

Advantages of Surface Ablation in Excimer Laser Surgery

Fouad Chraibi^{1*}

¹*University Hospital Hassan II of Fez, Sidi Mohamed Ben Abdellah University, Fez, Morocco.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

In this article, we review the advantages of corneal laser surface surgery to explain the current trend toward this technique. The excimer laser in corneal surface surgery can be used for two reasons. On the one hand, to correct a refractive error by photorefractive keratectomy (PRK) and its two variants; Laser epithelial keratomileusis (LASEK) and Epithelial Laser-assisted in situ keratomileusis (Epi-lasik).

On the other hand, it is used to perform superficial corneal capacities photoablation, among other uses, by Phototherapeutic keratectomy (PTK).

PRK is regaining popularity thanks to its better safety profile, mitomycin C usage and improvement of photoablation profiles. Lasek and Epilasik are less frequently performed nowadays.

PTK is an important element in the techniques used to improve visual acuity in a wide range of corneal conditions such as corneal scars, recurrent erosion syndrome and corneal dystrophies.

Keywords: Surface ablation; Excimer laser surgery; photorefractive keratectomy; keratomileusis.

1. INTRODUCTION

Epistemologically, the word “Excimer” results from contracting the words “excited” and dimmer.

In fact, this is a misnomer, because there is no such a thing as a dimmer in generating the laser, but there are two different molecules (rare gas and halogen molecules) that forms a complex

*Corresponding author: E-mail: fouadchraibi@gmail.com;

called exciplex under high voltage electrical discharge; which on separation there is photon energy released in the ultraviolet range (193 nm).

These photons are then concentrated through complex mechanisms to become the excimer laser ready to shape the cornea.

The shaping of the cornea occurs thanks to the photoablation effect provided by the photon's energy that exceeds the energy of chemical bonds of different molecules of the corneal tissues which dissociated and vaporized.

Surface laser ablation comprises different techniques:

- Photorefractive keratectomy (PRK) [1]: In which epithelium is removed and photoablation applied to the Descemet membrane and adjacent stroma.
- Laser epithelial keratomileusis (LASEK): In this technique, epithelium flap is created after loosening its adherence to the basal membrane by alcohol. photoablation is then applied with the replacement of the epithelial flap.
- Epithelial Laser-assisted *in situ* keratomileusis (Epi-lasik): The concepts are the same as inLasek, the only difference is the creation of the epithelial flap by an epikeratome.
- Phototherapeutic keratectomy (PTK): The laser is used to smooth ocular surface to improve clarity and help promote a healthy ocular surface.

Ablation profiles evolved through time to become more accurate, smoother with less induced haze and better management of high order aberrations (HOA).

There are four ablation profiles:

- Standard ablation: Although no longer practiced nowadays it's noteworthy to know that the first generations of excimer laser platforms dealt only with sphere and cylinder and performed blend zone at the edge of the treatment area. However; these profiles induced a great amount of high order aberrations.
- Topography guided: In these profiles, corneal ablations were performed on the basis of HOA and asphericity measured at

the level of the cornea by corneal topography.

- Wavefront-guided: Thanks to new generations of aberrometers, these ablation profiles are based on the whole HOA of the entire ocular system.
- Wavefront optimized: The profiles allowed to provide the final corneal shape with an asphericity close to normal corneas to reduce induced spherical aberrations.

PRK was a mainstream refractive procedure from the 80s up until the late 90s. But after that period; it was supplanted by Laser-assisted in situ keratomileusis (Lasik) surgery as the procedure of choice. It was until recently that PRK regained popularity thanks to its inherent advantages that were not obvious initially.

Two main factors contributed to this coming back to the surface: First, there were more corneal ectasia cases as Lasik surgery was mainstream; and second, because there were less healing surface problems and discomfort thanks to the optimal use of mitomycin [2,3,4] and advancements in laser profiles ablation and eye-tracking systems.

2. PRK AND ITS ADVANTAGES

2.1 Technique

PRK is best indicated for low to moderate myopia (less than 6D), low hyperopia (less than 3D), and low to moderate astigmatism (less than 6D).

It consists of two main steps: Epithelium removal and laser photoablation of Bowman's membrane and anterior stroma in the optical zone [5].

Epithelium removal should prompt in less than 1 to 2 minutes. The surgeon should pay attention to the risks of corneal desiccation or corneal hydration as this may influence the ablation rate. This is why it is generally recommended to start with the peripheral epithelium and keep the center until the last stage. Folded edges or rugged edges of the remaining epithelium could be a source of discomfort in the postoperative period.

Different methods described to discard epithelium are available; the epithelium is either scrapped with a sharp instrument aided by dilute alcohol in a well (Fig. 1) or by using a motorized corneal brush [6] which is more comfortable for

the patient during the surgery and is fast to perform avoiding excessive corneal hydration.

There is also transepithelial photorefractive keratectomy [7] in which the epithelium and stroma are abated in a single step with results similar to those using alcohol [8]. In performing transepithelial PRK, the surgeon must take into consideration the difference of epithelial thickness between the center and the periphery. It has many advantages such as obtaining smooth edges, simplicity of the technique, less time-consuming, and can be performed as retreatment after prior corneal surgery. But; It has drawbacks such as the fact that accuracy of epithelium thickness depends on hydration, and as some authors report more discomfort in the postoperative period in patients operated with transepithelial PRK [9]. Long term predictability of refractive results in PRK is similar to LASIK, but in PRK, patients are more prone to regression [10].

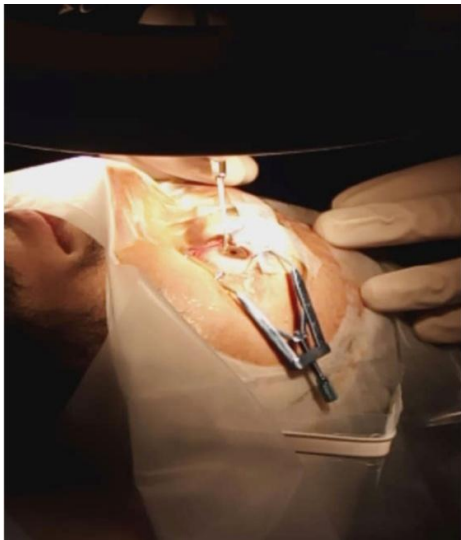


Fig. 1. Corneal epithelium removal using a sharp instrument

2.2 Advantages

- a- PRK is technically easy to perform: While in Lasik, there is a steeper learning curve to perform flaps especially with mechanical micro-keratomes, and to a less extent with femtosecond flap surgery.
- b- Corneal biomechanical aspects [11]: Since residual stroma after refractive surgery has been recognized as an important risk factor for ectasia, many surgeons prefer PRK, and sometimes in conjunction with CXL if there is suspicious corneal topography. There no

consensus about the minimal residual corneal thickness but most surgeons advocate a value of 400 microns to 350 microns.

Post-PRK ectasia does exist but very uncommon comparatively to post-LASIK ectasia. Also, there have been reports of corneal ectasia following LASIK in one eye but not after PRK in the fellow eye.

- c- Anatomical constraints: In some cases where there is prominent front edge of the orbit, narrow orbital fissure or tight lids; PRK could be a safer alternative than Lasik.
- d- PRK a flapless surgery: All complications related to flaps in Lasik are simply avoided. It's noteworthy to cite these potential flap related complications; which could be pre-operative like a thin flap, partial flap, buttonhole, and loose epithelium. post-operative like a shifted flap and diffuse lamellar keratitis. And; late postoperative like flap dislocation which may occur months to years after surgery.
- e- Keratoconus: PRK can be performed in cases of keratoconus with stable refraction and limited astigmatism.

There are mainly two ablation profiles that are used in the setting of keratoconus: Wavefront-guided ablation and topography-guided ablation.

In wavefront-guided ablation, the whole visual system is treated taking into consideration lenticular and posterior corneal optical errors. However, high order aberrations measurement is not accurate in cases of advanced keratoconus.

In topography-guided ablation: it flattens a part of the cone peak and an arcuate broader area away from the cone which causes a steepening of the flatter cornea adjacent to the cone with a resulting corneal "normalization". With topography-guided ablation, there is more tissue saving than in wavefront-guided ablation.

- f- In Lasik complications: First, PRK can be used as a conversion of a failed Lasik as in suction loss. Or as an enhancement procedure of an otherwise uncomplicated Lasik but with significant postoperative refractive error. In this last case, epi-keratome and motorized brushes are not recommended.

For cases of complicated Lasik flaps with irregular astigmatism, PTK or transepithelial PRK are more appropriate.

Table 1. Advantages and disadvantages of PRK surgery

Advantages of PRK	Disadvantages of PRK and prevention
-Easy learning curve. -Flapless surgery. -Lesser corneal biomechanical disturbances. -Can be used in keratoconus patients.	-Discomfort during initial days: painkillers, transitory. -Visual acuity: disturbed during the first days. -Corneal haze: Mitomycin C and steroid drops. -Regression: in high refractive error patients. -Defective epithelial healing: <ul style="list-style-type: none"> • Mitomycin C 0.02% for 10 seconds. • Avoid contact between Mitomycin C and limbal stem cell zone. • Avoid cortisone drops during the first days.

- g- Bioptics: PRK can be effectively used to manage refractive errors in patients operated for cataract or refractive clear lens exchange. Especially when multifocal intraocular lenses (IOLs) are used; where even the slightest astigmatism can be problematic and in monofocal IOLs for large spherical refractive surprises.
- h- In the setting of eyes implanted with phakic IOLs: Enhancement by surface laser surgery is best suited than Lasik; since the suction ring is best to be avoided to prevent phakic IOL displacement in an otherwise fragile eye.
- i- Following descent membrane keratoplasty [12]: PRK can be very helpful to correct either induced or pre-existing refractive errors in patients operated for Descmet membrane keratoplasty.
- j- "Borderline" cornea: PRK is safer in the thin cornea with normal topography than if operated by Lasik [13]; And in some cases of the cornea with suspicious topography, PRK coupled with corneal cross-linking could be used.
- k- Anterior membrane dystrophy: In the setting of pre-existing anterior membrane dystrophy with or without recurrent erosion, PRK is the ideal treatment providing both refractive correction and treatment of the underlying corneal disease.
- l- Dry eye: Dry eye can be a transitory contraindication or a complication in refractive surgery, and Lasik surgery is more prone to induce a severe dry eye [14].

symptoms postoperatively if not dealt with promptly before surgery.

m- PRK is cheaper: PRK has a lower cost than Lasik because of its extra costs represented by microkeratome or a femtosecond laser. In Table 1 we summarize advantages of PRK and we also mention some of its drawbacks and how to prevent them.

3. LASEK AND ITS ADVANTAGES

The paradigm of Lasek surgery is to restore the epithelium immediately after stromal photo-ablation with the aid of dilute alcohol [15]. There is a debate about the interest of replacing the epithelial flap in terms of decreased speed recovery and pain [16,17]. Theoretically, on the one hand, it has flap creation advantages with less discomfort and possibly increased recovery speed; on the other hand, the safety of PRK. Still, this technique is less practiced nowadays than before because of questions about the viability of epithelial cells after exposure to alcohol [18].

4. EPI-LASIK AND ITS ADVANTAGES

In this variant of PRK, the epithelium flap is created by using an adapted epikeratome that cuts just above the Descemet membrane allowing replacement of the epithelial flap after stromal photo-ablation.

There is a debate about pain and speed of recovery since some studies showed that there is more pain and slower recovery if a flap is replaced, but most studies show that the results are equal to whether the flap is replaced or discarded [19].

That said, even with PRK, dry eye symptoms must be addressed extensively to avoid the patient blaming the surgery, and because of the fact that patients will experience more dry eye

Most surgeons use the epikeratome to create the epithelial flap then discard it just to avoid the use of alcohol, and to obtain a very smooth edge of the remaining epithelium with less resulting postoperative pain.

Epikeratome is very gentle to epithelial cells, - unlike motored brushes which crash epithelial cells- so there are fewer cytokines released and less inflammation with resulting in fewer risks of postoperative pain and haze.

With epikeratome, we obtain smaller fusion line very different from the stellate fusion line we get in classic PRK that induces visual disturbances persisting for weeks (ghosting). It's noteworthy to know, that any disturbance at the bowman layer is a contraindication to epikeratome use (e.g.: Scarring, map-dot-fingertip dystrophy).

5. PTK AND ITS ADVANTAGES

PTK is used to treat corneal surface disorders with an ablation that is equal throughout the treatment zone using a soothing fluid in low points to perform ablation of only elevated corneal lesions; in transepithelial PTK the epithelium is used as the masking agent.

PTK nowadays is mainly used to improve visual acuity so it can be used to treat elevated lesions such as Salzmann's nodular degeneration and anterior stromal scars (anterior stromal dystrophies, band keratopathy), and to treat Lasik flap complications (buttonhole). Also, it can be used to treat pain such as in recurrent erosion syndrome and bullous keratopathy. And in some rare cases to treat infectious keratitis (fungal, acanthamoeba).

Ancillary tests are mandatory before performing PTK. Anterior segment ocular coherence tomography (OCT) is mandatory to assess the depth of lesions, and corneal topography to plan topography-guided PTK [20].

In planning PTK surgery, three important parameters must be taken into consideration: depth of ablation, the refractive status of both eyes and the ablation rate which could be lowered if corneal calcifications are present and higher if there is a corneal scar or excessive corneal hydration. The ablation depth should be no more than one-third of the corneal stroma with a residual bed of 250 microns or more.

Many techniques are described in managing PTK:

- Partial epithelial debridement: Like in recurrent erosion in which there is epithelial debridement in the site of the disease followed by localized laser at 5 to 6 microns depth which may induce astigmatism, or by photoablation including the entire zone of the visual axis.
- Trans-epithelial PTK: In which the epithelium is used as the masking agent. Blue fluorescence is a cue that indicates epithelium being removed. This variant of PTK is mainly indicated in keratitis, buttonhole and flap striae [21].
- Use of soothing fluids (e.g: hydroxymethyl cellulose 0.7 to 2%) that protects less prominent zones while allowing elevated zone to be photablated.
- Mechanical scraping for elevated lesions.

In persisting haze post-PRK surgery, PTK all together with mitomycin can be used to relieve this potential complication of PRK.

There are some complications that can occur with PTK including:

- Healing surface problems: Epithelial delayed healing, haze, and perforation.
- Biomechanical issues: Corneal ectasia.
- Infectious complications: corneal abscess formation.
- Refractive issues: Mainly there is a hyperopic shift (+3 to +9D) in central PTK or myopia and astigmatism in peripheral locations of PTK. A PRK with hyperopic ablation can be used to offset induced hyperopia, either practiced concomitantly or weeks after the initial surgery.
- Recurrence problems: mainly in cases of herpetic keratitis, macular dystrophy, and Reis-buckler disease.

6. CONCLUSION

So back to the surface is a reality thanks to the advantages that PRK offers especially after mastering healing surface issues.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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