheniramine maleate 0.3%. Patients were placed under the Summit Apex laser (fluence 180 mJ/cm², pulse frequency 10 MHz) (Summit Technologies, Waltham, Mass). A drop of tetracaine hydrochloride 1% was applied. Corneal epithelium was removed with a Maloney PRK spatula (ASICO, Westmont, Ill) over the entire cornea, except 1 mm from the limbus. Phototherapeu-
tive keratectomy was performed with an optical zone of 6.0 mm. Thirty pulses were distributed over the exposed Bowman’s layer using rotational head movement. A bandage contact lens (CIBA Vision Day & Night, Duluth, Ga; base curve 8.6; diameter 13.8) was placed on the eye and removed on postoperative day 4.

Epithelial defect was healed in all eyes by postoperative day 4. Postoperative drop regimen included prednisolone acetate 1% four times daily for 1 week, moxifloxacin hydrochloride 0.5% four times daily for 1 week, and Refresh Plus every 1 to 2 hours as needed.

Patients were followed with slit-lamp examinations, refraction, and measurements of UCVA and BSCVA. Refractions were recorded on two occasions: the first was at mean 4.5±2.34 months (range: 3 to 8 months) after PTK. The second and final refraction was at mean 9.50±2.59 months (range: 6 to 14 months) after PTK.

**Statistical Analysis**

SPSS statistical software (version 13.0 for Windows, Student Version; SPSS Inc, Chicago, Ill) was used for statistical analysis. Changes in refraction and visual acuity were compared with a paired samples t test. A P value <.05 was considered statistically significant.

**Results**

Refraction, UCVA, and BSCVA before and after LASIK for each of the eight eyes are shown in Table 1. Refraction, UCVA, and BSCVA after PTK for the eight eyes are shown in Table 2.

**Refractive Outcomes**

Six of eight eyes underwent LASIK for myopic astigmatism. Mean spherical equivalent refraction and astigmatism before and after LASIK and after PTK are shown in Figure 1. Following LASIK, residual myopic astigmatism remained. Following PTK, the spherical equivalent refraction and astigmatism were reduced. At final follow-up after PTK, mean spherical equivalent refraction and astigmatism did not differ significantly from the values at initial follow-up after PTK (P=.846 for spherical equivalent refraction; P=.530 for astigmatism). Overall, mean spherical equivalent refraction decreased by 1.42±0.94 D at final follow-up after PTK compared to the refraction before PTK (P=.014). Mean astigmatism decreased by 0.25±0.50 D (P=.275).

Two of eight eyes underwent LASIK for hyperopic astigmatism. Mean spherical equivalent refraction and astigmatism before and after LASIK and after PTK are shown in Figure 2. One year after LASIK, residual hyperopia remained and astigmatism increased. Three months after PTK, mean spherical equivalent refraction and astigmatism decreased. Nine months after PTK, mean spherical equivalent refraction remained similar to mean spherical equivalent refraction at 3 months after PTK and mean astigmatism increased. In comparison to the hyperopia and astigmatism before PTK, hyperopia decreased by 2.82 D and astigmatism increased by 0.80 D.

**Visual Acuity Outcomes**

Figure 3 shows mean logMAR UCVA and BSCVA before and after LASIK for myopic astigmatism and after PTK. Prior to LASIK, mean UCVA was 1.60±0.50 (Snellen 20/800 or counting fingers) and mean BSCVA was −0.10 (Snellen 20/15). After LASIK, mean UCVA was 0.39±0.31 (Snellen 20/50) and mean BSCVA was −0.03±0.05 (Snellen 20/20). At the first follow-up

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**Table 1**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (y)</th>
<th>Eye</th>
<th>Refraction</th>
<th>UCVA</th>
<th>BSCVA</th>
<th>Refraction</th>
<th>UCVA</th>
<th>BSCVA</th>
<th>PTK After LASIK (mo)</th>
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<tbody>
<tr>
<td>W.L.</td>
<td>28</td>
<td>Right</td>
<td>−9.50 +1.25 × 105</td>
<td>2.00</td>
<td>−0.10</td>
<td>−1.75 +1.25 × 021</td>
<td>0.30</td>
<td>0.00</td>
<td>3</td>
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<td>Left</td>
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<td>−0.10</td>
<td>−2.50 +0.50 × 122</td>
<td>0.40</td>
<td>0.00</td>
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<td></td>
<td></td>
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<tr>
<td>A.M.</td>
<td>49</td>
<td>Right</td>
<td>−8.00 +3.25 × 088</td>
<td>1.60</td>
<td>−0.10</td>
<td>−2.25 +1.50 × 094</td>
<td>0.18</td>
<td>0.00</td>
<td>8</td>
</tr>
<tr>
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<td>1.60</td>
<td>−0.10</td>
<td>−2.00 +1.00 × 092</td>
<td>0.30</td>
<td>0.00</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.S.</td>
<td>42</td>
<td>Right</td>
<td>−9.50 +1.50 × 151</td>
<td>2.00</td>
<td>−0.10</td>
<td>−2.75 DS</td>
<td>1.00</td>
<td>−0.10</td>
<td>9</td>
</tr>
<tr>
<td>Left</td>
<td>−8.50 +0.75 × 027</td>
<td>1.60</td>
<td>−0.10</td>
<td>−1.50 +0.25 × 010</td>
<td>0.18</td>
<td>−0.10</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J.F.</td>
<td>33</td>
<td>Right</td>
<td>+4.50 +2.75 × 026</td>
<td>1.00</td>
<td>−0.10</td>
<td>+2.50 +3.25 × 021</td>
<td>0.18</td>
<td>0.00</td>
<td>12</td>
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<tr>
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<td>−0.10</td>
<td>+3.00 +3.25 × 169</td>
<td>0.30</td>
<td>0.00</td>
<td>12</td>
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</table>

UCVA = uncorrected visual acuity, BSCVA = best spectacle-corrected visual acuity, DS = diopters sphere.
PTK for Residual Refractive Error After LASIK/Faktorovich & Nosova

after PTK, mean UCVA improved to 0.03±0.05 (Snellen 20/20–). Mean BSCVA was –0.10 (Snellen 20/15) in all eyes. At final follow-up after PTK, mean UCVA remained at 0.03±0.05 (Snellen 20/20–) and BSCVA remained at –0.10 (Snellen 20/15) in all eyes.

Figure 4 shows logMAR UCVA and BSCVA before and after LASIK for hyperopic astigmatism and at two follow-up times after PTK. Prior to LASIK, UCVA was 1.0 (Snellen 20/200) and BSCVA was –0.10 (Snellen 20/15). After LASIK, UCVA and BSCVA were 0.24 and 0, respectively (Snellen 20/35 and 20/20, respectively).

After PTK, both UCVA and BSCVA improved. At final follow-up after PTK, UCVA was 0.14 (Snellen 20/27) and BSCVA was –0.05 (Snellen 20/18).

**DISCUSSION**

The most common causes of residual refractive error after LASIK in patients with normal corneas and clear lenses are undercorrection, overcorrection, or regression. These refractive errors are typically treated with additional excimer laser ablation of the corneal stroma. Residual refractive error after LASIK has also

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (y)</th>
<th>Eye</th>
<th>No. of Months After PTK (First F/U)</th>
<th>Refraction</th>
<th>UCVA</th>
<th>BSCVA</th>
<th>No. of Months After PTK (Final F/U)</th>
<th>Refraction</th>
<th>UCVA</th>
<th>BSCVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>W.L.</td>
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<td>–1.25 +0.50 × 160</td>
<td>0.10</td>
<td>–0.10</td>
<td>10</td>
<td>–1.00 +0.75 × 180</td>
<td>0.10</td>
<td>–0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
<td>3</td>
<td>–0.50 +0.75 × 035</td>
<td>0.00</td>
<td>–0.10</td>
<td>6</td>
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<td>–0.10</td>
</tr>
<tr>
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<td>Right</td>
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<td>–0.75 +0.50 × 109</td>
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<td>–0.10</td>
<td>9</td>
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<tr>
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</tr>
<tr>
<td>A.S.</td>
<td>42</td>
<td>Right</td>
<td>3</td>
<td>–0.25 DS</td>
<td>0.00</td>
<td>–0.10</td>
<td>9</td>
<td>Plano +0.50 × 160</td>
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<td>–0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
<td>3</td>
<td>–0.25 +0.25 × 030</td>
<td>0.10</td>
<td>–0.10</td>
<td>9</td>
<td>–0.75 DS</td>
<td>0.10</td>
<td>–0.10</td>
</tr>
<tr>
<td>J.F.</td>
<td>33</td>
<td>Right</td>
<td>3</td>
<td>Plano +1.75 × 001</td>
<td>0.00</td>
<td>–0.10</td>
<td>9</td>
<td>Plano +2.50 × 010</td>
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</tr>
<tr>
<td></td>
<td></td>
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<td>3</td>
<td>+1.25 +1.75 × 155</td>
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<td>–0.10</td>
<td>9</td>
<td>+1.00 +1.75 × 180</td>
<td>0.18</td>
<td>0.00</td>
</tr>
</tbody>
</table>

F/U = follow-up, UCVA = uncorrected visual acuity, BSCVA = best spectacle-corrected visual acuity, DS = diopters sphere

LogMAR values given for UCVA and BSCVA.
been noted in patients with epithelial basement mem-
brane degeneration. 13 Phototherapeutic keratectomy
has been shown to be effective in treating the signs and
symptoms of epithelial basement membrane degenera-
tion. Changes in refractive error have often been noted
after PTK for epithelial basement membrane degene-
ration and include both myopic and hyperopic shift,
with a tendency towards induced hyperopia. 13-19 Re-
duction in astigmatism has also been noted, typically
associated with improvement in irregular astigmatism
and BSCVA. 6,13 Therefore, if a patient with epithelial
basement membrane degeneration and residual refrac-
tive error after LASIK desires a retreatment, is he or
she best treated with a traditional stromal ablation or
PTK or both? This is especially important when PRK
retraining is considered, either after the primary PRK
or LASIK. If PTK alone changes the refractive error,
then removing stroma by applying additional laser
pulses during PRK retreatment may lead to inaccurate
refractive outcome. Additionally, if PTK alone can
change the refractive error, then lifting the LASIK flap
and retreating the stromal bed can be avoided. This
would preserve the residual bed thickness and avoid
possible complications associated with lifting the flap
(e.g., epithelial ingrowth, diffuse lamellar keratitis, in-
flection in the interface, etc).

In this study, we performed epithelial removal fol-
lowed by application of 30 PTK pulses, diffusely dis-
tributed over the entire cornea, to eyes that developed
signs of epithelial basement membrane degeneration
The number of PTK pulses was too small to induce the refractive change observed in this study. Phototherapeutic keratectomy pulses were also applied to the corneas in the identical pattern in both myopic and hyperopic eyes. Therefore, it is unlikely that the reduction of the refractive error was due to stromal ablation. We hypothesize that in patients with signs and symptoms of epithelial basement membrane degeneration after LASIK, the epithelium thickens in the oblate areas of the cornea—centrally after myopic ablations and peripherally after hyperopic ablations. Such thickened epithelium could reduce the refractive effect of the LASIK procedure, resulting in postoperative myopia in myopic eyes and postoperative hyperopia in hyperopic eyes. During PTK, the thickened epithelium is removed by manual scraping and the PTK is hypothesized to create a stronger adhesion complex when the epithelium and basement membrane regenerate. As a result, this regenerated epithelial layer could be more normal and uniform in thickness over the entire cornea, significantly reducing or even eliminating refractive error after LASIK.

If the change in refractive error after PTK is simply due to the removal of the thickened epithelium, perhaps application of laser pulses is not necessary at all. A simple mechanical debridement of the epithelium may bring about the desired outcome. In the short-term, this may be the case. Epithelial scraping alone may reduce the refractive error. However, corneal healing after application of laser pulses may be different than after mechanical debridement. Fountain et al.10 showed that following PTK, epithelial cells reform hemidesmosomes and anchoring fibrils, resulting in better epithelial adhesion and smoother, more even epithelial thickness. In our study, we observed stable spherical equivalent refraction in both myopic and hyperopic eyes 9.5 months after epithelial removal followed by PTK. Mechanical debridement alone may not alter the adhesion pattern of the regenerating epithelium and, over time, the epithelium may loosen, thicken, and become irregular again, changing the refractive error. Further study is needed to compare the refractive outcomes after PTK and after epithelial scraping alone.

Another hypothesis may explain why PTK might bring about the reduction in refractive error. Epithelial basement membrane degeneration leads to corneal irregularity and reduced BSCVA, which in turn may result in imprecise refraction and apparent refractive error. After PTK, the cornea is smoother, BSCVA is restored, and a more accurate refraction is obtained. In this study, two of eight eyes did not lose BSCVA, and yet residual myopia after LASIK was significantly reduced following PTK. Six of eight eyes lost only one line of BSCVA after LASIK, yet their postoperative refractive error was also significantly reduced following PTK. Therefore, the most likely cause of reduced refractive error after PTK, at least in the eyes that did not lose BSCVA, is the removal of the thickened epithelium that accumulated in the oblate areas after LASIK.

Based on the results of this study, epithelial removal followed by PTK may be considered as the first, and perhaps the only, step in reducing refractive error in eyes that develop findings of epithelial basement membrane degeneration after LASIK. How significant should those findings be to warrant PTK rather than traditional stromal retreatment? Will PTK alone reduce the refractive error in an eye with just a few microcysts in the periphery of the flap? In our study, the treatments were limited to eyes that developed slit-lamp microscopic findings of epithelial basement membrane degeneration in the excimer ablation zone. Further study using confocal microscopy may shed light on the extent of epithelial changes in eyes with minimal slit-lamp findings of epithelial basement membrane degeneration. Prospective, randomized studies may also be considered in the future to compare refractive outcomes after PTK versus epithelial scraping alone. In the mean time, PTK may be a reasonable option. If it alone brings the patient to emmetropia, PRK or LASIK retreatment may be considered.
REFERENCES


