Review Article

Phototherapeutic keratectomy

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Phototherapeutic keratectomy (PTK) is done regularly for anterior corneal diseases such as corneal dystrophies, corneal degenerations, scars, and band-shaped keratopathy. The various indications include both therapeutic and visual. The aim of this article is to discuss the therapeutic indications for PTK, the specific technique pertaining to a specific etiology, the various other procedures like amniotic membrane graft combined with PTK or PTK being done for recurrences in the grafts, and PTK done before cataract surgery when the anterior corneal pathology coexists with the cataract. Post PTK management such as healing of an epithelial defect, use of steroids in the post PTK period, recurrences of primary disease pathology, and infections, will be discussed. Methods of literature search: A Medline search was carried out for articles in the English language, with the keywords, phototherapeutic keratectomy, band-shaped keratopathy, spheroidal degeneration, scars, bullous keratopathy, and corneal dystrophy. The relevant references are mentioned here.

Key words: Band-shaped keratopathy, corneal dystrophy, phototherapeutic keratectomy, phototherapeutic keratectomy with amniotic membrane grafts, scar, and Salzmann nodular degeneration

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Corneal diseases such as scars, degenerations, dystrophies, bullous keratopathy, and band-shaped keratopathy (BSK) are important causes of visual blindness; anterior stromal disease being superficial can be treated using various minimally invasive surgical procedures like lamellar keratoplasty (LKP) or superficial keratectomy or by excimer lasers, that is, phototherapeutic keratectomy (PTK).[1-11] PTK can be considered to be a bridge between medical and surgical management of corneal diseases. PTK can be used for therapeutic and / or refractive indications. This review deals with therapeutic indications for PTK. In this review, we highlight the indications of PTK, the technique, and management.

A Medline search was carried out for articles in the English language up to October 2010, with keywords such as phototherapeutic keratectomy, band-shaped keratopathy, spheroidal degeneration, scars, bullous keratopathy, and corneal dystrophy. PTK was performed with an excimer laser (193 nm) and worked on the principle of photoablation, by breaking the bonds between the molecules. One pulse of laser removed 0.25 microns of corneal tissue, making it more precise, while keeping the tissue removal depth under better control; also, the treated surface was smooth and regular, improving the visual outcome.[4] The goals of PTK were to improve corneal surface irregularities, remove or reduce the density of the deposits,[3,10,12,13] and alleviate symptoms such as recurrent corneal erosions (RCE), in the superficial corneal lesions;[9,14,15] PTK, therefore, gave a clear visual axis, improving vision, or improved symptoms, or both; The broad beam laser was used initially and now flying spots lasers are used. Also, PTK was shown to be safe and effective in children for visual improvement and relief of symptoms of pain, irritation and photophobia.[10,16,17]

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Preoperative Selection of a Patient

The key to a successful outcome depends on proper case selection. Systemic diseases such as uncontrolled diabetes, collagen vascular diseases like rheumatoid arthritis, and systemic lupus erythromatosus may have delayed epithelial healing.[1] The ocular selection criteria depend upon the corneal disease pathology, such as, the site, size, and depth, whether there is progressive-like dystrophy (progressive) or a scar (nonprogressive)-associated symptom (pain, watering, foreign body sensation, etc.), and preoperative refractive error. Corneal diseases limited to anterior stroma are amenable to treatment. Mitomycin C (MMC) is used as an adjunctive treatment to prevent recurrences.[18] PTK improves symptoms of pain, watering, and foreign body sensation in RCE, in dystrophies, bullous keratopathy, and spheroidal degeneration.[6,15,19-21]

Visual improvement after PTK is due to reduced density or removal of a scar and reduced irregular astigmatism. The PTK procedure must not be compared with Photorefractive keratectomy (PRK) where the uncorrected visual acuity (UCVA) improves. In fact, there may be a reduction in UCVA due to induced refractive errors, but the best corrected visual acuity (BCVA) improves.[2,12,22] The clear cornea may help in accurate keratometry for intraocular lens (IOL) power calculation.[23]

Therapeutic Indications [Table 1]

Spheroidal degeneration

Spheroidal degeneration clinically presents in two forms; smooth fine gelatinous dew-drop appearance and yellow, raised spherules, with an irregular surface [Fig. 1]. The two forms may co-exist. The material is present in the sub-epithelial layer, Bowman's membrane, and superficial stroma. The irregularity affects the vision, and causes repeated epithelial breakdowns resulting in pain and

Table 1: Therapeutic Indications

A.	Spheroidal degeneration
B.	Salzmann nodular degeneration
C.	Band shaped keratopathy
D.	Recurrent corneal erosions
E.	Bullous keratopathy
F.	Corneal dystrophies
G.	Scars
H.	Keratitis
I.	PTK combined with or before and after other surgeries
	i. PTK combined with amniotic membrane graft
	ii. PTK after pterygium surgery
	iii. PTK before and after keratoplasty
	iv. PTK before cataract surgery

PTK: Phototherapeutic keratectomy

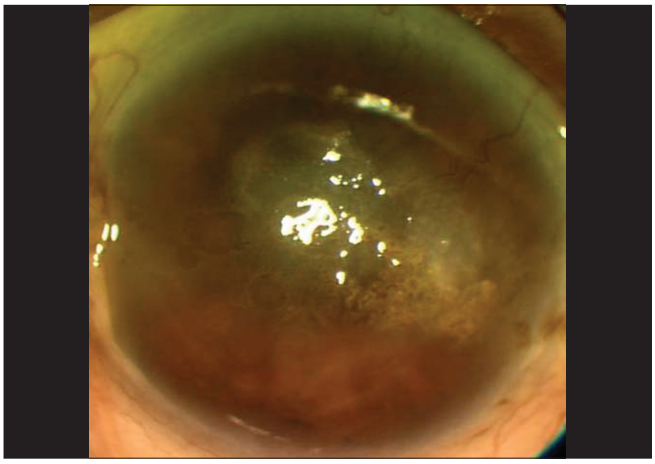

Figure 1: Spheroidal degeneration with yellow spherules and irregular surface before phototherapeutic keratectomy

photophobia, and predisposes the cornea to infections.[24] Sridhar *et al.*, have reported the proximity of an infiltrate close to the spherules, necessitating treatment, irrespective of their location.[24] The management options include superficial keratectomy (manual or laser), with or without amniotic membrane grafts (AMG).[1,23,25] LKP or penetrating keratoplasty (PKP) may be required for deeper involvement.[26] PTK removes the spherules, resulting in a smoother surface, thus alleviating the symptoms. Badr *et al.*, has shown that PTK has been successful in reducing corneal opacification in both smooth and rough spherules in 75 eyes with a clear-to-mild hazy cornea, in a smooth form, compared to the irregular form;[19] 21% had delayed healing and 10% had infectious keratitis, with irregular spherules, as compared to smooth spherules, where delayed healing was noted in 9% and infectious keratitis in 1.8%.[19] Spherules treated prior to cataract surgery resulted in better intraoperative visualization and patient satisfaction.[23,24]

Salzmann nodular degeneration

Salzmann nodular degeneration (SND) is characterized by the presence of bluish-white peripheral nodules raised above the corneal surface, slowly progressive, more common in females with longstanding scars and chronic uveitis. The raised surface may be associated with tear film abnormality, irregular astigmatism, and difficulty in contact lens fitting. Surgery is the only treatment. The nodules are removed either by manual excision or by PTK.[6,10,12,27] The outcome is better with superficial SND, when the Bowman's membrane is not touched, as against deeper SND, where more ablation is required.[28] The induced myopia, after removal of the peripheral nodules, is not because of PTK, but because of the manual removal of nodules.[29,30] Khaireddin *et al.*, had used MMC 0.02% for 30 seconds in patients with SND, after PTK, as also superficial keratectomy, to prevent recurrence.[31] The epithelium is metabolically active in these patients. MMC inhibits DNA synthesis and prevents further proliferation in these patients.[31]

Band-shaped keratopathy

Clinically these present in two varieties, smooth and rough.[32] In smooth BSK, the calcified material is at the Bowman's membrane level with a stable epithelium above it. The treatment includes removal of deposits either with Ethylenediaminetetraacetic acid (EDTA), superficial keratectomy or PTK.[10,32-34] PTK is effective in BSK when performed for symptomatic relief or for vision improvement;[33] but some authors have not found improvement after PTK[2,13] [Fig. 2a, b].

Bullous keratopathy

Bullous keratopathy is characterized by bullae formation and its rupture, resulting in symptoms of pain, foreign body sensation, watering. The treatment is two-fold symptomatic relief and visual improvement. The first goal of symptomatic relief is with hyperosmotic agents, bandage contact lens (BCL) or with anterior stromal puncture (ASP), AMG, PTK, ASP with AMG, and PTK with AMG.[15,20,35-38] The second goal is visual improvement.[39] PTK is a very promising and effective treatment for bullous keratopathy and can also be repeated.[20,40] Deeper ablations give more symptomatic relief than superficial shallow ablations. Nerve endings are ablated with deeper ablations and pain is less.[21] With a deeper ablation of 25% of corneal thickness, better alleviation of symptoms is noted as compared to the superficial and intermediate.[21] Bullae formation may occur outside the area of the ablation.[15,21]

Corneal dystrophy

Phototherapeutic keratectomy is indicated for anterior basement membrane dystrophies and stromal dystrophies for both symptomatic relief and visual improvement.[41-48] It is also tried in cases of Fuchs' endothelial dystrophy for subepithelial scarring or for removal of a substantial part of the stroma, to reduce the load on the endothelium.[4,40] All these indications are done with a varying success rate and a varying rate of recurrence.[43,45] Dystrophies being central, the ablation profile of PTK mimics myopic correction and thereby induces hyperopia. This depends on the amount of ablation depth. Also, intraoperative application of MMC helps prevent recurrences.[49-51]

1. Map dot finger print dystrophy: PTK is indicated for RCE or reduced vision because of irregular astigmatism or both.[41,52-54] Early recurrences are noted at six-to-nine months or a year or more.[41,52,55,56]
2. Granular Dystrophy: PTK is the first line of treatment as recurrence is slow.[10,43,57] Also, the ocular surface health is better after PTK.[3]
3. Macular dystrophy: The deeper deposits persists after PTK and recurrences are heavy so PKP should be preferred.[45]
4. Lattice dystrophy: PTK is indicated for repeated RCE and later on for a scar.[1,4,42]

5. Schnyder's dystrophy: PTK is also performed for Schnyder's dystrophy.[43,46,47,58,59]
6. Avellino dystrophy gets worsened or aggravated if PTK is done.[56]

Recurrent corneal erosion

Recurrent epithelial breakdown occurs when the epithelial attachments to the underlying stroma are loose.[60-62] It is characterized by sudden onset of pain in the eyes, usually on awakening in the morning, associated with redness, watering, and photophobia. The episodes of RCE may vary in the intensity of symptoms and erosion may show a slipped-rug appearance.[61] RCE is managed by lubricants, BCL, oral doxycycline, topical corticosteroids, ASP or PTK.[55,60,61,63-66] The main goal is to form adhesion complexes between the epithelium and stroma by ablation of the Bowman's layer.[67]

The excimer laser is also used in a persistent epithelial defect or shield ulcers.[68,69] Ablation is performed at the elevated edges of the defect so that epithelial cells migrate to cover the defect.[69]

Scars

Superficial anterior stromal avascular scars (less than 100 microns), are amenable to treatment by PTK.[70] These scars may be post-traumatic, post-infectious or post-pterygium excision.[12,71,72] The aim is to improve vision and delay or obviate the need for keratoplasty.[2,4,12,54,71,73,74] Scars after healed bacterial or fungal keratitis can be treated with PTK. Scars post-viral keratitis need to be treated with caution because of risk of recurrence after PTK.[12,75]

The outcome is comparable between post-traumatic and post-infectious scars. Migden *et al*., have shown a significant improvement in visual acuity in 50% of the cases of post-traumatic scars (4 / 8 eyes) as against 0 / 5 eyes with post-infectious scars.[73] Fagerholm *et al*., have shown a success of 67% in post-traumatic scars and 80% in post-herpetic scars.[4] Sher *et al*., have shown improvement in 5 / 8 eyes with post-traumatic scars and 3 / 5 eyes with post-infectious scars.[71] Campos *et al*., have shown good visual outcome in post-traumatic as against post-infectious scars, but the number is quite less.[2]

Scars post-pterygium surgery can be treated either as a primary scar or as a topography-guided treatment, with correction of irregular astigmatism.[12,54,76] PTK is indicated for scars of previous refractive surgeries and nodular sub-epithelial scars of keratoconus.[74,77-79] Elsahn *et al*., had performed PTK in 15 eyes of keratoconus patients with nodules who were contact lens–intolerant.[79] Eleven were successfully refitted with the contact lens, but three patients had recurrence of the nodule and one patient underwent re-PTK for the same.[79]

Keratitis

Phototherapeutic keratectomy was shown to be effective in the management of microbial keratitis of bacterial, fungal, viral, and parasitic origin.[80-84] Most bacterial keratitis responded well to the treatment. Lindbohm *et al*., had performed PTK in the interface after lifting and rinsing the flap, in a patient who had infectious keratitis after laser-assisted *in situ* keratomileusis (LASIK).[83] The authors concluded that PTK could be helpful in these cases, when the ulcer did not respond to the topical or oral antibiotic treatment.[83]

Phototherapeutic keratectomy can be performed for both superficial and deep fungal infections.[80] The advantages are reduction in the duration of treatment, fastened re-epithelization, along with debulking, and improving drug penetration, especially in deeper infections. The medical treatment should be continued if required. The complications are perforation of the cornea during PTK. This is because of the different ablation rates of the cornea in the presence of infection and corneal edema. The other complications include irregular astigmatism resulting in reduction in visual acuity, hyperopic shift, delayed epithelial healing, haze, and scarring, as steroids are not advised in active infection, and the ablation is deeper.[80]

Unresponsive acanthamoeba keratitis can be treated with PTK. The advantage is the direct removal of the amoebic cysts. PTK should be performed early; if delayed, the infection would go to the deeper level, which would need more ablation and would increase the risk of perforation. The focus of infection should be removed completely. The residual amoebic lesion could worsen and a repeat PTK procedure would have to be performed. The end point is difficult to judge on diffuse illumination and one may have to move the patient repeatedly to the slit lamp to examine the surface or may use the sclerotic scatter illumination technique for better visualization of the opacity and avoid the excessive ablation.[81]

Imaging Techniques

The main diagnosis and planning of PTK is based on clinical judgment, on slit lamp examination, and the amount of refractive error. Hyperopic refraction before PTK for central corneal disease will increase the amount of hyperopia and may result in anisometropia, warranting a contact lens trial. Imaging techniques are used to plan and manage the postoperative outcome.

Corneal topography

Corneal topography helps in the planning and following up of patients after a PTK procedure. It also helps in correcting the pre-existing refractive error by the topography-guided laser treatment.[85,86] This helps in reducing irregular astigmatism and improving visual acuity. Vinciguera *et al*., have conducted PTK with corneal topography-based aberrometry after epithelial debridement and achieved good results.[86]

Ultrasound biomicroscopy

Ultrasound biomicroscopy (UBM) uses a high frequency ultrasound to produce high resolution images of the cornea. The UBM measurement overestimates the corneal pathology, and the ablation required is inversely proportional to the depth of the pathology and does not help in the planning of the procedure.[87]

Ocular coherence tomography

Ocular coherence tomography (OCT) is a noncontact, cross-sectional, high-resolution representation of cornel configuration, before and after PTK. The quantitative differences in the epithelial thickness after PTK can be monitored for epithelial hyperplasia and anterior stromal changes.[88] OCT is used to measure the depth of opacities in the cornea and it helps in the planning of either a lamellar or a penetrating procedure depending on the depth of the opacities [Fig. 3].

Technique of Phototherapeutic Keratectomy

The technique of PTK varies according to the underlying pathology, size, and site. Hence, it is better explained as a common method first and then the specific technique in the specified pathology can be modified as described.

General technique of the phototherapeutic keratectomy procedure

The procedure is generally done under topical anesthesia, unless some additional surgical procedure is combined with PTK (local anesthesia) or when the procedure is done in pediatric patients, general anesthesia may be required.[10,15] The topical anesthetic agents used are Xylocaine 4% or Proparacaine HCl (0.5%). We usually use three to four drops at an interval of two minutes each, just before the procedure. Written informed consent is taken from the patients or guardian. The procedure is done under strict aseptic precautions. After applying the wire speculum, the epithelium is debrided manually with a hockey stick knife. The epithelium comes out easily in bullous keratopathy. Some surgeons do use alcohol for the debridement of the epithelium. After debriding the epithelium, ablation is performed either by asking the patient to look into the green fixation light or a laser is centered manually. In an eccentric or peripheral lesion, the surgeon needs to manually rotate the patient's head or eye for ablation.[22] If the surface is rough, a masking agent such as hydroxypropyl methylcellulose (HPMC) 0.7 to 2% is spread to smooth the cornea. This masks the deeper tissue and only the protruding irregularities of the cornea are exposed for laser ablation. Kornmehl *et al.*, have compared three masking fluids with different viscosities and found that dextran 0.1% provides the smoothest postoperative surface.[89] We routinely use 0.7% HPMC. Masking fluids need to be applied intermittently during the procedure, although applying fluid too many times will delay the procedure and may further increase the irregularities of the surface after the procedure.[89] The sharp edge of ablation can be avoided by using the polishing technique by annular motion of the eye under a laser and by avoiding the point shooting.[22] A few visual and auditory signals during the procedure may help in guiding the extent of the treatment. A snapping sound is heard when the tissue is ablated, and when the masking fluid gets ablated, a soft sound is heard. A bubbling sound indicates too much of methylcellulose.[5] Similarly, the ablation of the epithelium shows blue fluorescence in the dark room, while stromal ablation does not produce blue fluorescence.[5] This gives a guideline for the depth of ablation.[12] After firing 70 to 80% of the target ablation, the patient must be examined on the slit-lamp.[10] Some machines have in-built slit-lamps, so that one does not have to move the patient from the machine to the slit lamp. This is necessary to protect over-ablation of thin areas and to decide about additional treatment if needed. The endpoints for superficial opacities are usually the visible iris details. Granularity may remain with spheroidal degeneration. MMC can be used intraoperatively.[18,49]

Technique: Specific to etiology

The ablation rate of a corneal scar is different as compared to normal corneal stroma;[90] meticulous planning is required when faced with special scenarios, as follows:

1. Spheroidal degeneration: The smooth spherules can be treated similar to PRK, by centering the ablation on the cornea after epithelial debridement, either on a wet or dry surface. Large single zone ablations of 6 mm or more usually suffice. Masking fluid is used when the surface is irregular. The rough spherules are treated first directly and then with a large single zone polishing ablation. The end point is a relatively clear cornea with some granularity.
2. Salzmann nodular degeneration: The nodules are treated directly with a small ablation zone diameter after the epithelial debridement[91] [Fig. 4]. Sometimes it is easy to remove the nodules with a smoother surface manually, but when this is difficult, ablation is to be titrated according to the irregular surface with the use of masking fluid.[27] Once the nodules are ablated, an overall larger ablation zone diameter can be used to have an overall smooth corneal surface.[1,10,27] It may not be possible to completely clear the cornea, but the surface will be smoother.
3. Corneal Dystrophies: As the dystrophies involve the central cornea, treatment is targeted to the central 6 mm to 7 mm.[10a,92] The endpoint is not to remove all the deposits, but to reduce the density of the deposits, clear the visual axis, and remove surface irregularities. Kim *et al.*, have described the use of MMC in four patients over a follow-up of a year;[49] but recent studies have shown that the recurrences are severe when MMC is used with PTK over a long follow-up.[93]
4. Bullous keratopathy: The epithelium being very loose comes off easily with a surgical sponge. A large ablation is performed either on a dry or wet surface, to have a wider area of healing.[15,21] The cornea being thick, about a 100-micron ablation can be done to have stronger epithelial adhesions and reduced pain after PTK.[21]
5. Recurrent corneal erosions: The epithelium is debrided manually so that the adhesions formed are better. RCE may occur as a sequel to trauma, dystrophies or spontaneously. Furthermore, the amount of ablation may range from 3 microns in RCE due to trauma, to 100 microns in RCE in bullous keratopathy and cornea dystrophies like lattice.[40,63,94] In shallow ablations, the haze formation is less.[94] With an ablation of five microns, there is no induced astigmatism and treatment can be done in the center or periphery without significant refractive shifts.[94]
6. Band-shaped keratopathy: The laser can be fired directly in the center of the cornea over 6 – 7 mm after epithelial debridement.[10,32,33] Masking fluid may be required.[32] As calcium has a lower ablation rate, more pulses are required for PTK.[32] Smooth BSK can be treated directly with a single large ablation zone. O'Brart *et al.*, have performed PTK on an intact epithelial surface, with cessation of brighter fluorescence with treatment, the treatment was stopped in a smooth BSK.[32] In a rough BSK, multiple overlapping ablation zones are required, with intermittent mechanical debridement of the epithelium, to smoothen the surface. Large calcified plaques should be removed with a blade. With the resultant irregular surface, the troughs should be filled with the masking fluid and the laser should be done later.[32]
7. Scars: The location of scars in the cornea (central or peripheral) is important. The central scar can be treated with the general technique. For peripheral scars, the eye has to be rotated manually to center the treatment over it or PTK can be performed using a joystick-controlled platform like Technolas 217z. Associated irregular astigmatism can best be treated with topography-guided PTK.[4]

Contraindications

Phototherapeutic keratectomy should be limited to the anterior corneal lesions only, as deeper scars need deeper ablations and may result in a more haze formation.[4,12,56,70] The best candidates are patients with opacities in the anterior 10 – 20% of the cornea, without significant irregularity and thinning. Patients who have both superficial and deep stromal lesions, only superficial lesions are easily treated as shown by Paparo *et al*.[59] Also, complete treatment is not possible. Systemic diseases such as diabetes mellitus and autoimmune disorders are contraindications for PTK.[1] The decreased corneal sensation may affect epithelial healing, with an increased risk of melt. Any viral activity within last six months is a contraindication.

Post Phototherapeutic Keratectomy Management

Poor epithelial healing would result in haze formation or infection. Either BCL such as the Silicone hydrogel lens or patching of the eye is required to facilitate the healing. Prophylactic antibiotic eye drops such as newer generation fluoroquinolone is instilled till the epithelium heals, and the BCL is removed. If the eye is patched, then antibiotic ointment is instilled twice a day with the patch, till the epithelium heals. Topical NSAIDs such as Diclofenac sodium, reduce postoperative pain and do not affect the healing of the epithelium and may reduce the need for oral analgesics.[95] Oral analgesics can be given as required. However, NSAIDs must be used with caution as topical nepafenac is reported for corneal melt after PRK.[96] Once the defect heals and BCL is removed, topical corticosteroids such as Fluorometholone alcohol must be given four times daily, tapered by one drop per week, over a month. Topical lubricants are prescribed for a month, four to six times daily.

Phototherapeutic keratectomy combined with or before and after other surgeries

Phototherapeutic keratectomy combined with amniotic membrane grafts

Amniotic membrane grafts are being used extensively in various ocular surface disorders, as they result in a smooth surface, rapid epithelization, reduced inflammation, and scarring.[97] Post PTK anterior stromal scarring depends upon the depth of the ablation and the duration of epithelial defect healing.[12,70] Wang *et al*., have shown that an AMG-covered cornea had minimal inflammation and no keratocyte apoptosis on days one and seven, after photoablation in rabbit eyes, resulting in minimal haze formation.[98] Choi *et al*., have shown that AMG promotes rapid epithelization in rabbit eyes.[99] PTK can be combined with AMG for severe subepithelial fibrosis after PRK, in painful bullous keratopathy, SND, scars, and spheroidal degeneration.[15,99] It reduces pain and prevents bullae formation.[15,100]

Phototherapeutic keratectomy after pterygium surgery

Phototherapeutic keratectomy is combined with bare sclera excision of the pterygium.[101,102] Good visual recovery is reported when PTK is performed with ablation to a depth of 40 – 80 microns, to smoothen the cornea, and 10 microns on the limbus and bare sclera, to remove the residual tissue in the recurrent pterygium, and recurrence was noted in one eye two months postoperatively and over a follow-up of one year for 20 patients.[101] When PTK and pterygium excision is combined with topical MMC (0.02%) twice daily, for four days; 2.9 and 6.4% recurrences are noted in the primary and recurrent pterygia. [102]

Phototherapeutic keratectomy before and after penetrating keratoplasty

Phototherapeutic keratectomy is indicated in patients who have recurrences of dystrophy after PKP. In macular dystrophies, PTK can improve the visual acuity for a limited period and recurrences are known to necessitate PKP later.[45] PTK is shown to be effective in granular and lattice dystrophy before PK, with good clinical outcome in granular dystrophy.[43] Similarly, with recurrences of dystrophy after PTK, repeat PTK can be performed and keratoplasty can be considered when the cornea is too thin to tolerate the repeat PTK.[9] Park *et al*., have performed deep anterior lamellar keratoplasty in four patients who had recurrence of Avellino dystrophy after PTK, with a good surgical outcome.[103] Szentmary *et al*., have shown that a preceding PTK does not affect the outcome of PKP.[104] Descemet stripping endothelial automated keratoplasty (DSAEK) is a preferred technique nowadays, in patients with endothelial dysfunction. In these patients, PTK is shown to be effective for the treatment of subepithelial fibrosis. There is a report of PTK being performed for the subepithelial fibrosis along with the use of MMC after DSAEK.[105]

Phototherapeutic keratectomy before cataract surgery

Phototherapeutic keratectomy prior to cataract surgery helps in multiple ways. The presence of corneal opacities may interfere with intraoperative visualization and postoperative patient satisfaction. As the surface becomes smooth after PTK, keratometry or corneal topography is possible, with better accuracy [Fig. 5].[23] PTK is indicated before cataract surgery in patients with spheroidal degeneration and BSK.[10,23,34]

Outcome

Clinical outcome

Clinical outcome is defined either as a reduction or amelioration of symptoms and / or clarity of visual axis. The clinical outcome may vary depending on the pre-existing corneal disease. Spheroidal degeneration may have residual granularity after PTK. SND may have a residual scar; the pre-existing scar is deeper and smooth, and the haze is superficial in the area of ablation.[8,12]

Residual deposits may remain in the cornea, but frequency of RCE is reduced in dystrophies and also the visual axis is relatively clear.[11,92,106] Lattice, Macular, and Granular dystrophies are known to recur.[10,43] The patient may have good vision even in the presence of a recurrence.[43] Clinically significant recurrences may not need further intervention, unless it becomes a cause for visual disturbance[10,43] [Fig. 6].

Visual outcome

Best corrected visual acuity (BCVA) improves and Uncorrected Visual Acuity (UCVA) may reduce after PTK, because of the induced refractive error.[2,12,22] Occasionally, PTK may be combined with PRK and vision may improve in those patients.[54,107] The visual outcome may be unaffected when

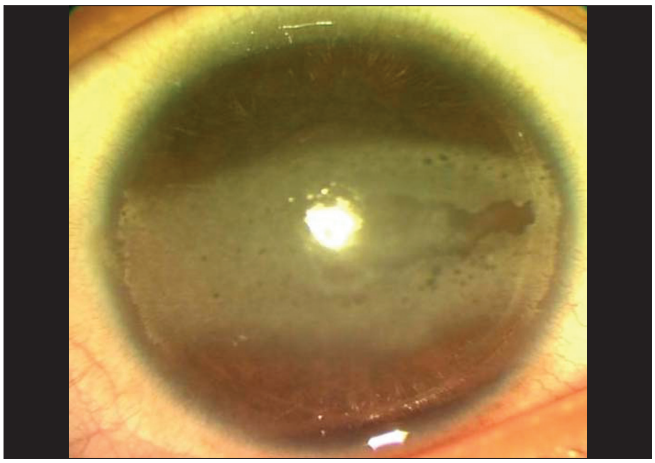

Figure 2a: Band-shaped keratopathy obscuring the visual axis with no view of pupil or lens

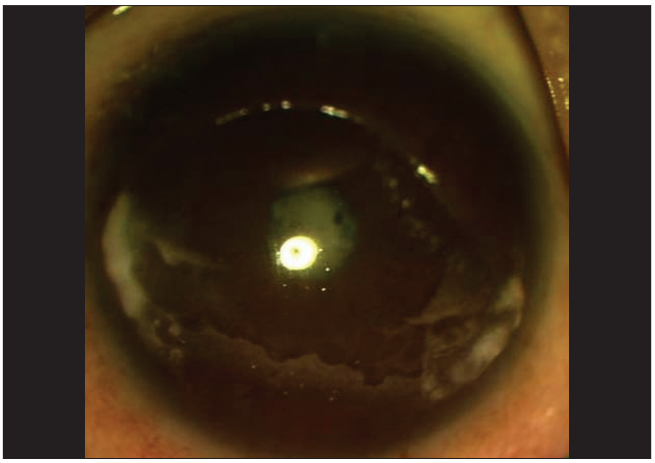

Figure 2b: The visual axis is clear and the cataract is visible after phototherapeutic keratectomy for band-shaped keratopathy

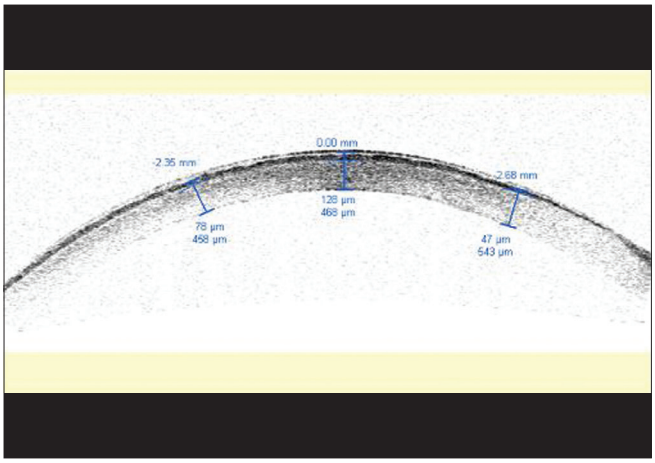

Figure 3: Ocular coherence tomography shows the depth of corneal opacity in a patient with Reis-Buckler dystrophy

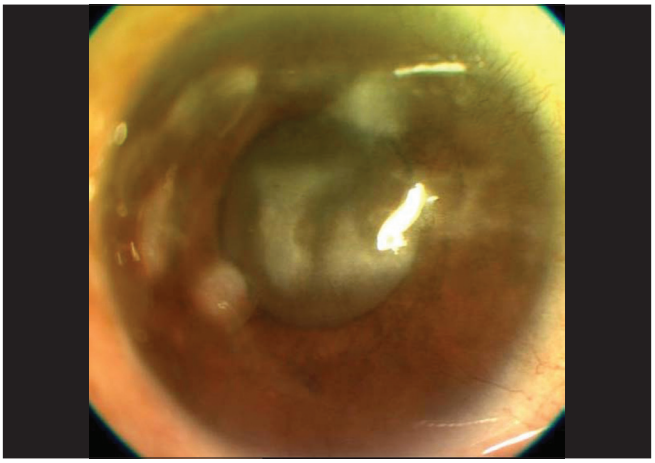

Figure 4: Salzmann nodular degeneration with the nodules in the periphery. The area of the nodules should be treated individually

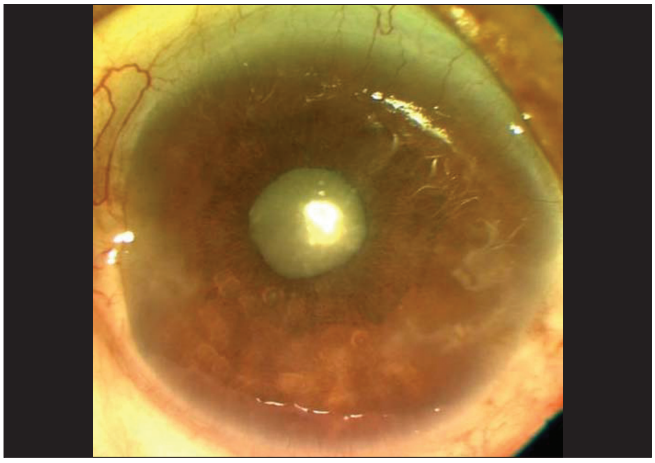

Figure 5: The clear visual axis after phototherapeutic keratectomy for spheroidal degeneration (Figure 1)

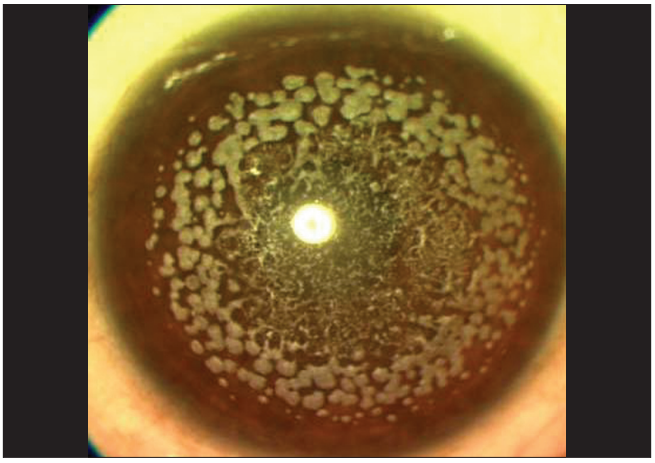

Figure 6: The recurrence of granular deposits in a patient who had phototherapeutic keratectomy for granular dystrophy. Uncorrected visual acuity was 20 / 40, N6 and the patient was comfortable with his vision

PTK is performed, to give symptomatic relief, as in bullous keratopathy.[20,21] The visual improvement may depend upon the co-existing ocular disease.

Refractive outcome

A significant amount of tissue removal will induce refractive error, the type and amount depends on the site and depth of ablation; central ablation will flatten the cornea and induce a hyperopic shift, like a photorefractive keratectomy, similarly peripheral ablation will result in removal of tissue in the periphery, like hyperopic ablation, and will induce myopia.[2,12,22,106] Ablations above 85 – 100 microns show a hyperopic refractive shift.[8,108] Starr *et al.* have shown a refractive shift of more than or equal to 1 D in 63% of the patients.[8] This hyperopic shift can be reduced by a standard peripheral transition zone of 0.5 D.[8] The ablation also depends upon the corneal hydration, and drying of the cornea during the procedure may induce more hyperopia;[109,110] this is important for a novice surgeon, as the delayed treatment time would reduce the stromal thickness and in turn increase ablation. Usually the refraction gets stabilized after three months.[12]

Amm *et al*., had found lack of refractive changes when spot mode was used for ablation.[22] PTK with PRK was reported as in scars, dystrophy, Thygeson's superficial punctuate keratopathy, and diffuse lamellar keratitis.[54,110,111]

Repeat Phototherapeutic Keratectomy

Clinical recurrences may not warrant repeat treatments, whereas, in a visually significant recurrence (reduced BCVA by more than two lines), PTK can be repeated, provided corneal thickness is enough and the corneal topography does not show too much flattening.[41,43,55,57,62,92]

Complications

Recurrence of primary disease pathology

Corneal dystrophies and RCE recur.[4,41,43,55,57] Reis Buckler dystrophy has a high rate of recurrence.[43] Miller *et al*., have tried topical intraoperative MMC, to avoid recurrence of Reis Buckler dystrophy, stating that fibrocellular material replaces the Bowman's layer, which is analogous to neoplastic proliferation.[51] With the high rate of recurrence after PTK for macular dystrophy, PKP must be the first line of treatment for macular dystrophy and PTK can be performed during the waiting period.[45] Recurrence has been reported in BSK, in nine eyes (five with silicone oil) out of the 122 treated eyes.[32] Dinh *et al*., have noted no recurrence in Schnyder's dystrophy over a short follow-up and Koksal over the longest follow-up of 68 months.[43,58] Paparo *et al*., have reported recurrence after a year in the periphery, in Schnyder's dystrophy.[59] PTK can be repeated till the final limit of 250 microns is reached to avoid keratectasia, and PKP could be considered then.[43]

Infections

al-Rajhi *et al*., have reported three cases of bacterial keratitis after PTK in three out of 258 patients of spheroidal degeneration, over one to 24 months.[112] Even when PTK is successful, the occurrence of infectious keratitis can adversely affect the final visual outcome. Fagerholm has reported bacterial keratitis between one to eight weeks after surgery and believed it to be because of RCE.[72]

Reactivation of herpes simplex virus

Spontaneous reactivation of the virus could occur after PTK. Viral shedding was noted in one patient of BSK three days after PTK, without any clinical signs, and the authors concluded that excimer laser irradiation might elicit HSV reactivation.[113] Vrabec *et al*., reported recurrence of herpetic keratitis about three months after PTK, in patients with a past history of herpetic keratitis.[114] Starr *et al*., have shown recurrence in their patients, 4, 14, and 17 months after PTK.[115] The excimer laser emits at 193 nm and the UV radiation ranges between 180 and 450 nm. The ablation depth is not responsible for recurrence as also the epithelial removal.[114] Also corneal trauma, postoperative pain, and topical steroid use may activate the virus.[113] Herpes virus reactivation should be considered if the defect does not heal or there is a persistent epithelial defect after PTK.[116] PTK for scars of Epidemic keratoconjunctivitis must be carried out when the eye becomes quiet, else recurrence can occur.[8]

Delayed healing of epithelium

The epithelial defect usually heals within a week's time and delayed healing can increase the risk of infection and haze formation. This may need AMG along with lubricants and BCL especially in lattice dystrophy.[42] Zuckerman *et al*., have noticed delayed healing in patients with corneal leucoma (8.1 ± 2.6 days).[14] The causes of non-healing can be the concomitant use of topical NSAIDS or reduced corneal sensation.[56,117]

Other complications reported are keratectasia, when PTK is done for nebulae of keratoconus. A larger ablation zone is recommended in thinner cornea, because of the uniform stress distribution, with less stress on a single, thin area.[9,118] Permanent corneal edema following the use of 0.02% drops of MMC for six days after PTK in a young patient who had PTK for RCE, has been reported.[119] Graft rejection has been reported after PTK.[120,121]

Conclusion

Phototherapeutic keratectomy is a safe and effective procedure in the management of superficial corneal diseases such as corneal scars, degenerations, and dystrophies. It reduces RCE and improves vision. Also, as repeat PTK is possible, keratoplasty can be delayed or obviated. Even when visual improvement is not the goal, as in bullous keratopathy, PTK will result in having a firm adhesion of the epithelium to the underlying stroma, and may prevent bullae formation and RCE. The smooth surface obtained in spheroidal degeneration will help in improving the visual acuity, also keratometry or topography is more precise for IOL power calculation when these patients undergo cataract surgery.

With the better overall outcome of PTK procedures, the research should be directed toward preventing recurrences of primary disease pathology, and for better predictability of post-PTK refractive error and combining PTK with PRK for both good visual and symptomatic outcome, in the future, so that keratoplasties can be avoided. Also, the role of the AMG with PTK procedure must be studied.

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