articles

Epi-LASIK: Preliminary clinical results of an alternative surface ablation procedure

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Purpose: To evaluate the clinical results of epi-LASIK, a new surface ablation surgical technique for the treatment of low myopia.

Setting: Vardinoyannion Eye Institute of Crete, University of Crete, Greece.

Methods: Forty-four eyes of 31 patients had epi-LASIK for the correction of low myopia. Mean preoperative spherical equivalent was 3.71 diopters (D) ± 1.2 (SD) (range −1.75 to −7.00 D) and the mean baseline logMAR best spectacle-corrected visual acuity was −0.01 ± 0.06 (range 0.10 to −0.10). All the epithelial separations were performed with the Centurion epikeratome (CIBA Surgical). The enrolled patients were followed daily until the epithelial healing was complete as well as at 1- and 3-month intervals. On the operative day, patients filled out a questionnaire grading visual performance and pain score of treated eyes every 2 hours for a total of 5 records.

Results: The mean epithelial healing time was 4.86 ± 0.56 days (range 3 to 5 days). The mean logMAR uncorrected visual acuity on the day of reepithelization was 0.19 ± 0.09 (range 0.40 to 0.10). At 1 month, the mean was spherical equivalent of the treated eyes (N = 44), −0.3 ± 0.6 D (range −1.0 to 0.87 D), and at 3 months it was (N = 37), −0.10 ± 0.4 D (range −0.75 to 0.75 D); 97% of eyes had clear corneas or trace haze 3 months after treatment.

Conclusions: Preliminary clinical results suggest that epi-LASIK is a safe and efficient method for the correction of low myopia. Further studies will establish this method as an alternative surface ablation procedure.

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A recent survey of trends among the U.S. members of the International Society of Refractive Surgery determined that laser in situ keratomileusis (LASIK) is the leading surgical procedure for photorefractive corrections ranging from −0 to 3 diopters (D).[1] The same survey, however, showed a clear trend of participating refractive surgeons toward surface ablation. Nearly 70% of responding surgeons noted that they had either already performed laser-assisted subepithelial keratectomy (LASEK), which made its debut in the survey 2 years earlier, or would begin performing the procedure in the future. Laser-assisted subepithelial keratectomy is an amalgam of photorefractive keratectomy (PRK) and LASIK. The operative eye is prepared with an alcohol solution that allows the excision of the corneal epithelial layer as a sheet. Instead of being scrapped away, the separated epithelial sheet is replaced on the corneal surface after the photoablation. Its replacement is thought to have a beneficial effect on corneal healing and patients' visual recovery.[2,3]

The Centurion Epi-Edge epikeratome (Norwood Eyecare) is a device for the mechanical separation of the corneal epithelium before photorefractive treatments. With the use of this device, the corneal epithelium can be separated en toto from the underlying stroma without previous preparation of the corneal surface with alcohol. The separated epithelial sheet can be replaced on the operated cornea after photoablation.

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This surgical procedure, which has been called epi-LASIK,[4,5] represents an advanced alternative surface ablation photorefractive procedure for the correction of ametropia. We present the first clinical results of epi-LASIK for the correction of low myopia and myopic astigmatism.

Patients and Methods

Mechanical Separator

The Centurion Epi-Edge epikeratome is an electrically powered device designed to separate the corneal epithelium from the underlying stroma, thus preparing the cornea for photoablation. The device achieves epithelial separation by forward movement of a disposable, oscillating poly(methyl methacrylate) (PMMA) block with an advance speed of 3.5 mm/s and oscillation rate of 11 400 rpm. The device operates under suction pressure of 65 mm Hg.

Surgical Procedure

The operative eye is anesthetized with 3 drops of topical tetracaine hydrochloride 0.5% applied every 5 minutes before the procedure. The eye is then prepared with povidone-iodine and is covered with a sterile drape. An angulated Barraquer lid speculum provides adequate space for unimpeded course of the device during separation. As with other LASIK treatments, the operative eye is irrigated with balanced salt solution, and the cornea is marked with a customized epi-LASIK marker (Epi-LASIK marker, Duckworth & Kent). The epithelial surface is marked with 2 concentric circles crossed by 8 radial arms. Because of its elastic properties, the separated epithelial sheet tends to overflow its original position on replacement. Any deformity of the preoperative marks on replacement dictates the proper repositioning of the epithelial sheet once photoablation is complete. After corneal marking and the irrigation of ink remnants, the epikeratome's preassembled hand piece is applied to the operative eye with its central circular opening centration around the limbus. Then suction is activated. A Barraquer tonometer ensures adequate suction before the separation, and 1 drop of balanced salt solution acts as lubricant to the operative cornea. By depressing a foot pedal, the oscillating block runs parallel to the horizontal corneal plane, separating the epithelial sheet. The separator does not oscillate on reverse movement. Once the separator reaches its final position, the suction is released, and the device is removed from the eye. With the use of a moistened Merocel sponge, the epithelial sheet is reflected nasally to reveal the corneal stroma to be ablated. The separated epithelial sheet has a diameter of about 10 mm.

Immediately after ablation, the epithelial sheet is replaced, often in a single motion, with the aid of a moistened Merocel sponge. Any inward or outward folds of the edges are restored with the use of an anterior chamber irrigation cannula under constant irrigation. Once the epithelial sheet is stuck to the underlying stroma, a therapeutic contact lens is applied to the eye.

All treatments were performed with the Allegretto excimer laser (Wavelight Laser Technologie AG). All the corrections attempted to achieve emmetropia. The treatment zone in each case equaled patients' mesopic pupil diameter and ranged from 6 to 7 mm.

Patient Population

Ninety-five eyes (52 patients) had epithelial separation with the use of the Centurion Epi-Edge epikeratome. Treatment of 51 eyes (40 patients) were reversed to PRK, and the separated epithelial sheets were excised and examined histologically. In 2 eyes of 2 patients, the cleavage plane of the separation was uneven, slightly deeper superiorly. The separated sheets were left in place, and the eyes did not receive laser treatment. The clinical results in these eyes as well as the histological findings in the excised epithelial sheets are reported elsewhere (data under publication).

The 3-month clinical results were reported in the remaining 44 eyes of 31 patients who received epi-LASIK treatment as described. All the operations were performed with the use of the Centurion Epi-Edge epikeratome. Thirteen patients had bilateral treatments (26 eyes); the rest of the Epi-LASIK treatments were performed in 1 eye of 18 patients. All operations were performed by the same surgeon (I.G.P.) in the Vardinoyannion Eye Institute of Ophthalmology of the University of Crete from May through August 2003.

Mean patient age was 27.3 $\pm$ 6.1 years (range 18 to 45 years). Enrolled patients had stable refraction, no ocular disease, no previous refractive surgery, and no systemic disease that could affect the epithelial healing. The preoperative spherical equivalent was a maximum of -7.00 D and the cylinder a maximum of -2.00 D.

The preoperative examination included manifest and cycloplegic refractions, corneal videokeratography (Technomed, C-Scan), biomicroscopy, mesopic pupil size measurement

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(Colvard pupillometer), applanation tonometry, and dilated fundoscopy.

Mean preoperative spherical equivalent refraction was −3.71 ± 1.2 D (range −1.75 to −7.00 D). Mean refractive cylinder was −0.65 ± 0.54 D (range 0 to −2.00 D). Mean preoperative logMAR best corrected visual acuity was −0.01 ± 0.06 (range 0.10 to −0.10).

All participants were informed about the investigational nature of the procedure and signed a consent form according to the Declaration of Helsinki.

Follow-up

Patients were followed daily until removal of the therapeutic lens. Examination included record of subjective pain score, uncorrected visual acuity (UCVA), and biomicroscopy. Pain scores were evaluated according to a predetermined scale ranging from 0 to 4 as follows: 0 = no discomfort or pain, 1 = mild discomfort, 2 = moderate burning pain, 3 = burning pain that required medication, and 4 = severe constant or sharp pain.

On the day of the operation, patients were asked to record pain scores every 2 hours for a total of 5 records. The same scale was used in the postoperative daily visits when we obtained a single pain and discomfort score from each enrolled patient.

After the reepithelialization was complete, patients were followed at 1- and 3-month intervals. Examination included manifest refraction, biomicroscopy, applanation tonometry, and videokeratography.

Subepithelial haze was graded according to a predetermined scale[6] as follows: 0 = clear cornea, 1 = trace haze that could be seen only with broad-beam illumination, 2 = mild haze visible by slit-beam illumination, 3 = moderate haze somewhat obscuring iris details, and 4 = marked haze obscuring iris detail.

The plano Focus Night & Day bandage contact lens (CIBA Vision Opthalmics) was used. Postoperative medication included diclofenac sodium 0.1% 4 times daily (Denaclof) for 2 days and combined eyedrops of tobramycin–dexamethasone 4 times daily (Tobradex) until the removal of the therapeutic lens. After removal of the lens, all treated eyes received fluorometholone eyedrops 4 times daily (FML) in a tapered dose for 5 weeks. Prescribed artificial tears (Refresh) were prescribed to be used at the patients' discretion.

Results

Early Postoperative Period

The epithelial separation was successfully performed in all eyes. The replaced epithelial sheet often overlaid its initial gutter at the end of the surgery. Immediately after the treatment, the epithelial sheet was transparent. In the following days, it began to have a hazy appearance. Starting from the peripheral part around the edges of the sheet on the first postoperative day, the sheet became hazy over the total area until about the third day. At the same time, biomicroscopy showed a front of newly synthesized, transparent epithelium that migrated from the corneal periphery toward the center of the corneal surface. There was often a clear border between the migrating epithelium and the separated sheet. As healing progressed, the migrating cells seemed to gradually replace the separated epithelial sheet, which was subsequently constricted in the central area. Because the haziness of the epithelial sheet varied among patients, this border was also variably evident on slitlamp examination.

By about the third postoperative day, most operated eyes showed a central island of hazy epithelium that was stained with fluorescein (Figure 1). After this stage, the transparency of the corneal epithelium was restored within 24 to 48 hours and the therapeutic contact lens was removed (Figure 2). The mean time of epithelial healing was 4.86 ± 0.56 days (range 3 to 5 days).

One day after the treatment, the mean logMAR UCVA was 0.37 ± 0.21 (range 0.70 to 0.00). Figure 3 summarizes the daily records of the mean logMAR UCVA in all eyes until the day of reepithelialization. As is evident from Figure 3, the visual performance of the treated eyes was related to the progress of the epithelial healing as well as the transparency changes in the replaced epithelial sheet. By the day of reepithelialization, mean logMAR UCVA was 0.19 ± 0.09 (range

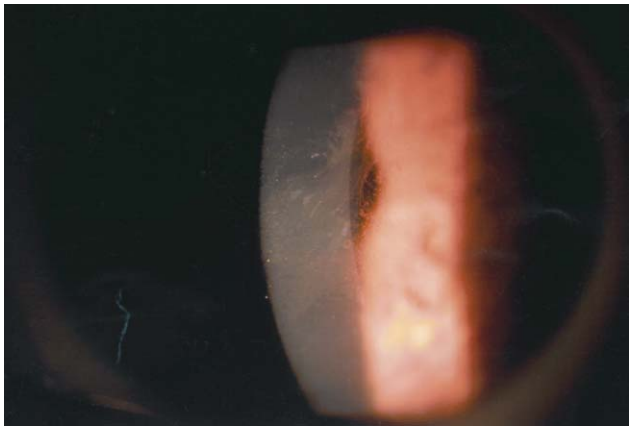

Figure 1. Slitlamp photograph of an eye treated with epi-LASIK on day 3. As reepithelialization progresses, the separated epithelial sheet shrinks in the central part and has a hazy appearance.

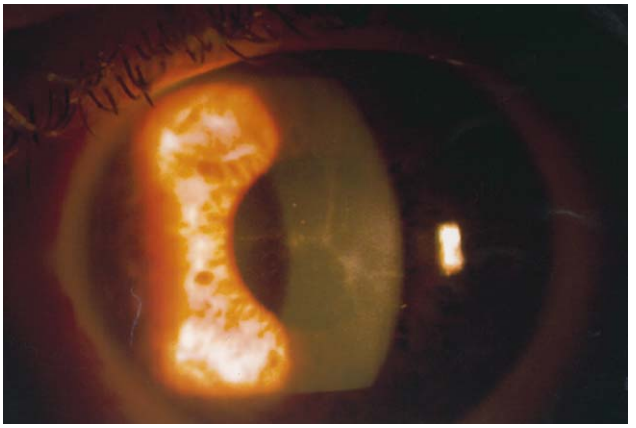

Figure 2. Slitlamp photograph of an eye treated with epi-LASIK on day 5. The repopulation of the corneal surface with epithelial cells and the central healing line signaled the removal of the therapeutic contact lens.

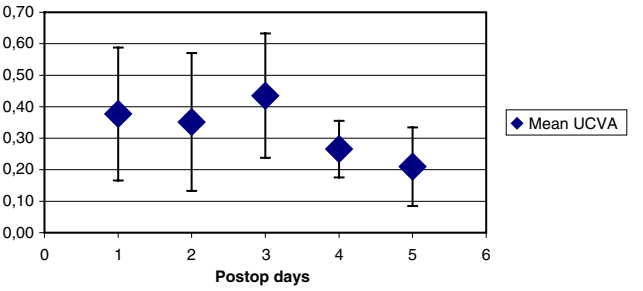

Figure 3. Mean (±SD) daily records of logMAR UCVA during the first 5 days after epi-LASIK for low myopia (N = 44).

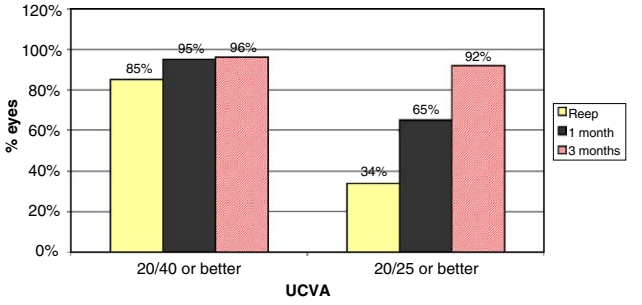

Figure 4. Uncorrected visual acuity on the reepithelialization day (N = 44) and 1 (N = 44) and 3 (N = 37) months after epi-LASIK for low myopia.

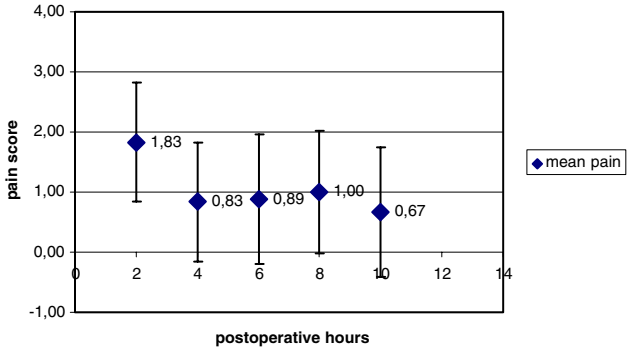

Figure 5. Mean (±SD) subjective score of pain (grade 0 to 4) during the first 10 hours after epi-LASIK.

0.40 to 0.10). Fifteen eyes (34%) had logMAR UCVA equal to or better than 0.10 and 37 (85%) eyes had logMAR UCVA equal to or better than 0.30 (Figure 4).

Figure 5 summarizes the subjective mean pain scores of the first postoperative hours. During the first 2 hours after the treatment, 5 (16%) patients (1 with bilateral and 4 with unilateral epi-LASIK treatments) reported burning pain that required medication (pain score grade 3). None of them received oral analgesic because the pain subsided within the next postoperative hours. The rest of the patients reported no pain (65%, 20 patients) or mild discomfort (19%, 6 patients).

On the first postoperative day, 8 (26%) treated patients reported mild discomfort (pain score grade 1). Four had bilateral epi-LASIK, and 4 had 1 eye treated with epi-LASIK and the fellow eye treated with PRK (3 patients) or LASIK in simultaneous bilateral treatments. Patients whose fellow eye was treated with PRK reported the pain to be the same in both eyes. The patient who was treated with LASIK in his fellow eye reported that the discomfort was in the eye treated with epi-LASIK.

By the third postoperative day, there was no report of pain or discomfort related to any epi-LASIK treatment.

Late Postoperative Period

The mean logMAR UCVA was 0.11 ± 0.10 (range 0.50 to −0.10) at the first postoperative month (N = 44); 3 months after the treatment (N = 37), mean logMAR UCVA improved to 0.01 ± 0.09 (range 0.20 to −0.10) with 92% (N = 34) of treated eyes having logMAR UCVA of 0.10 or better (Figure 4).

Three months after treatment, mean logMAR best spectacle-corrected visual acuity (BSCVA) was −0.04 ± 0.05 (range 0.10 to −0.10). No eye lost more than 1 line of BSCVA, and 13 eyes (35%) gained 1 or 2 lines (1 eye) of BSCVA (Figure 6).

Figure 7 plots the attempted and achieved corrections in all eyes during the follow-up period. The mean spherical equivalent was −0.30 ± 0.60 D (range −1.0 to 0.87 D) 1 month after treatment when 21 eyes (48%) were within ±0.50 D and 42 (95%) eyes were within ±1.0 D of attempted correction. Three months after treatment, the mean spherical equivalent was −0.009 ± 0.41 D (range −0.75 to 0.75) with 29 (78%) of the treated eyes within ±0.50 D and 37 eyes (100%) within ±1.00 D of the target refraction.

Figure 8 plots the recorded haze during the follow-up period. With the exception of 1 (3%) eye that had patches of mild haze within the treatment zone, 3 months after the treatment the operated corneas were either clear (56%) or had trace haze. The mean haze score 1 month after treatment was 0.66 ± 0.71 and was reduced to 0.46 ± 0.55 3 months after the operation.

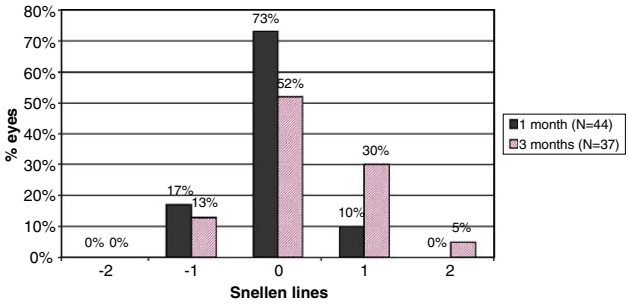

Figure 6. Difference (gain/loss) of BSCVA lines during the follow-up period from baseline.

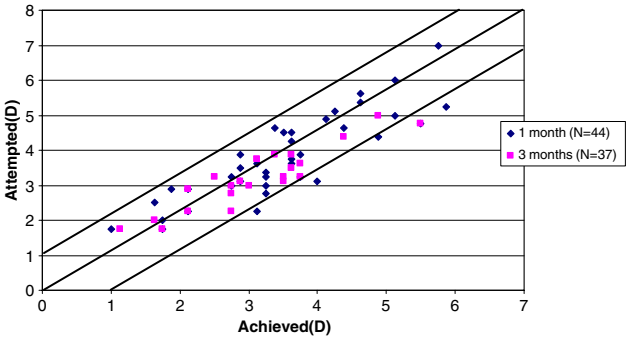

Figure 7. Attempted versus achieved spherical equivalent correction 1 (N = 44) and 3 (N = 37) months after epi-LASIK.

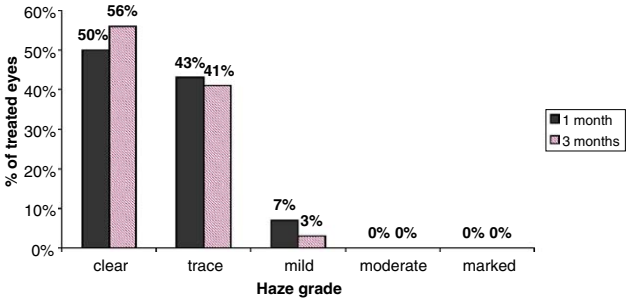

Figure 8. Corneal haze (grade 0–4) at 1 (N = 44) and 3 (N = 37) months after the treatment.

Discussion

The idea of Camellin (M. Camellin, M. Cimberle, "LASEK technique promising after 1 year of experience." Ocular Surgery News, International Edition, 2000, pages 14–17) and others[3,7] to maintain an epithelial flap that can be replaced on the cornea renewed interest among refractive surgeons in surface treatments. In a comparative prospective study of 27 patients, Lee et al.[2] provided the first clinical evidence that patients treated with LASEK for low and moderate myopia had lower postoperative pain and haze scores than PRK-treated eyes. Although Litwak et al.[8] conducted a similar study that questioned these results, an increasing number of authors suggest that LASEK may provide advantages over PRK for the correction of myopia.[2,3,7,9–17]

The fundamental difference between epi-LASIK and LASEK is that the separation of the epithelial sheet is obtained mechanically without requiring the preparation of the cornea with alcohol or other chemical agent. Mechanical separation not only avoids the probable toxic effect of alcohol[18–21] on the separated epithelial sheet but also provides an automated surgical procedure with a short learning curve for LASIK surgeons.

This study shows that epi-LASIK is an efficient method for the correction of low myopia. The main goal of any alternative surface procedure, however, is to deal with the main drawbacks of conventional PRK, that is, postoperative pain, delayed visual rehabilitation, and, most important, the risk of haze.

In this series, 38% of the treated eyes had UCVA of 20/40 or better on day 1. The percentage of eyes with UCVA of 20/40 or better on day 1 after LASEK ranges between 10%[9] and 45%.[10] We assume that the differences among LASEK studies of UCVA on day 1 may be related to the variable effect of alcohol on the separated epithelial sheet. In any case, the day 1 visual

performance of epi-LASIK-treated eyes in our series seem to correlate well with the best reported results of LASEK treatments.

In most patients in our series (78%), the therapeutic contact lens was removed by day 5 (ie, 1 day later than after LASEK treatments[9,11,14]). The most probable explanation for this relative delay is the wider epithelial separation with the epikeratome (10 mm or more) resulting in a larger epithelial defect.

Similar to LASEK,[7,11,14] epi-LASIK was not a totally pain-free procedure. In our series, 16% of the treated patients reported burning pain, which presented within the first postoperative hours and disappeared without administration of any oral medication.

Most patients (97%) had clear corneas or trace haze 3 months after the treatment. As shown in Figure 8, there was a trend toward haze improvement from the first to the third postoperative month with no recorded new cases of haze by the third month after epi-LASIK. Stramer et al.[21] recently used a rabbit organotypic culture model and showed that the integrity of the basement membrane is a deciding factor in determining the regenerative character of the corneal repair. Our previous histological studies of mechanically separated corneal epithelial sheets have shown that the cleavage plane of the mechanical separation is underneath the basement membrane, thus preserving its integrity upon separation.[4,5] The lack of late-onset corneal haze during the follow-up of our patients is definitely an encouraging clinical result that may be related to the replaced epi-LASIK sheet, but we cannot exclude that it is also related to both the low attempted correction of the treated eyes[22] and the smooth ablation pattern of the laser we used for our treatments.

We did not find any statistically significant difference of spherical equivalent refraction between the first and third month postoperative intervals (matched paired, 2-tailed Student t test; $P = .22$) in this series. All the treated eyes were within 0.50 D of refractive change between 1 and 3 months after the procedure. Despite the stability of the refractive result, we recorded an improvement of visual performance during the follow-up period (Figure 6), suggesting some corneal remodeling at that period. Four eyes in our series had 1 line loss 3 months after the treatment for no obvious reason. In all these cases, visual acuity decreased from 20/16 to 20/20.

We feel that future studies should include contrast sensitivity testing and wavefront analysis of the treated eyes to provide some answers regarding the quality of vision of these patients. In summary, Epi-LASIK seems to be effective for the correction of low myopia. Although not totally pain free and not having as rapid visual recovery as LASIK, it provides reasonable visual results during the early postoperative period after the treatment. The majority of the treated patients had satisfactory visual performance and reported minimal irritation because of the treatment. Our preliminary results show a stable refractive effect with minimal haze of the treated eyes and compare well with those of myopic LASEK. The potential benefits of the retained epithelial sheet are yet to be determined in a prospective randomized comparative study between Epi-LASIK and PRK.

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