

Penetrating Keratoplasty for Keratoconus

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Abstract

Keratoconus is a common corneal dystrophy in which penetrating keratoplasty is an effective form of treatment. A retrospective study on patients with keratoconus who underwent penetrating keratoplasty in the Singapore National Eye Centre between 1991 and 1995 was undertaken to describe and characterise the patient population and the success of this procedure. Thirty-two penetrating keratoplasties for keratoconus in 32 eyes of 29 patients were identified. Twenty eyes of 20 patients had a postoperative follow-up period of at least 12 months (range 12 to 44 months). These eyes were specifically examined for success rate and complications.

Of the 32 eyes in the study, 18 (54%) belonged to Indians patients and 23 (72%) belonged to male patients. In those eyes with 12 months or more of postoperative follow-up, the visual acuity of 16 (80%) eyes improved postoperatively, with 14 (70%) eyes having a best corrected visual acuity of 6/12 or better. There were no graft failures. Nine eyes (45%) had complications postoperatively. Five eyes underwent refractive surgery for correction of astigmatism. Useful vision of 6/60 or better was achieved within 1 week postoperatively in 8 (40%) of the eyes. The authors conclude that penetrating keratoplasty is a successful procedure in keratoconic eyes not correctable by conservative therapy. The incidence of postoperative complications were however not uncommon. Although the majority of these complications were treated successfully, severe complications such as retinal detachment and glaucoma were the main causes of poor visual outcome after penetrating keratoplasty for keratoconus.

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Introduction

Keratoconus is a progressive, non-inflammatory disorder that is characterised by gradual stromal thinning and ectasia of the cornea. The aetiology of the condition is unclear and is thought to be heterogeneous in nature. One of the suggested causes is related to the degradation of the stromal tissues in the keratoconic cornea. Keratoconic corneas have been shown to have increased collagenolytic and gelatinolytic activity due to an increased level of activity of matrix metalloproteinases. This is thought to be due to a decrease in the level of tissue inhibitors of these proteinases.¹ Baum² further proposed that keratoconus may be induced by chronic eye rubbing, causing irritation to the old epithelial cells on the cornea. This promotes an increase in proteolytic enzymatic activity, resulting in an increase in breakdown and thinning of the cornea.² Keratoconus is also thought to be more common in certain groups of patients such as those with Down's syndrome, atopy and Marfan's syndrome.

Keratoconus usually presents at puberty and has a variable course. The resulting irregular astigmatism and complications such as hydrops and scarring are

responsible for poor vision. Management of the condition depends on the severity, with the use of spectacles or no correction in mild cases to contact lenses and penetrating keratoplasty (PK) in severe cases.^{3,4} Penetrating keratoplasty, being a surgical procedure, is usually used as the last resort following failure of conservative therapy with spectacles and contact lenses.

Studies have looked into various aspects of the treatment, progression and prognosis of keratoconus.^{3,4} The success and complications of each modality of treatment, especially penetrating keratoplasty, are well known.^{3,4} However, no study has been done in Singapore to understand the patients' characteristics and the success of the various treatment modalities for keratoconus. The objective of this paper was to study the characteristics of these patients who had PK, as well as to compare the success of treatment with other overseas studies.

Materials and Methods

Inclusion and Follow-up Criteria

Three hundred and forty-five cases of PK performed at the Singapore National Eye Centre (SNEC) between

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23 January 1991 and 25 November 1995 were reviewed. The diagnosis of keratoconus in the eyes selected for the study was made based on clinical signs or corneal topography. Thirty-four eyes belonging to 30 keratoconic patients were found. Two of these PKs were for re-grafts following graft rejection carried out before the study period and were not enrolled. The case records of the remaining 32 eyes were reviewed in a retrospective study.

Twenty eyes of 20 patients with 12 months or more of postoperative follow-up were studied for success and complications of the treatment.

Study Parameters

The study parameters were:

- 1) Patient characteristics;
- 2) Indications for surgery and the surgical parameters used;
- 3) Outcome of surgery, including the best corrected visual acuity (BCVA) pre and postoperatively and pre and postoperative visual aids required for the eyes that had at least 12 months of follow-up;
- 4) Complications after surgery and any additional surgery required;
- 5) Postoperative refraction and correction of astigmatism; and
- 6) Time taken for the patient to acquire useful vision of an unaided visual acuity of 6/60 or better postoperatively.

Best Corrected Visual Acuity (BCVA)

The BCVA includes only the best corrected visual acuity with the applied means of refractive correction that is successful for the patient. In eyes that were contact lens failures, the preoperative BCVA used refers to the vision that is obtained using spectacles, or if spectacles were not prescribed for that eye prior to surgery, as it is often the case, the vision recorded was that obtained using the pinhole.

Complications

Complications include any process that might potentially compromise the visual outcome. Specifically, complications such as graft rejection, cataracts, raised intraocular pressure, wound dehiscence, microbial keratitis and retinal detachment were noted during the postoperative period.

Graft failure is considered to have occurred when the cornea is unable to maintain its clarity at the end of follow-up period or when a re-graft has to be carried out. Even if the re-graft is successful, the case will be considered as a failure as the aim of the study was to investigate the success of the initial surgery.

Graft failure may be due to immunological or non-immunological reasons. If it is due to an immunological

rejection, it must be unresponsive to immunosuppressive therapy before being considered a failure.

Statistical Analysis

The data collected were entered into a database with statistical analysis done by the Statistical Package for Social Sciences (Windows Release 6.0, SPSS Inc, Chicago, Illinois).

Results

Patients' Characteristics

Thirty-two PKs were performed for 32 eyes in 29 patients. Eighteen (56%) operations were for the left eye and 14 (44%) were for the right eye.

Eighteen eyes (56%) belonged to Indian patients, 10 (31%) belonged to Chinese patients, 3 (10%) belonged to Malay patients and 1 (3%) eye belonged to a Eurasian patient. Twenty-three (72%) of the eyes belonged to male patients and 9 (28%) to female patients. The median age of the patients at time of surgery was 23 years (range 15 to 54 years). The male patients were younger with a median age of 22 years (range 15 to 38 years) compared to the female patients with a median age of 31 years (range 16 to 54 years).

All the eyes belonged to patients with bilateral keratoconus. Ten eyes (31%) belonged to patients with a history of atopy, 5 eyes had a previous history of hydrops and 4 eyes had a history of previous PK in the contralateral eye.

Indications for Surgery and Surgical Parameters

The indications for surgery were divided into 3 main groups: 1) due to scarring so that the resultant vision was unacceptable; 2) due to failure of contact lens wear which included, inability to obtain prolonged useful vision with the contact lens, inability to fit the contact lens such that useful vision cannot be obtained or due to tendency for the contact lens to fall out; and 3) due to prolong unresolved hydrops such that no useful vision was possible. For the purposes of this study, we have chosen to define useful vision for each individual as that vision necessary and adequate for normal function in his activities of daily living. Fifteen (47%) eyes had surgery due to scarring, 10 (31%) were due to contact lens failure, 2 (6%) were for hydrops and 5 (16%) required PK due to both scarring and contact lens failure.

The PKs in the 32 eyes were done by 3 surgeons. The suture technique used was interrupted sutures. One eye required PK together with extracapsular cataract extraction and posterior chamber intraocular lens implantation. The remaining eyes did not require any additional surgery together with the PK.

The mean trephine size for the donor graft was 8.2 mm $\pm$ 0.3 (mean $\pm$ standard deviation) (range 7.5 to 9.0 mm).

The mean trephine size for the recipient was $8.0 \text{ mm} \pm 0.4$ (range 7.0 to 9.0 mm).

The average age of the donor was 40 ± 14 years (range 16 to 64 years). Corneas belonging to younger donors were selected for PK in keratoconic patients because these patients were on the whole younger than patients that needed PK for other corneal diseases.

Outcome of PK

Twenty eyes with 12 months or more of follow up were studied for the long-term outcome of PKs. They were followed up for an average period of 29 months (range 12 to 44 months).

At the end of the study period, all 20 PKs remained clear. This is consistent with other studies which demonstrated that penetrating keratoplasty is a highly successful procedure for keratoconus. However, what was of greater interest to us was the ability of the eye to achieve good visual acuity postoperatively with no complications.

Preoperatively, 12 eyes (60%) had best corrected visual acuity (BCVA) of 6/60 or worse (Fig. 1). There were no eyes with BCVA better or equal to 6/6.

Postoperatively, 16 eyes (80%) had an improvement in visual acuity (Fig. 1). Two eyes (10%) had BCVA of 6/60 or worse, 14 (70%) eyes had BCVA equal to or better than 6/12 and 3 eyes (15%) had BCVA of 6/6 or better.

Preoperatively, 16 eyes (80%) were using visual aids, while 4 eyes (20%) had no visual improvement with any form of visual aids. Ten eyes (50%) were wearing spectacles, 4 (20%) were wearing rigid gas permeable contact lenses and 1 (5%) was using soft **contact** lenses. One (5%) was wearing spectacles with soft contact lenses.

At the end of the study period, 3 eyes (15%) were not using any visual aids. One of them had good vision

following the PK while 2 had poor vision that was **not** correctable by visual aids. Nine eyes (45%) were using spectacles while 3 eyes (15%) were using rigid gas permeable contact lenses. Five eyes (25%) underwent surgery for astigmatism. Four had excimer laser photoastigmatic refractive keratotectomy (PARK) and 1 had graft refractive surgery. Two of the eyes that underwent PARK did not need any visual correction after the procedure, while 1 was using soft contact lenses and 1 had not achieved stability in refraction at the end of the study. The eye that had graft refractive surgery required cataract surgery just before the end of the study period. A pair of spectacles was finally prescribed for this eye 8 months after the operation, improving the visual acuity from 6/9 to 6/7.5.

Complications (Not Including Astigmatism)

Nine (45%) eyes had complications (Fig. 2). Five eyes had one complication each and 4 eyes had more than one complication. In the 4 eyes with more than one complication, 3 eyes had both graft rejections and posterior subcapsular cataract as complications. In addition, 2 of the 3 eyes also developed raised intraocular pressure. One of the 4 eyes had 4 complications of wound dehiscence, keratitis, cataract and retinal detachment.

The first complication in 4 of the 9 eyes (44%) occurred within the first 6 months postoperatively. One occurred at 9 months, one at 13 months and the remaining 3 occurred after 18 months.

Treatment of Complications and Additional Surgery (Not Including Astigmatism)

The most common complications (Fig. 2) were graft rejection and posterior subcapsular cataracts. There were 5 rejections, 3 of which occurred during the first year after surgery at 1, 3 and 9 months. The remaining 2 rejections occurred at 30 and 32 months after the opera-

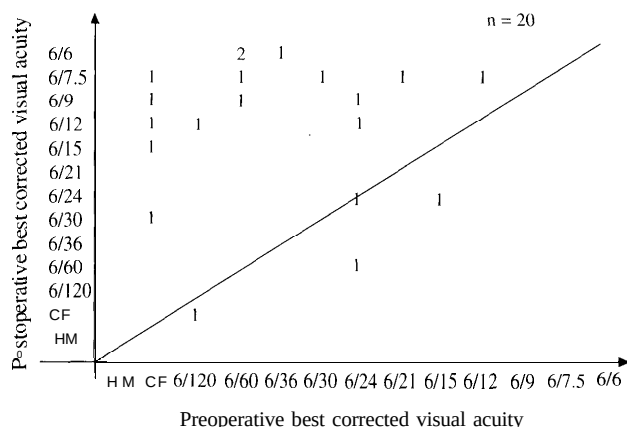
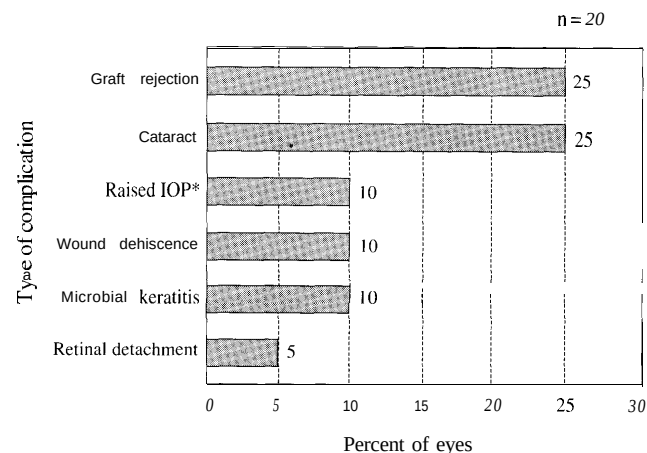


Fig. 1. Preoperative versus postoperative best corrected visual acuity. Eighty per cent of the eyes had an improved best corrected visual acuity postoperatively. The number on the chart represents the number of eyes with the specified preoperative and postoperative visual acuity.

CF: able to perceive counting fingers; HM: able to perceive hand movement



*raised intraocular pressure

Fig. 2. Incidence of postoperative complications after penetrating keratoplasty for keratoconus. The major postoperative complications were graft rejections and cataracts.

tion. All the graft rejections were well controlled with medication and none of the grafts failed. Of the 5 eyes with cataracts, 1 eye underwent cataract surgery with posterior chamber intraocular lense implantation (IOL). The remaining 4 eyes with cataracts did not undergo surgery. Three of the cataracts were considered to be at an early stage and did not need surgery yet; 1 eye did not have any useful vision following retinal detachment and surgery was not performed. The high incidence of cataracts as a complication of the surgery could be due to the postoperative use of steroid eye drops to prevent rejections.

Two eyes had raised intraocular pressures. One was controlled medically, the other deteriorated despite medical treatment and developed glaucoma. This eye finally required a trabeculectomy. The final BCVAs of these 2 eyes were 6/9 for the medically controlled one and 6/30 for the eye that required trabeculectomy.

Both cases of wound dehiscence were treated successfully with resuturing. Two cases of microbial keratitis were treated successfully. There was one case of retinal detachment which underwent 2 operations. The postoperative BCVA was 6/120. No visual aids were prescribed for this patient.

Postoperative Refraction

Postoperative refractions were available for 18 out of the 20 eyes. One eye did not have refraction done as it was still resolving from an episode of rejection at the close of the study. This eye was subsequently lost to follow-up. The other eye did not have any refraction done as there was no useful vision left in that eye (due to retinal detachment).

The average refractive cylinder at the end of the study period was $-3.8 \text{ D} \pm 2.1$ (range 0.00 to -8.00). The average spherical equivalent was $-3.2 \text{ D} \pm 3.7$ (range -9.00 to $+1.00 \text{ D}$). Fourteen eyes (78%) were myopic and 4 (22%) were hyperopic.

Five eyes underwent operations for the correction of astigmatism (Table I). The BCVA after the surgery, which was either PARK or graft refractive surgery, was good with 4 eyes, with BCVA better or equal to 6/12 and 1 eye with BCVA of 6/30.

Time Taken for the Eye to Achieve Useful Vision

We had arbitrarily chosen to define useful vision as someone who had an unaided visual acuity (UAVA) of 6/60 or better after the PK.

Eight (40%) of the 20 eyes achieved UAVA of 6/60 within 1 week postoperatively. Five (25%) eyes reached UAVA of 6/60 between 1 week and 1 month while 1 eye never reached UAVA of 6/60 (Fig. 3). Ten of the 13 eyes that achieved 6/60 vision within 1 month went on to have a 6/12 or better BCVA at the end of the study.

Nine eyes (45%) achieved BCVA of 6/12 or better within the first 3 weeks. Eight of these eyes had a final BCVA of 6/12 or better at the end of the study. Sixteen (80%) eyes achieved BCVA of 6/12 or better within 3 months. Of the remaining 4 eyes, 2 never reached BCVA of 6/12, 1 took 3 months and the other took 14 months.

Discussion

Of all the PKs done at the SNEC over the last 5 years, only 9% were for keratoconus. This is lower than other studies which placed the percentage of PKs done for keratoconus between 15% and 37.5%.⁵⁻¹⁰ The lower prevalence of PK for keratoconus in Singapore suggests that either the emphasis here is more on the use of conservative therapy such as contact lenses (which may still be

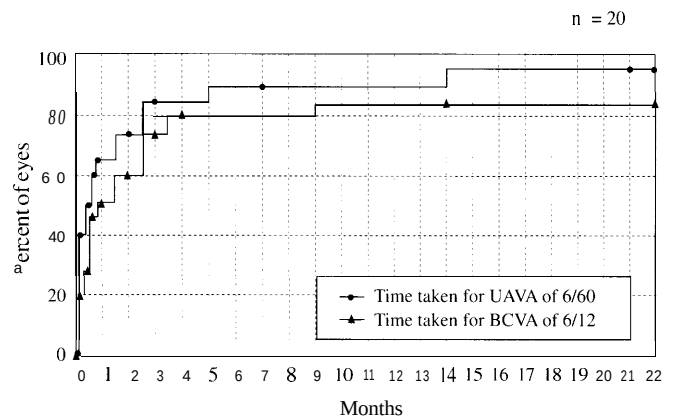


Fig. 3. Time taken to achieve unaided visual acuity of 6/60 or better and best corrected visual acuity of 6/12 and better. Eight eyes (40%) had an unaided visual acuity of 6/60 or better within 1 week postoperatively while 9 eyes (45%) achieved a best corrected visual acuity of 6/12 or better within 3 weeks postoperatively.

UAVA: unaided visual acuity; BCVA: best corrected visual acuity

TABLE I: REFRACTION OF EYES BEFORE AND AFTER SURGERY FOR POST-PENETRATING KERATOPLASTY ASTIGMATISM

Refraction before surgery	Type of surgery	Final refraction	Final BCVA
$-7.50/-3.50 \times 176^\circ$	PARK	$-6.25/-0.50 \times 180^\circ$	6/30
$+0.50/-1.00 \times 90^\circ$	Graft refractive surgery	-9.00 DS	6/9
$-2.00/-7.00 \times 5^\circ$	PARK	plano/ $-1.50 \times 15^\circ$	6/6
$+2.00/-10.00 \times 180^\circ$	PARK	$+3.50/-6.00 \times 170^\circ$	6/12
$+2.50/-6.00 \times 175^\circ$	PARK	$+3.00/-5.00 \times 10^\circ$	6/7.5

BCVA: best corrected visual acuity; PARK: photoastigmatic refractive keratectomy

DS: diopters sphere

successful in eyes with initial contact lens failures”) or there may be a lower incidence of keratoconic patients here as the condition seems to affect Indians (which is a minority) more than other racial groups.

In our study, 56% of the 32 eyes belonged to Indian patients compared to the approximately 8% of Indians in the Singapore population. This strongly suggests that either the incidence of keratoconus is higher in Indians or the severity of keratoconus is greater in Indians. In a study by Tuft et al,¹² racial difference was observed to be a factor in determining progression of keratoconus towards PK. However, Tuft et al¹² did not observe a difference in incidence of keratoconus in the different racial groups.

The age and gender distributions were not unexpected since similar differences were found in other studies.^{3,13} The median age of male patients that had undergone PK was also lower than female patients. A similar trend was observed by Tuft et al¹² whose study noted that the mean age at diagnosis was significantly lower for males compared to females.

The trephine size used for the PKs was large, with a mean donor trephine size of 8.2 mm. This contrasts with Sharif and Casey¹³ who reported a mean donor trephine size of 8.0 mm $\pm$ 0.4 and Lass et al³ who reported a mean trephine size of 7.8 mm $\pm$ 0.3. The main objective for large grafts in keratoconus is to entirely encompass the cone, and hence attempt to reduce postoperative astigmatism by virtue of having a recipient bed which most closely resembles normal corneas curvature and morphology. However, a larger graft is also associated with a higher risk of graft neovascularisation and rejection.

Seventy per cent of the eyes achieved BCVA of 6/12 or better postoperatively. This compares favourably with other reports which showed 81 % to 98% of the eyes achieving BCVA of 6/12 or better.^{3,13-16} In our study, 80% of the eyes achieved an improvement in the best corrected visual acuity. This is lower than that achieved by Goble et al¹⁴ who reported 100% improvement. In the 4 eyes that did not improve, the BCVA in 1 eye (5%) remained the same with a preoperative as well as postoperative BCVA of 6/24, both corrected with spectacles. In the remaining 3 eyes (15%), the postoperative BCVA was poorer than preoperative BCVA. Two of these eyes had severe postoperative complications, one with retinal detachment and the other glaucoma. The last eye had a preoperative UAVA of 6 / 120 which improved to 6 / 15 with the help of a pinhole but had to undergo surgery due to contact lens failure. This eye went on to have a postoperative BCVA of 6/24.

There were no graft failures at the end of the study period. This is not unexpected as PK for keratoconus is consistently associated with low failure rates.^{6-8,17-19} A longer follow up is required to determine long-term success.^{3,13,15}

Five graft rejections (25%) were noted. The incidence of corneal graft rejections vary from 5% to 21% in different studies and is attributed to various factors such as the use of different suture materials and techniques.^{3,7,13,16} The higher incidence of graft rejection found in our study may be due to the larger corneal grafts used which is known to be associated with a higher incidence of rejection.^{6,20} There was a relatively higher percentage of posterior subcapsular cataracts of 25% compared to that reported by Sharif and Casey of 12%¹³ and Kirkness et al of 4%.¹⁶ Of note, 3 eyes with cataract also had rejection (2 before diagnosis of the cataract and 1 after) as a complication. Two of these eyes also developed raised intraocular pressure with one progressing to glaucoma. The cause of the cataract in the 2 eyes that occurred following rejection may be due to the increased frequency and strength of steroid eye drops used to treat the rejection episode. The raised intraocular pressure and glaucoma were also likely to be related to the use of topical steroids.

Astigmatism was a problem in 5 eyes (25%) that required additional surgery which is higher than that reported by Sharif and Casey (8%),¹³ Goble et al (6%)¹⁴ and Kirkness et al (18%).²¹ Of note was Goble et al¹⁴ used a trephine size that was equal for the donor graft and host bed.

The difference between the host and donor trephine size was 0 mm to 0.5 mm. This resulted in an average spherical equivalent of -3.2 D. The myopic spherical equivalent after PK has been attributed to both the increase in the axial length of the eye as well as the steepening of the cornea due to the difference in size of the donor graft and host bed.^{22,23} Goble et al¹⁴ has also demonstrated that if the host and donor trephine sizes were equal, the residual myopia can be further reduced to an average of only 0.5 D.

Thirteen (65%) of the eyes were able to achieve UAVA of 6/60 within 1 month postoperatively. In addition, 9 eyes (45%) achieved BCVA of 6/12 or better within 3 weeks. The time taken for 90% of our eyes to reach 6/12 or better BCVA was 14 months which is better than the 38 months reported by Kirkness et al.¹⁶ However, 91% of their eyes went on to retain 6/12 or better BCVA at the end of study (up to 20 years of follow-up) compared to 70% in our study. Although there appeared to be a trend that suggests that early acquisition of good visual acuity predicts a good final visual outcome, this was not statistically significant ($P = 0.095$).

In summary, there were more young Indian males undergoing PK for keratoconus in this study. Penetrating keratoplasty is an effective treatment for keratoconic eyes not correctable by conservative means such as spectacles or contact lenses. Eighty per cent of the eyes achieved a better visual acuity postoperatively and 70% of the eyes had BCVA of 6/12 or better. The incidence

of complications such as graft rejection (25%), cataract (25%) and astigmatism requiring surgery (25%) were not uncommon. However, treatment for these conditions resulted in a good final visual outcome. Severe complications such as retinal detachment and glaucoma exist and were the main reasons for poor visual outcome in eyes undergoing PK for keratoconus.

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