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Epi-Bowman keratectomy versus alcohol-assisted photorefractive keratectomy: wound healing and complications

Suphi Taneri, Saskia Kießler, Anika Rost, Tim Schultz and H. Burkhard Dick

Abstract

Purpose: In Epi-Bowman Keratectomy™ (EBK), a new dynamic multi-blade single-use device (Epi-Clear™, Orca Surgical, Israel) is utilized to remove the epithelium by sweeping movements across the corneal surface. Epithelial cells are discarded. Alcohol or other chemical agents are not utilized. We wanted to compare clinical results of Epi-Clear photorefractive kertectomy (PRK) to alcohol-assisted PRK.

Study design: Retrospective, comparative study.

Methods: Consecutive case series: Adult patients seeking laser vision correction of myopia or myopic astigmatism without ocular diseases or prior surgery were included. The Epi-Clear PRK group comprised 50 consecutive eyes of 27 patients and the PRK group 50 eyes of 25 patients.

Results: No intraoperative complications occurred. Epi-Clear PRK: At day 1, day 4, and 3 months, uncorrected distance visual acuity (UDVA) was 0.41/0.47/0.93 (decimal scale); epithelial defect diameter was 4.7/0.2/0 (mm); pain level was 3.8/0.3/0 (visual analogue scale, 0–10), respectively. At 3 months, efficacy index was 0.86 and spherical aberrations were unchanged. Three eyes (6%) showed (presumably sterile) infiltrates. PRK: At day 1, day 4, and 3 months, UDVA was 0.56/0.46/1.15; epithelial defect diameter was 6.3/0.2/0 (mm); pain level was 5.0/0.3/0, respectively. At 3 months, efficacy index was 1.1 and spherical aberrations were unchanged.

Conclusion: The new method of epithelial debridement with Epi-Clear before laser ablation seems to offer fast epithelial removal without nicking Bowman's layer (as observed with the laser microscope). However, we found significantly inferior results of Epi-Clear PRK compared to alcohol-assisted PRK. Furthermore, after Epi-Clear PRK corneal infiltrates as a new type of postoperative complication were observed.

Keywords: Epi-Bowman Keratectomy, Epi-Clear, surface ablation

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Correspondence to:
Suphi Taneri
Center for Refractive Surgery, Eye Department, St. Francis Hospital, Hohenzollernring 70, 48145 Münster, Germany
University Eye Hospital, Ruhr-University Bochum, Bochum, Germany
taneri@refraktives-zentrum.de

Saskia Kießler
Anika Rost
Center for Refractive Surgery, Eye Department, St. Francis Hospital, Münster, Germany

Tim Schultz
H. Burkhard Dick
University Eye Hospital, Ruhr-University Bochum, Bochum, Germany

Introduction

Photorefractive keratectomy (PRK) is a well-established method of refractive surgery to correct low to moderate ametropia and astigmatism.[1] Before the corneal stroma is ablated with an excimer laser, the epithelium is removed either purely mechanically with a blade or a rotating brush or after chemically loosening the adherence of the epithelium to the underlying Bowman's layer with an alcoholic solution.[2] After ablation, the stromal bed is exposed to the tear film until the epithelium heals after a couple of days.[3] At times, the wound-healing response in this unprotected stromal bed leads to subepithelial haze formation.[4] In addition, the final outcome may be influenced by, among other factors, the comparatively strong wound-healing response.[5]

In 2012, a new instrument (Epi-Clear, Orca Surgical, Kiryat-Shmona, Israel) for epithelial removal was developed. This handheld device has a bowl-shaped single-use flexible head consisting of biocompatible polymer. The tip has a central groove with double-bladed rims, designed to

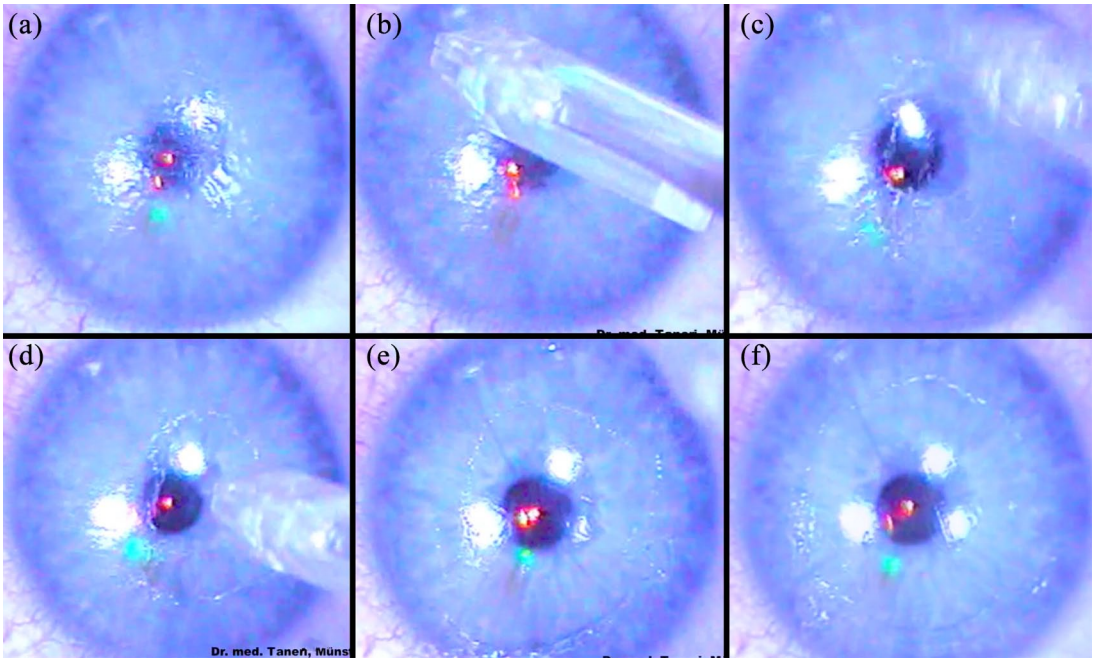

Figure 1. Illustration of epithelial removal: (a) untreated cornea, (b–e) epithelial removal by sweeping movements until bowman's layer is reached, and (f) complete epithelial debridement.

remove the epithelium layer by layer as it is repeatedly swept across the corneal surface with gentle pressure (Figure 1, Supplemental Video 1).

While other mechanical instruments may damage Bowman's layer during epithelial removal, the comparatively softer material of the Epi-Clear device may potentially provide a debris-free stromal surface for laser ablation without harming Bowman's layer.[6] No chemical substance such as alcohol or other potentially toxic agents are needed. The refractive procedure consisting of using the new Epi-Clear device for epithelial removal and subsequent laser ablation was named Epi-Bowman Keratectomy (EBK). The device is not yet approved by the Food and Drug Administration (FDA).

Some authors have reported that Epi-Clear PRK yields superior results compared to alcohol-assisted PRK in terms of higher patient comfort, faster healing, and faster visual recovery.[7–15] As peer-reviewed studies of Epi-Clear PRK are rare to date,[16] we wanted to compare clinical results of Epi-Clear PRK to alcohol-assisted PRK.

Patients and methods

This study consists of a prospective consecutive case series of 50 Epi-Clear PRK treatments with a control group of 50 alcohol-assisted PRK (PRK group) treatments.

Adult patients seeking vision correction were counseled about their surgical options during the preoperative examination. If they were deemed suitable for LASIK and surface ablative procedures, they could choose according their preference.

Exclusion criteria for this study, in addition to other commonly accepted contraindications to surface ablation, included a history or slit lamp signs of ocular trauma or ocular surgery and systemic use of corticosteroid, anti-metabolite, or immunosuppressant agents. Patients with a history of recurrent basement layer dystrophy or recurrent erosion syndrome were also excluded.

Soft contact lenses wear was discontinued at least 2 weeks, and rigid contact lenses at least 4 weeks before the initial examination. Preoperative evaluation included uncorrected distance visual acuity (UDVA, decimal scale), subjective refraction, corrected distance visual acuity (CDVA, decimal scale), low contrast visual acuity, stereoscopic depth perception (Stereo Test), slit lamp biomicroscopy, Orbscan IIz anterior segment evaluation (Technolas Perfect Vision GmbH, Munich, Germany), aberrometry (Zywave, Technolas Perfect Vision GmbH), dim-light pupillometry

(Zywave), endothelial microscopy (SP 3000 P, Topcon Medical Systems, Oakland, NJ, USA), intraocular pressure measurement (Rebound-Tonometer, iCare Ta-01, Bon Optic, Luebeck, Germany), and dilated fundus evaluation. Automated refraction in miosis and after pharmacologic pupil dilation was obtained with a Canon R-F10 device (Canon Inc., Tokyo, Japan).

All patients provided informed consent before surgery and gave written consent to anonymous collection of their data for scientific analysis, as required by the local ethics committee (Ethikkommission der Ärztekammer Westfalen-Lippe und der Westfälischen Wilhelms-Universität). The same ethics committee waived the need for a specific approval of this study as patients were not randomized and no additional tests were performed than is our routine protocol. The study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki.

Surgical technique

The same surgeon (S.T.) performed all procedures in a standardized manner. The pre-treatment was described previously.[17] Approximately 30 minutes before surgery, one drop of unpreserved oxybuprocaine (Conjucain EDO, Dr. Mann Pharma, Bausch & Lomb, Berlin, Germany) and one drop of unpreserved ofloxacin eye-drops (Floxal EDO, Dr. Mann Pharma, Bausch & Lomb, Berlin, Germany) were instilled in the eyes. In addition, patients received a single tablet of bromazepame 6 mg (Bromazepam, F. Hoffmann-La Roche AG, Basel, Switzerland) to minimize intraoperative discomfort. Immediately before surgery, the eyelids were disinfected with povidone iodine 10% (Betaisodona, Mundipharma, Limburg, Germany) and draped in a sterile fashion. Topical anesthesia was achieved with several drops of unpreserved oxybuprocaine (Conjucain EDO, Dr. Mann Pharma, Bausch & Lomb, Berlin, Germany). Then a speculum with suction was placed in the operative eye. Ice-cool physiologic saline solution was administered for 30 seconds to cool the ocular surface and reduce postoperative pain perception.[18]

Epithelial separation

In the Epi-Clear PRK group, epithelial debridement was performed by sweeping movements with the Epi-Clear device until the stromal surface appeared smooth and clean under the laser microscope (see Supplementary Video EBK. mp4). Intended epithelial defect size was 8.7 mm and was controlled using the head of the Epi-Clear device (9.0 mm) as a gauge.

Postoperatively, achieved epithelial defect was measured for statistical analysis as follows: Using the surgical videos, the horizontal and vertical diameter of the defect was determined and the average taken.

In the PRK group, an epithelial defect with a standardized diameter was obtained as follows:[17] A Vidaurri Fluid Retention Ring (Katena, Denville, NY, USA) with an 8.7 mm inner diameter was placed on the cornea and filled with 18% ethanol for 30 seconds. Then, the ethanol was absorbed using dry non-fragmenting sponges and the ocular surface was rinsed again with cooled saline solution. The loosened epithelium was then peeled back using a dedicated epithelial rake and a blunt spatula. If epithelial removal was not sufficiently facilitated by 30 seconds of ethanol exposure, the application was repeated for another 10 seconds. The epithelial flap was completely removed.

The underlying stromal bed was ablated with an excimer laser using an aspheric ablation profile in all eyes. Then ice-cooled saline solution was again applied approximately for 30 seconds.

In eyes with a planned ablation depth of more than 100 µm (or more than 75 µm in patients younger than 30 years), mitomycin-C (MMC) 0.02% (compounded by our pharmacy) was used to prevent haze and scar formation.

A therapeutic soft contact lens (PureVision, Bausch & Lomb, Rochester, NY, base curve 8.6 mm, optical power 0 D) was then placed over the cornea as described previously.[17] One drop of prednisolone acetate (Inflanefran forte, Allergan Pharm., Ireland, Westport Co. Mayo, Ireland) and one drop of ofloxacin were applied at the end of surgery.

Postoperative protocol

Fluorometholone (Fluoropos, Ursapharm, Saarbrücken, Germany) and unpreserved ofloxacin eye-drops were prescribed qid. Ofloxacin was stopped after 5 days or epithelial closure. Fluorometholone was tapered every 3 weeks (total 12 weeks). Oral analgesics (novaminsulfon, novaminsulfon, ratiopharm, Ulm, Germany) were prescribed to

Table 1. Baseline demographic and refractive data.

	Epi-Clear PRK	Alcohol-assisted PRK	*p* value
Number of eyes	50 of 27 patients	50 of 25 patients	
Gender (female/male)	16/11	14/11	
Age	33 years	32 years	
Median (range)	(19–52 years)	(21–56 years)	
Ametropia (D) mean ± SD (range)			
Sphere	−3.36 ± 1.48 D (−7.0 to −0.25 D)	−3.48 ± 1.44 D (−6.25 to −0.50 D)	$p = .505$
Astigmatism	−1.05 ± 0.98 D (−4.25 to +0.0 D)	−0.91 ± 0.71 D (−2.75 to −0.25 D)	$p = .953$
Spherical equivalent	−3.88 ± 1.35 D (−7.13 to −1.0 D)	−3.91 ± 1.37 D (−6.75 to −0.75 D)	$p = .605$
CDVA mean (range)	1.15 (0.8 to 1.6)	1.07 (0.63 to 1.6)	$p = .062$
Pachymetry thinnest (µm) Mean ± SD (range)	543.80 ± 49.38 µm (462 to 622 µm)	548.1 ± 40.22 µm (423 to 623 µm)	$p = .664$

CDVA, corrected distance visual acuity; D, diopters; PRK, photorefractive keratectomy; SD, standard deviation.

be taken as needed. Oral ascorbic acid 500 mg every day was recommended for 6 weeks. The contact lenses were removed after epithelial closure.

Follow-up visits

Postoperative follow-up visits were scheduled at 1 day, 4 days, and 3 months. Slit lamp examination including haze grading was performed by the surgeon without prior access to the patient's chart. We report haze levels based on the Fantes classification (0—Normal, 0.5—Possible to observe opacity under indirect light, 1—Possible to observe opacity under direct light, 2—Possible to observe iris in detail, 3—Difficult to observe iris in detail, 4—Impossible to observe iris in detail).[4] All other tests were performed by technicians without access to the patient's chart. The size of the epithelial defect was measured at the slit lamp by adjusting the length of a 0.3-mm wide slit-beam aligned with the microscope to coincide with the largest diameter of the defect before its length was read at the slit lamp while the patient was looking straight. Postoperative ocular pain level was evaluated for both eyes separately using a visual analog scale, that was correlated to a numeric analog scale from 0 to 10: 0 = absence of pain, 10 = unbearable pain (Janssen-Cilag, Neuss, Germany).

Statistical analysis

Statistical analysis was performed with SPSS for Mac (SPSS 20, IBM-Corporation). A non-parametric Mann–Whitney *U*-test was performed to test for differences in distribution between PRK and Epi-Clear PRK in preoperative data, postoperative visual acuity, pain level, epithelial defect, haze formation, and spherical aberration. A paired Wilcoxon signed-rank test was performed to compare preoperative and postoperative spherical aberrations. A p value less than 0.05 was considered statistically significant.

Results

All patients were available for follow-up-visits on the first postoperative day and after 3 months. Baseline demographic and refractive data are shown in Table 1.

The composition of both groups was comparable in terms of age and gender. There was no statistically significant difference in preoperative sphere,

Table 2. Treatment data.

Parameter	Epi-Clear PRK ($n = 50$)	Alcohol-assisted PRK ($n = 50$)	p value
Treatment data (D)			
SE			
Mean ± SD (range)	−4.21 ± 1.42 (−7.48 to −1.01)	−4.13 ± 1.35 (−7.12 to −1.16)	
Sphere			
Mean ± SD (range)	−3.68 ± 1.57 (−7.35 to −0.26)	−3.70 ± 1.42 (−6.58 to 1.42)	
Cylinder			
Mean ± SD (range)	−1.05 ± 0.98 (0 to −4.25)	−0.89 ± 0.76 (−0.16 to −2.81)	
OZ diameter (mm)			
Mean ± SD (range)	6.49 ± 0.25 (6.0 to 7.0)	6.67 ± 0.40 (6.0 to 7.5)	$p = 0.006$[a]
Maximum ablation depth (µm)			
Mean ± SD (range)	85.02 ± 21.94 (38 to 135)	90.68 ± 20.77 (32 to 127)	$p = 0.126$
MMC used (n)	10	25	
Duration of MMC (average)	10 × 30 second	16 × 15 second 9 × 30 second (20.4 sec)	$p = 0.003$[a]

D, diopters; MMC, mitomycin-C; OZ, optical zone; PRK, photorefractive keratectomy; SE, spherical equivalent; SD, standard deviation.
[a]Statistically significant ($p < 0.05$).

astigmatism, spherical equivalent, pachymetry, and CDVA between groups.

Treatment data

There was no statistically significant difference in treatment sphere, cylinder, and spherical equivalent between groups (Table 2). MMC was used more often in the PRK group.

Handling

We found a fast epithelial removal with the Epi-Clear device in the central part of the cornea. However, in the mid-periphery, the number of sweeps necessary to obtain a clean stromal surface varied, and epithelial cells were not completely collected inside the devices' head. Total time for complete epithelial removal ranged from 10 to 60 seconds.

Pain perception

Reported pain level was significantly lower on day 1 after Epi-Clear PRK than after PRK (3.7 vs 5.0), but no significant difference was found at day 4 (0.28 vs 0.02). Pain level was 0 after 1 week in all examined eyes.

Epithelial closure

Figure 2 shows the diameter of epithelial defect immediately after abrasion, on day 1, and day 4.

Initial epithelial defect was statistically significantly smaller in Epi-Clear PRK group, with an

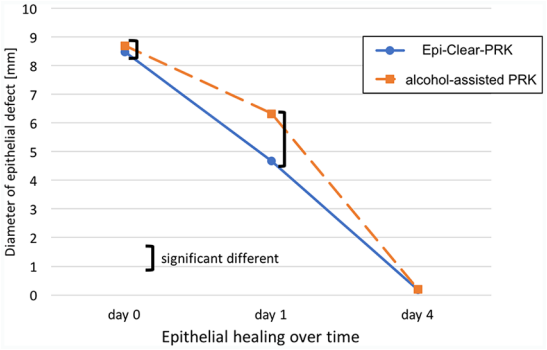

Figure 2. Epithelial healing over time, comparing Epi-Clear PRK and alcohol-assisted PRK.

average diameter of 8.5 mm compared to 8.7 mm of PRK group. At the first postoperative day, epithelial healing was statistically significantly ($p = 0.00$) more progressed in the Epi-Clear PRK group. However, no significant difference was found at day 4, when the epithelium was closed in all but one Epi-Clear PRK eye and four PRK eyes of three patients. The epithelium of the Epi-Clear PRK eye was closed after 1 week; however, it loosened again spontaneously shortly after removal of the contact lens. It remained intact after re-removal of a second contact lens 2 weeks later. In all PRK eyes, the epithelium was closed after 1 week and remained so during follow-up.

Haze

At 3 months, mean haze level was significantly higher after Epi-Clear PRK than after alcohol-assisted PRK (0.35 vs 0.1; $p = 0.006$). Five Epi-Clear PRK eyes of four patients had haze grade 1 at 3 months. Maximum haze level 3 months after Epi-Clear PRK was grade 2 and occurred in both eyes of two patients. In these eyes, corticoid therapy was prolonged for another 3 months. At 10 months, in one of these patients, haze remained grade 1 and 2. However, visual acuity was not affected (efficacy index OD 1.25, OS 1.125). In both eyes of the second patient, only trace haze was noticeable after 1 year.

Three months after alcohol-assisted PRK maximum haze level was grade 1 in four eyes.

Visual acuity and efficacy index

Three months postoperatively, UDVA was 1.0 or better in 71% of Epi-Clear PRK eyes and 98% of PRK eyes. Similarly, UDVA was within one line of preoperative CDVA in 74% of Epi-Clear PRK eyes and in 100% of PRK eyes (Figure 3).

Mean UDVA after Epi-Clear PRK was significantly worse than after alcohol-assisted PRK on day 1 ($p = 0.003$) and after 3 months ($p = 0.001$; Figure 4).

Efficacy index, that is, the quotient of postoperative UDVA and preoperative CDVA, was 0.86 for Epi-Clear PRK and 1.10 for alcohol-assisted PRK at 3 months, thus Epi-Clear PRK was significantly less effective than alcohol-assisted PRK.

Spherical aberration

Figure 5 shows preoperative and postoperative spherical aberration for Epi-Clear PRK and PRK-treated eyes. At 3 months, the treatment-induced spherical aberrations were not statistically significant in both groups, respectively.

Complications

No intraoperative complication including damage to Bowman's layer before and during epithelial removal occurred in any eye as evaluated through the laser microscope.

After Epi-Cear PRK treatments, we observed a new complication, namely presumably sterile infiltrates: three eyes of three different patients developed infiltrates (Figure 6) close to the center of the cornea.

One eye had a small infiltrate 1 month after surgery which was almost completely resolved after another 2 months (Figure 6(a)). Preoperative CDVA was 1.25 and UDVA 3 months after Epi-Clear PRK was 0.80. Another eye presented with two small infiltrates adjacent to each other 2 weeks after surgery (Figure 6(b)). After 3 months, its appearance had changed to a circular opacification with a sharp border reaching down into the stromal layer. Six months after Epi-Clear PRK only haze grade 1 was left as a residue (see Figure 7 for development over time).

At this point in time, UDVA was 0.8 and CDVA was 1.0 (preoperative CDVA 1.0). The third patient presented with a small infiltrate 1 month after Epi-Clear PRK that had a less well-defined borderline than the other infiltrates (Figure 6(c)). The aspect of this infiltrate did not change during

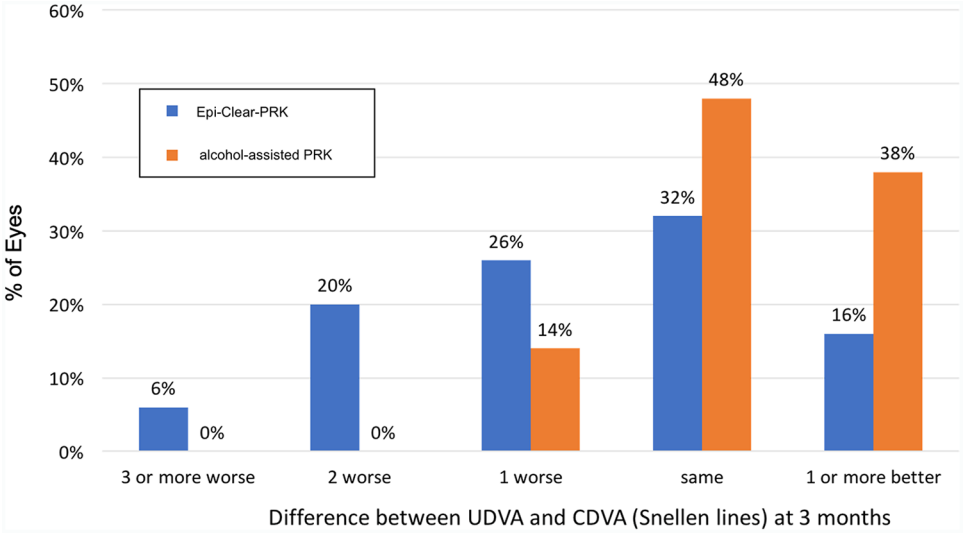

Figure 3. Visual acuity after Epi-Clear PRK and alcohol-assisted PRK: difference between uncorrected distance visual acuity at 3 months postoperatively and preoperative corrected distance visual acuity.

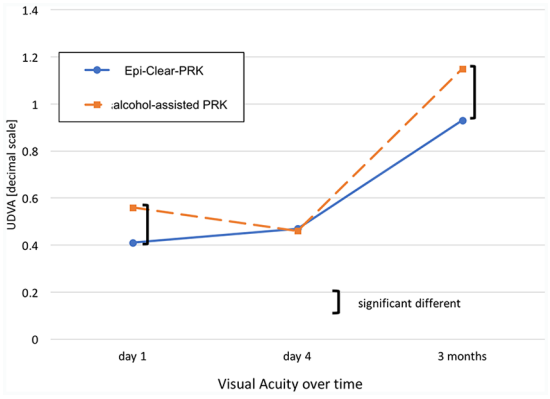

Figure 4. Uncorrected visual acuity over time, comparing Epi-Clear PRK and alcohol-assisted PRK.

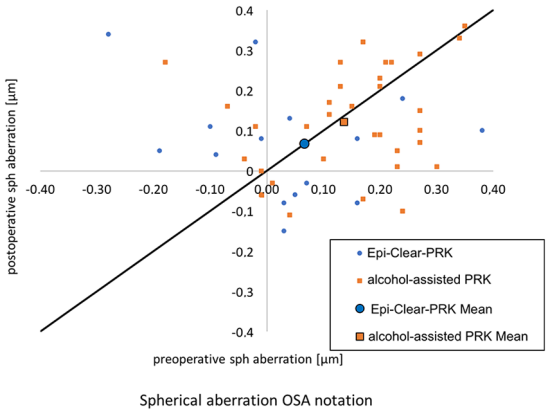

Figure 5. Change in spherical aberration preoperative and postoperative (3 months), comparing Epi-Clear PRK and alcohol-assisted PRK.

the next 2 months, and UDVA was 0.63 (CDVA 1.0). This patient was lost to further follow-up.

As the affected eyes did not show any sign or symptom of an active infection, no antibiotics were given to treat these infiltrates. However, no microbiological testing was performed to rule out an infection. A complaint was filed after each case to the manufacturer of the Epi-Clear device. The response was that this complication had not been reported before. Remaining Epi-Clear devices of the same lot as the one used in a case developing an infiltrate were returned to the manufacturer to be examined for microbial contamination or toxic particles on its surface. These evaluations yielded no explanation.

No other postoperative complication was observed in any Epi-Clear PRK or PRK-treated eye.

Discussion

PRK is known to safely, effectively, and predictably correct low to moderate ametropias. However, its equally known disadvantages, pain perception, and slow visual recovery, have led to numerous modifications of the original technique.[2] EBK is the latest of these modifications reported to have significant benefits over alcohol-assisted PRK. However, most of these reports are anecdotal, lack a control group, or have a small sample size.[16]

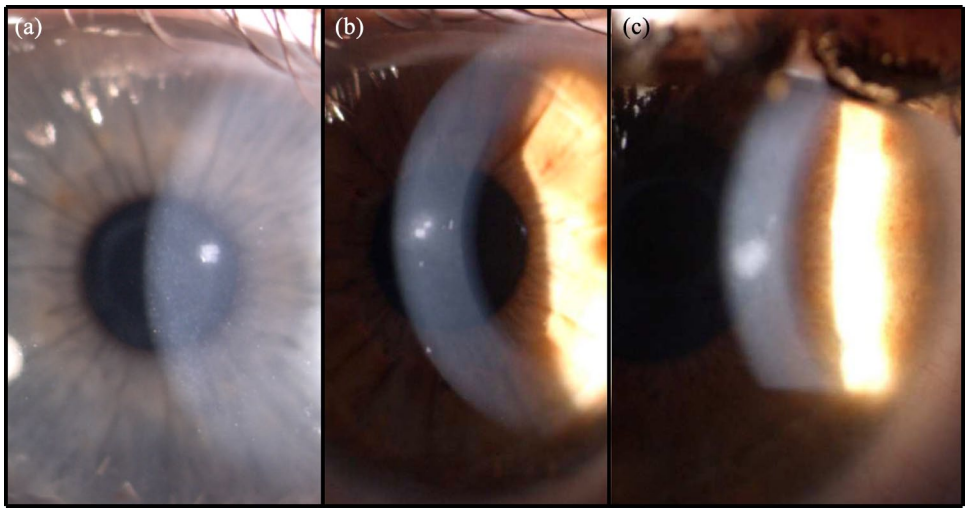

Figure 6. Slit lamp photos of infiltrates in three eyes of three different Epi-Clear patients: (a) first eye at 1 month, (b) second eye at 2 weeks, and (c) third eye at 2 months.

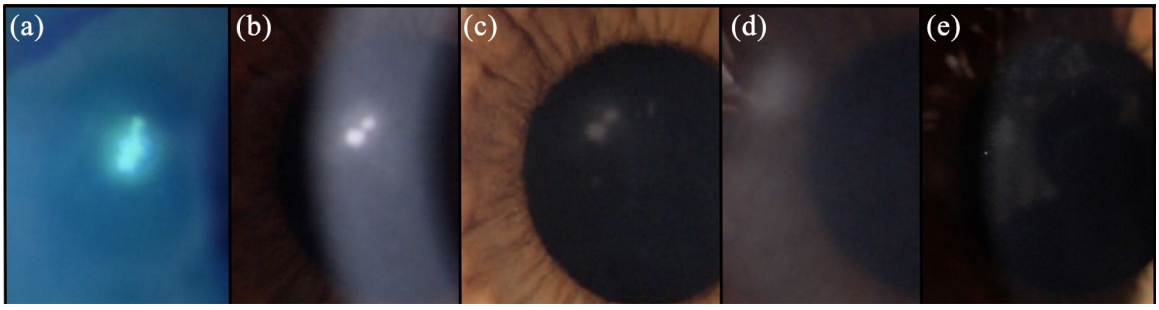

Figure 7. Change of sterile infiltrate over time: (a) 49 days postoperative, (b) 55 days postoperative, (c) 2 months postoperative, (d) 3 months postoperative, and (e) 6 months postoperative.

Therefore, we evaluated several aspects in this study, including ease of performing Epi-Clear PRK, its clinical outcomes and complications.

There are two reports[8,11] stating 10 seconds as the mean time for epithelial removal with the Epi-Clear device; another study reports a range from 30 to 60 seconds.[19] Similarly, it is reported that epithelial removal with Epi-Clear is significantly faster than with alcohol[7] or with a metallic scraper.[10] In our hands, the Epi-Clear device constantly enabled a fast central epithelial removal. However, the sweeping movements were not equally effective in the corneal mid-periphery, causing the time to complete the abrasion to range from 10 to 60 seconds, with most abrasions lasting approximately 30 seconds. We consider this a negligible advantage to epithelial removal with an alcoholic solution.

In terms of pain perception, we found a significantly favorable outcome 1 day after epithelial removal with Epi-Clear than with alcohol. We may speculate that the alcohol used in the PRK treatments may have augmented the pain perception. However, we found no difference on day 4 and later. To examine this potentially relevant benefit of Epi-Clear PRK in the early postoperative period, further studies with shorter time intervals in between pain reporting would be necessary.

Two studies reported significantly less pain after Epi-Clear PRK, comparing intra-individually,[11] to PRK with epithelial removal using a metallic scraper. Taieb and colleagues[8,20] report that Epi-Clear PRK patients stopped complaining about pain or discomfort after 3 days, whereas some patients with epithelial removal with a metallic scraper still complained about pain after 5 days.

In contrast, no differences in postoperative pain perception were found in two studies comparing Epi-Clear PRK with alcohol-assisted PRK[7,21] and in three studies comparing Epi-Clear PRK to PRK with epithelial removal by a metallic scraper.[12,13,15]

Epithelial closure

The role of Bowman's layer is not yet completely investigated, but it seems to promote wound healing and re-epithelialization after corneal trauma.[22] Shetty and colleagues[10,23] analyzed images of optical coherence tomography (OCT), comparing the integrity of Bowman's layer after epithelial removal with Epi-Clear and with a mechanical scraper, respectively. After using Epi-Clear, they found an undamaged Bowman's layer in healthy as well as keratoconic corneas, whereas Bowman's layer showed nicks after using a mechanical scraper. We may speculate that preserving an intact Bowman's layer could be beneficial when cross-linking the cornea with UV light and riboflavin. We are not aware of a comparative study of using the Epi-Clear device and other methods of epithelial removal before corneal cross-linking, but would ask for such a study. However, in laser ablative surgery at the stromal surface, irrespective if it is Epi-Clear PRK or alcohol-assisted PRK, Bowman's layer will be damaged anyway. Consequently, at least in theory Epi-Clear PRK offers no benefit over other methods of epithelial abrasion in this regard.

The initial epithelial defect after surgery was statistically, but in our opinion not clinically significantly different as the mean difference was only 0.2 mm. We found a significantly smaller epithelial defect on day 1 after Epi-Clear PRK (by approximately 2 mm) and a similar epithelial defect size on day 4 in both groups. However, the smaller defect 1 day after Epi-Clear PRK may be influenced by the smaller initial defect size in this group compared to the PRK group. Ideally, the epithelial defect size and shape in such a study would be identical in all eyes. That is why we used an alcohol-retention ring with suction in all alcohol-assisted PRK eyes to obtain a circular epithelial defect with a constant diameter (8.7 mm). Despite our best efforts to standardize the epithelial defect with Epi-Clear PRK, too, we found a smaller mean epithelial defect (8.5 mm) when evaluating the surgical videos after the surgery.

Five studies claim a faster epithelial closure after Epi-Clear PRK than after conventional PRK.[7,9,10,12,14] However, they fail to report the size of the initial epithelial defects. Kaluzny and colleagues[7] found the same epithelial defect diameter after Epi-Clear PRK and alcohol-assisted PRK in the first 2 days. At day 3, epithelial defect was significant smaller after Epi-Clear PRK. Again, no initial size was reported. However, without providing the initial defect size the value of comparing the epithelial healing speed is questionable because the smaller the initial defect, the faster a closure is to be expected.

Visual acuity

Visual acuity in this study was significantly worse after Epi-Clear PRK than after alcohol-assisted PRK at the first postoperative day and after 3 months. We assume the lower visual acuity 3 months after Epi-Clear PRK may be a result of the more pronounced postoperative haze in this group rather than a consequence of the three complicated cases as the visual acuity in these eyes was only slightly affected. This is compatible with two studies with a shorter follow-up reporting no differences in visual acuity between Epi-Clear PRK and alcohol-assisted PRK 4 and 7 days after treatment.[9,21] Similarly, two studies with intra-individual comparison between Epi-Clear PRK and PRK using a metallic scraper showed no difference in visual recovery within the first 30 days.[12,14] Recently, a prospective contralateral eyes study in 22 patients has been published.[24] The main conclusions were that Epi-Clear PRK may minimize postoperative pain, accelerate re-epithelialization, and offer earlier visual recovery, compared to alcohol-assisted PRK in myopic ablations. This is in clear contrast to our findings.

In both groups, we found no significant induced aberrations which may be due to the comparatively low degree of attempted correction, the aspheric ablation profile used, and the large treatment zones.

Postoperative complications

The most common postoperative complication after surface ablation is haze formation.[2] In our study, we found more haze in Epi-Clear PRK than in PRK after 3 months. However, MMC was used less frequently in Epi-Clear PRK which may have contributed to this difference. A longer follow-up would be needed to evaluate haze in the long-term.

After Epi-Clear PRK, we observed infiltrates in three eyes of three different patients (6%). The infiltrates were located near the corneal center where the epithelium typically closes last. However, initial epithelial healing had been uneventful in all of these eyes and the earliest patient presented 2 weeks after Epi-Clear PRK. We presume these infiltrates were sterile because they responded well to corticoid therapy without the use of antibiotics. Corneal scraping was not performed because visual acuity was only minimally affected, and signs and symptoms did not justify invasive diagnostic interventions. Unfortunately, we could not identify a cause for this potentially serious complication. We have not encountered such infiltrates after corneal surface ablations in any other of our refractive patients to date. In contrast, we have observed sterile infiltrates after corneal cross-linking in a few cases as first described by Mangioris and colleagues.[25] In this case report, a hypersensitivity reaction to the riboflavin or UVA light in the anterior stroma is assumed to be causative. We have no similar potential causes in Epi-Clear PRK as no chemical agent or more intense UV light compared to alcohol-assisted PRK are utilized. Other distinguishing features of sterile infiltrates after corneal cross-linking are the ring-shaped location at the periphery of the initial epithelial defect and a surrounding inflammatory corneal edema as opposed to the paracentral location without edema observed after Epi-Clear PRK. Moreover, infiltrates after corneal cross-linking typically present in the early postoperative days (usually before epithelial closure); however, the earliest presentation after Epi-Clear PRK was 2 weeks post-surgery. Because of these differences, we assume that both types of infiltrates are of different origin.

This study has limitations. One limitation is the comparison of two groups, rather than comparing intra-individually between both techniques. Therefore, some confounding factors cannot be ruled out. However, one major finding, the infiltrates after Epi-Clear PRK, are not affected by this study design.

A second limitation of our study is the postoperative measurement of the epithelial defect diameter on a computer screen, rather than exactly measuring it during surgery; which would be difficult to perform and could cause drying of the cornea if too time consuming. This may have led to a different initial defect size in both groups. However, no study with a better methodology is published to the best of our knowledge.

In conclusion, the new method of epithelial debridement with the Epi-Clear device before laser ablation includes an extra cost that needs be added to the total expense of this procedure and seems to offer fast epithelial removal without using alcohol. However, we found significantly inferior results of Epi-Clear PRK compared to alcohol-assisted PRK. Furthermore, corneal infiltrates as a new type of postoperative complication were observed after Epi-Clear PRK. Therefore, we ceased to perform Epi-Clear PRK in our patients.

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ORCID iD

Suphi Taneri https://orcid.org/0000-0003-0593-6847

Supplemental material

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References

1. Seiler T, Bende T, Wollensak J, *et al.* Excimer laser keratectomy for correction of astigmatism. *Am J Ophthalmol* 1988; 105: 117–124.
2. Taneri S, Weisberg M and Azar DT. Surface ablation techniques. *J Cataract Refract Surg* 2011; 37: 392–408.
3. Lee JB, Choe C-M, Kim HS, *et al.* Comparison of TGF-beta1 in tears following laser

subepithelial keratomileusis and photorefractive keratectomy. *J Refract Surg* 2002; 18: 130–134.

4. Fantes FE, Hanna KD, Waring GO 3rd, *et al.* Wound healing after excimer laser keratomileusis (photorefractive keratectomy) in monkeys. *Arch Ophthalmol* 1990; 108: 665–675.
5. Detorakis ET, Siganos DS, Kozobolis VP, *et al.* Corneal epithelial wound healing after excimer laser photorefractive and photoastigmatic keratectomy (PRK and PARK). *Cornea* 1999; 18: 25–28.
6. Orca Surgical. www.orcasurgical.com
7. Kaluzny B, Szkulmowski M, Grulkowski I, *et al.* Epi-Bowman Keratectomy vs. alcohol-assisted PRK: healing process evaluation with spectral OCT with novel speckle reduction technique. In: *Presented at the congress of the ESCRS*, Amsterdam, October 2013.
8. Taieb M, Bar-on Y, Fink A, *et al.* Epi-Bowman Keratectomy. *Cataract Refract Surg Today* 2013; 2013: 30–31.
9. Ashar J. Paired eye comparison of Epi Bowman Keratectomy (EBK) versus alcohol assisted (AA) PRK surgery. In: *Presented at ESCRS winter meeting*, Athen, February 2016.
10. Shetty R, Nagaraja H, Pahuja NK, *et al.* Safety and efficacy of Epi-Bowman Keratectomy in photorefractive keratectomy and corneal collagen cross-linking: a pilot study. *Curr Eye Res* 2016; 41: 623–629.
11. Taieb M. EBK: Epi-Bowman's Keratectomy. Long term results (160 eyes). In: *Presented at the congress of the ESCRS*, Amsterdam, October 2013.
12. Gyenes A, Filkorn T, Kránitz K, *et al.* Epi-Bowman Keratectomy: a new technique for the improvement of outcomes in surface ablation procedures. In: *Presented at the congress of the ESCRS*, Amsterdam, October 2013.
13. Nagy Z. Evaluation of clinical results obtained with PRK compared with new procedure: Epi-Bowman Keratectomy. In: *Presented at ASCRS symposium*, San Francisco, CA, April 2013.
14. Güell J. The use of a novel device for removal of the epithelium in surface ablation procedures. In: *Presented at ESCRS winter meeting*, Warschau, February 2013.
15. Aroor CD, Shetty R, Mahajan S, *et al.* Epithelial healing, haze, and optical outcome with Epi-Bowman Keratome used for surface ablation in photorefractive keratectomy. In: *Presented at ASCRS symposium*, San Diego, CA, April 2015.
16. Taneri S, Kießler S, Rost A, *et al.* Epi-Bowman-Keratektomie: klinische Beurteilung einer neuen Variante der Surface Ablation. *Klin Monatsbl Augenh* 2018; 235: 1371–1382.
17. Taneri S, Oehler S, MacRae S, *et al.* Influence of a therapeutic soft contact lens on epithelial healing, visual recovery, haze, and pain after photorefractive keratectomy. *Eye Contact Lens* 2018; 44: S38–S43.
18. Niizuma T, Ito S, Hayashi M, *et al.* Cooling the cornea to prevent side effects of photorefractive keratectomy. *J Refract Corneal Surg* 1994; 10(Suppl. 2): S262–S266.
19. Wajnsztajn D. Epi-Bowman's Keratectomy for crosslinking for keratoconus. In: *Presented at ESCRS winter meeting*, Amsterdam, October 2013.
20. Taieb M. Epi-Bowman Keratectomy (EBK) with the Epi-Clear*, new device for corneal epithelial ablation: the 10 first treated patients. In: *Presented at the congress of the ESCRS*, Milan, September 2012.
21. Ruiz-Mesa R and Abengozar-Vela A. A comparative study of Epi-Bowman Keratectomy and ethanol in photorefractive keratectomy. In: *Presented at the congress of the ESCRS*, Copenhagen, September 2016.
22. Lagali N, Germundsson J and Fagerholm P. The role of Bowman's layer in corneal regeneration after phototherapeutic keratectomy: a prospective study using in vivo confocal microscopy. *Invest Ophthalmol Vis Sci* 2009; 50: 4192–4198.
23. Tejal S, Shetty D, Nagaraj D, *et al.* Epithelium, Bowman's and cross-linking: a pilot study. In: *Presented at the congress of the ESCRS*, Copenhagen, September 2016.
24. Vingopoulos F and Kanellopoulos AJ. Epi-Bowman blunt keratectomy versus Diluted EtOH epithelial removal in myopic photorefractive keratectomy. *Cornea* 2019; 38: 612–616.
25. Mangioris GF, Papadopoulou DN, Balidis MO, *et al.* Corneal infiltrates after corneal collagen cross-linking. *J Refract Surg* 2010; 26: 609–611.