

Indications and Outcomes of Phototherapeutic Keratectomy in the Developing World

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Purpose: To analyze the indications and outcomes of phototherapeutic keratectomy (PTK) in the developing world.

Methods: In this retrospective study, the records of 203 consecutive eyes of 191 patients who had undergone PTK at a tertiary eye care center were evaluated. The parameters assessed were indications of PTK, demographic features, best spectacle-corrected visual acuity (BSCVA), and pachymetry. PTK was done by using a 193-nm Ar-F Excimer laser (Chiron Technolas Keracor 217 C) in a 6-mm optic zone. Patients were followed up for 6 months.

Results: The most common indication of PTK was symptomatic bullous keratopathy (103 eyes). The patients were divided into 2 groups: those with bullous keratopathy (PTK BK) and those with superficial corneal pathologies (PTK CS). In the PTK CS group, the most common indications were Salzmann nodular degeneration (n = 27) and spheroidal degeneration (n = 22). BSCVA improved from 20/222 (0.09) to 20/86 (0.23) in the PTK CS group and 20/384 (0.05) to 20/202 (0.09) in the PTK BK group ($P < 0.0001$ in both groups). There was a significant decrease in the number of patients with severe symptoms in the PTK-BK ($P < 0.0001$) and PTK-CS ($P = 0.017$) groups. The change in BSCVA was significantly related to both pre-PTK BSCVA and pachymetry in PTK-BK.

Conclusions: PTK is an efficacious treatment modality for symptomatic relief and visual gain in cases with superficial corneal involvement and bullous keratopathy.

Key Words: phototherapeutic keratectomy, developing world, bullous keratopathy, corneal scarring

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Anterior corneal diseases and bullous keratopathy have been treated by phototherapeutic keratectomy (PTK) with promising results.^{1–8} In developed countries, major indications of PTK include superficial corneal dystrophies and scars.^{1–4} In

developing countries, PTK may be used in patients awaiting keratoplasty, sometimes as a curative measure,^{1,9–15} because there is a paucity of donor corneas. Because of poor socioeconomic conditions, ignorance, and the absence of a prompt referral system, many patients present to tertiary centers in an advanced stage of the disease. In this study, we evaluate the indications and outcomes of PTK at a tertiary eye care center in the developing world.

MATERIALS AND METHODS

From January 2000 to March 2006 203 eyes of 191 patients undergoing excimer laser PTK were evaluated at the Cornea Services of our center. Preoperative evaluation consisted of history taking and clinical examination. The parameters assessed were visual acuity, ultrasonic pachymetry (Sonogage, Cleveland, OH), intraocular pressure (by applanation/noncontact tonometer, with correction for corneal thickness), and findings of slit-lamp biomicroscopy. Posterior segment evaluation was done in each eye. The severity of symptoms was graded on a fixed response scale (Table 1). The procedure and possible outcomes were explained to each patient, who then gave his or her informed consent.

The procedure was performed under topical anesthesia (0.5% proparacaine), which was instilled 3 times every 5 minutes just before starting the laser. After putting on the drape and the lid speculum, the practitioner scraped off the epithelium manually with a hockey stick spatula. Corneal nodules, if any, were manually scraped off before starting the laser. A flying spot, technology-based, 217 C laser (193-nm ArF Excimer laser; Chiron Technolas Keracor, Bausch & Lomb, NY) was used to ablate the cornea. The centration of the laser beam was ensured by asking the patient to fixate on the coaxial light target and by using the eye-tracker system. The eye tracker was turned off if the patient was unable to fixate on the target light because of poor visual acuity. The treatment zone was confined to a central 6-mm area of the cornea. The extent of opacity was assessed preoperatively by using slit-lamp biomicroscopy. Depending on the results of the assessment, the depth of ablation varied between 25 and 100 μm .

After laser ablation, a bandage contact lens was placed on the cornea, and 1 drop of 0.3% ofloxacin was instilled. Immediately after the PTK procedure, patients were examined by using a slit lamp.

Postoperatively, each patient was prescribed topical 0.3% ofloxacin and 0.1% fluorometholone 4 times a day for 4 weeks. Patients were also prescribed preservative-free

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TABLE 1. Symptom Scale for Pain, Photophobia, and Watering in Patients Undergoing PTK

| Category Score | Symptom Scale | Patient History |
|----------------|---------------|---|
| 0 | Asymptomatic* | The patient was asymptomatic without any medication. |
| 1 | Minimal* | On minimal to maximum medication, symptoms were under control. |
| 2 | Mild† | Diurnal variation in symptoms, mostly significant during certain times of the day. |
| 3 | Moderate† | Unbearable symptoms during lid opening or daytime. |
| 4 | Severe† | Unbearable symptoms round the clock or pain significant enough to disrupt sleep at night. |

In all the patients, except categories 0 and 1, medical management was unable to control symptoms.

*Not considered for PTK.

†Underwent PTK.

artificial tears 4 times a day for 12 weeks. Each day, a bandage contact lens was placed in situ until complete epithelialization was detected on slit-lamp evaluation. Further follow-up was done at 1, 3, and 6 months postoperatively.

RESULTS

Patient Characteristics

The mean age of patients undergoing PTK was 54.47 ± 17.4 years (range, 14–83 years). There were 113 men and 78 women. The right and left eyes, respectively, were involved in 117 and 86 cases. In patients with bilateral, asymmetric involvement, the worst eye was treated first. Twelve patients, 8 men and 4 women, had bilateral advanced pathology and underwent treatment with a minimum interval of 1 month between the 2 eyes. Of 191 patients, 153 (80.1%) were from rural/underdeveloped areas and had a monthly per capita income of less than US\$15.

Indications for PTK

The most common indication of PTK, which was symptomatic bullous keratopathy secondary to cataract surgery (previously known as bullous keratopathy, referred henceforth in the article as bullous keratopathy), was found in 107 eyes. Ninety (44.3%) eyes had pseudophakic bullous keratopathy and 17 (8.3%) eyes had aphakic bullous keratopathy. Among the pseudophakic eyes with bullous keratopathy, 52 had an anterior-chamber intraocular lens placed with a posterior capsular defect. The remaining 38 had a posterior-chamber intraocular lens. These patients had persistent watering, photophobia, and pain on lid movement.

Salzmann nodular degeneration and spheroidal degeneration, which occurred in 27 and 22 eyes, respectively, were the next most common indications of PTK after bullous keratopathy. Band-shaped keratopathy was the indication for PTK in 22 eyes (Table 2), of which 12 occurred in silicone oil-filled eyes after retinal surgery. Each of the 22 eyes had undergone at least 1 unsuccessful EDTA chelation procedure.

Many of our patients had bullous keratopathy (107 of 203 eyes). The baseline variables of age, pachymetry, and visual acuity differed significantly between those undergoing PTK for bullous keratopathy after cataract surgery (PTK BK

group) and those undergoing PTK for superficial corneal scarring of various etiologies (PTK CS group; Table 3). Hence, we analyzed the results of these 2 groups separately.

Ablation Depth

In the PTK CS group, the mean ablation depth was 61.14 ± 18.8 μm (range, 25–100 μm). In the PTK BK group, the mean ablation was 89.95 ± 20.56 μm (range, 25–100 μm).

Change in Best Spectacle-corrected Visual Acuity

Visual acuity was recorded in Early Treatment Diabetic Retinopathy Study (ETDRS) equivalents. Acuity was converted into decimal scores for analysis, and the results were converted back to ETDRS equivalents for easier interpretation. Mean preoperative and postoperative values for best spectacle-corrected visual acuity (BSCVA) were 20/222 (0.09) and

TABLE 2. Frequency and Percent Distributions for Indications of PTK

| Indication | Frequency | % |
|--|-----------|------|
| Pseudophakic bullous keratopathy | 90 | 44.3 |
| Aphakic bullous keratopathy | 17 | 8.4 |
| Salzmann nodular degeneration | 27 | 13.3 |
| Spheroidal degeneration | 22 | 10.8 |
| Silicone oil-filled eye with BSK | 12 | 5.9 |
| Idiopathic BSK | 7 | 3.5 |
| Failed graft with BSK | 3 | 1.5 |
| Healed superficial keratitis | 7 | 3.5 |
| Posttraumatic corneal opacity | 7 | 3.5 |
| Post-ptyerygium removal scarring | 3 | 1.5 |
| Iridocorneal endothelial syndrome with 2° glaucoma | 2 | 0.1 |
| Map-dot dystrophy | 2 | 0.1 |
| Trachomatous keratopathy | 2 | 0.1 |
| Graft rejection | 1 | 0.5 |
| Cogan dystrophy | 1 | 0.5 |
| Total | 203 | 100 |

BSK, band-shaped keratopathy.

TABLE 3. Pretreatment Parameters of the Two Groups

| Variable | PTK CS (n = 96) | | PTK BK (n = 107) | | Mann-Whitney U Test (P) |
|-----------------|--------------------|------|---------------------|--------|-------------------------------|
| | Mean | SD | Mean | SD | |
| Age (y) | 48.6 | 20.1 | 59.7 | 12.8 | <0.0001 |
| Pachymetry (µm) | 549.8 | 87.0 | 748.9 | 125.28 | <0.0001 |
| Pre-PTK BSCVA | 0.09 (20/222) | 0.1 | 0.05 (20/384) | 0.08 | <0.0001 |

20/86 (0.23), respectively, in the PTK CS group and 20/384 (0.05) and 20/202 (0.09), respectively, in the PTK BK group. In each group, the mean decimal score BSCVA increased significantly ($P < 0.0001$).

There was an improvement in BSCVA in 72 (79.1%) of 91 eyes in the PTK CS group and in 75 (72.8%) of 103 eyes in the PTK BK group. Scatterplots of the pre-PTK and post-PTK BSCVA of the 2 groups showed that patients in the PTK CS group had greater gain in visual acuity than those in the PTK BK group (Figs. 1 and 2).

Postoperative Haze

Mild postoperative haze was seen on slit-lamp examination in 22 eyes. In 12 of these eyes, the postoperative haze resolved by the last follow-up visit. The amount of postoperative haze was not enough to cause a major reduction in BSCVA in most of these cases.

Refractive Shift

Because of the presence of advanced corneal opacification, refraction could be done preoperatively in 57 of 203 eyes only, each of which belonged to the PTK CS group. The mean refractive shift was $+2.32 \pm 0.93$ D, for a mean ablation

of 57.87 ± 17.7 µm. Refractive shift and ablation depth were strongly correlated (Pearson correlation coefficient = +0.64; $P < 0.0001$).

Epithelialization Time

Mean epithelialization time in the PTK CS patients was 3.54 ± 1.17 days (range, 2–7 days). In the PTK BK group, the mean epithelialization time was 6.44 ± 3.51 days (range, 2–17 days). Four patients with bullous keratopathy took >14 days for complete epithelialization (17, 15, 16, and 15 days, respectively, for the 4 eyes). The nonadvancing edges of the heaped epithelium were scraped in each eye, which was patched for 24–48 hours.

Symptomatic Relief

A fixed response scale was used to classify the presenting symptoms as mild, moderate, and severe on the basis of the degree of pain, photophobia, and watering (Table 1). Each of the 107 patients with bullous keratopathy (PTK BK) and each of the 52 patients with PTK CS had various degrees of watering, pain, and photophobia.

The procedure significantly reduced the number of patients with severe symptoms (Table 4) in the PTK-BK group

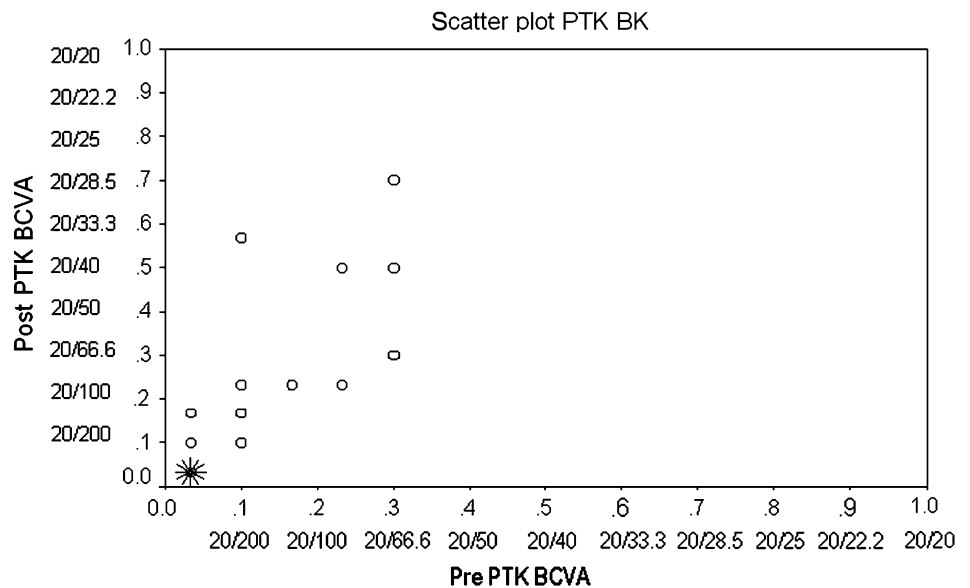


FIGURE 1. Scatterplot of pre- and postlaser BSCVA of the PTK BK group.

* each spoke on the circle near $x = 0.05, y = 0.05$ denotes 6 cases
(For both axes, visual acuity is in decimal score and corresponding snellen's equivalents)

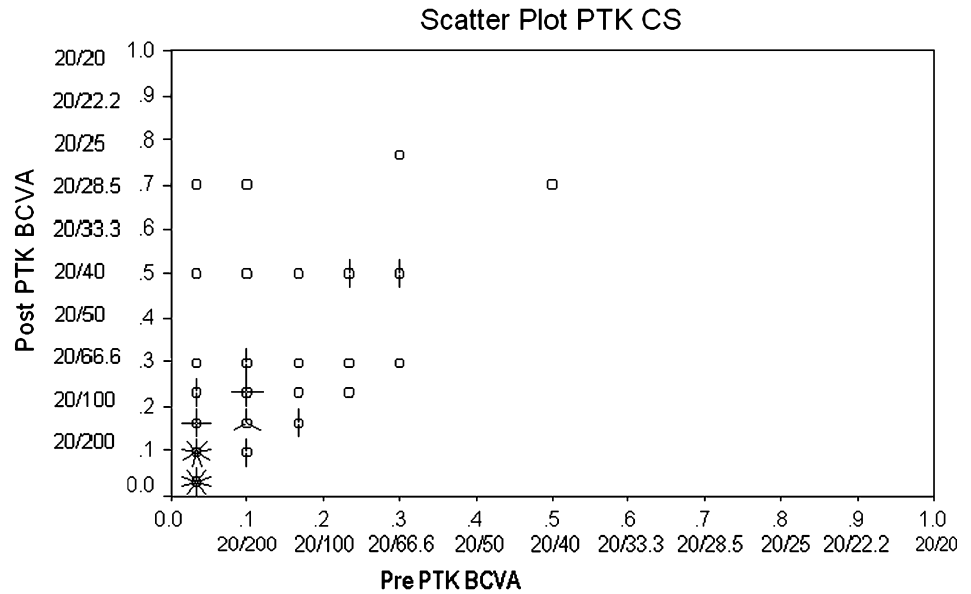


FIGURE 2. Scatterplot of pre- and postlaser BSCVA of the PTK CS group. * each spoke on the circles denotes 2 cases (For both axes, visual acuity is in decimal score and corresponding snellen's equivalent)

($P < 0.0001$) and the PTK-CS group ($P = 0.017$). There was an overall decrease in the percentage of patients with higher symptom scores.

Factors Related to Change in BSCVA After Treatment and Those Related to Epithelialization Time

Relationships among prelaser variables and postoperative outcomes were analyzed (Table 5). In both groups, pre-PTK BSCVA was significantly correlated with pachymetry but not with age. Change in BSCVA was significantly correlated with pre-PTK BSCVA and ablation depth in the PTK BK patients but not in the PTK CS patients. In each group, epithelialization time and pre-PTK pachymetry were significantly correlated. In addition, epithelialization time was related to ablation depth in patients with bullous keratopathy (PTK BK).

DISCUSSION

PTK has been used for the treatment of anterior corneal disorders.^{1-8,16-19} In 1 study, many patients undergoing PTK were those with bullous keratopathy after cataract surgery. Because there is no large, combined, national corneal registry in India, the prevalence and burden of bullous keratopathy is difficult to assess. In a previous study at our center, Sony et al²⁰ evaluated the eye bank records of penetrating keratoplasties performed during the period from June 1997 to November 2003. Of 2022 penetrating keratoplasties, aphakic bullous keratopathy (7.27%) and pseudophakic bullous keratopathy (6.18%) accounted for >13% of cases.

In our tertiary eye care center, many patients with early symptomatic bullous keratopathy either undergo PTK or their symptoms are controlled by medication. Many of these patients are referred from peripheral centers in northern India, often in advanced stages of the disease. Consequently, the frequency of bullous keratopathy may be unusually high in our

TABLE 4. Symptom Assessment Before and After PTK

| Category Score | Symptom Scale | Symptomatic PTK-CS Patients (n = 52)* | | Symptomatic PTK-BK Patients (n = 107)* | |
|--|---------------|---------------------------------------|----------|--|----------|
| | | Pre-PTK | Post-PTK | Pre-PTK | Post-PTK |
| 0 | Asymptomatic | 0 | 0 | 0 | 0 |
| 1 | Minimal | 0 | 16 | 0 | 18 |
| 2 | Mild | 13 | 24 | 7 | 34 |
| 3 | Moderate | 26 | 8 | 44 | 40 |
| 4 | Severe | 13 | 4 | 56 | 15 |
| Pearson χ^2 (category score 4 vs. <4) P | | <0.0001 | | 0.017 | |

*Patients with corneal edema with symptom score <2 were not offered PTK for PTK CS; pre-PTK symptom grade 1 or below was analyzed for visual indications only.

TABLE 5. Correlation Coefficients of the Various Pre- and Postlaser Parameters in the Two Groups

| Factors Compared | PTK CS (n = 96) | | PTK BK (n = 107) | |
|--|-----------------|--------|------------------|----------|
| | Correlation | P | Correlation | P |
| Prelaser BSCVA–Age | –0.011 | 0.9 | –0.047 | 0.6 |
| Prelaser BSCVA–prelaser pachymetry | –0.218 | 0.03† | –0.282 | 0.003* |
| Change in BSCVA–prelaser BSCVA | +0.22 | 0.03† | +0.546 | <0.0001* |
| Change in BSCVA–prelaser pachymetry | –0.16 | 0.1 | –0.151 | 0.1 |
| Change in BSCVA–ablation depth | –0.08 | 0.4 | –0.201 | 0.04* |
| Epithelialization time–prelaser pachymetry | +0.31 | 0.002* | +0.337 | <0.0001* |
| Epithelialization time–ablation depth | +0.10 | 0.3 | +0.304 | 0.001* |
| Epithelialization time–age | +0.13 | 0.2 | +0.12 | 0.2 |

*Significant for $P \leq 0.01$, Pearson correlation.
†Significant for $P \leq 0.05$, Pearson correlation.

sample. Nevertheless, bullous keratopathy is a major corneal disorder in our facility. The results of PTK are encouraging as it offers a viable interim treatment option in our patients, for symptomatic relief which was achieved in most eyes. The proposed mechanism of PTK in bullous keratopathy is 1) ablation of the superficial epithelial nerve plexus, 2) ablation-related reduction of osmotic load of the stroma that increases the efficacy of “dehydration” of the cornea by the remaining endothelium, and 3) creation of a smooth anterior surface.²¹

In our study, Salzmann nodular degeneration and spheroidal degeneration were the most common indications of PTK after bullous keratopathy. In these cases, the aim was to create a smooth optical surface. Nodules were scraped manually before PTK to ensure uniform ablation. Most of our cases had advanced corneal pathology, and the nodules extended into the anterior cornea. The depth of the nodules was assessed on slit-lamp biomicroscopy and was used as a guide to plan the depth of the ablation. However, with the aid of anterior-segment OCT or ultrasound biomicroscopy,²² exact assessment of the depth of the nodules is possible. This approach could obviate a greater amount of ablation and hence may reduce the postoperative hyperopic shift.

Treatment improved BSCVA in each group in our study. However, the improvement was much greater for PTK CS patients than for PTK BK patients. The outcomes in our study are generally similar to those described in the literature.^{16,17,19,23,24}

In patients with bullous keratopathy, the primary aim of PTK was symptomatic relief. Ablation resulted primarily in smoothing of the anterior corneal surface and symptom alleviation. Visual improvement was a secondary aim in these eyes. However, vision was improved in many eyes because of a stable tear film and a smoother anterior corneal surface. There is a paucity of high-quality donor corneal tissue in developing countries, and patients must wait for long periods for keratoplasty. PTK can be a useful interim measure in these patients. In our view, PTK does not jeopardize the outcome of a subsequent keratoplasty.

Most of our patients have low socioeconomic status and come from remote and rural areas. The cost of medications for bullous keratopathy and the need for frequent follow-up after

keratoplasty are significant economic burdens. PTK decreases the quantity of medications needed and allows for a more liberal follow-up schedule.

In the PTK BK group, correlations between pre-PTK pachymetry, pre-PTK BSCVA, and change in BSCVA suggest that a better initial visual acuity and corneal status facilitates the creation of a smooth anterior corneal surface and better postoperative visual acuity. Time to complete epithelialization was longer in the PTK BK group than in the PTK CS group. However, pre-PTK pachymetry differed significantly between the 2 groups, and hence it was not possible to compare them. A positive correlation between the initial pre-PTK pachymetry and the time to complete epithelialization was present in each group. In the PTK BK group, this finding may be attributed to the compromised endothelial pump and epithelial desmosomal status. However, a similar mechanism is unlikely for the PTK CS group. Further studies are needed to understand the correlation between pre-PTK thickness and epithelialization rates.

In patients with superficial corneal scarring, the primary aim of PTK is visual improvement by removal of opacity. However, for Salzmann nodular degeneration and spheroidal degeneration, there is a significant ocular surface disorder together with corneal opacification. This condition causes symptoms of pain, photophobia, and watering, which may also reduce visual acuity. The alleviation of these symptoms by PTK is an added advantage in this group, which may contribute to the overall outcome of the procedure.

In patients with superficial corneal opacities, the procedure obviates the need for a lamellar graft, thus reducing the demand for corneal tissue. Because there are no sutures or long-term medications, fewer follow-up visits are needed.

Therefore, PTK is a safe and efficacious procedure. It can alleviate symptoms and result in interim improvement in visual acuity in patients with bullous keratopathy awaiting penetrating keratoplasty. In patients with superficial corneal opacities, it clears the visual axis and improves visual acuity. This keratoplasty-sparing benefit of PTK is especially relevant in developing countries where economic constraints and high demand for corneal donor tissue are major problems.

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