Penetrating Keratoplasty for Keratoconus: Visual Outcome and Success

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Objective: To determine the long-term effect on vision of penetrating keratoplasty performed for keratoconus.

Design: Retrospective noncomparative case series.

Participants: All patients with keratoconus who received a corneal graft and who remained in our center for follow-up and visual rehabilitation during the study period.

Intervention: Penetrating keratoplasty was performed in 93 eyes of 78 patients.

Main Outcome Measures: Graft survival, visual acuity, and astigmatism.

Results: One (1.08%) graft failure was encountered over a mean follow-up of 46 months. Mean preoperative (best corrected) and postoperative visual acuity is (best-tolerated correction) were 0.9 (20/160) and 0.24 (20/80) logMAR, respectively. Visual acuity in 86% of eyes was 0.3 logMAR (20/40) or better at the latest follow-up, with 67% of eyes being corrected with spectacles. Mean preoperative corneal power by keratometry was more than 52 diopters (D) in 83% of eyes; mean postoperative corneal power was 45 $\pm$ 2 D. No significant predictors of postgraft astigmatism were found. Mean preoperative and postoperative best-eye acuities of the better eye were 0.32 (20/40−1) and 0.18 (20/32+1) logMAR, respectively ($P < 0.001$).

Conclusions: Graft survival was excellent. A corrected visual acuity of 20/40 or better was obtained in 86% of eyes. Astigmatism could not be predicted from preoperative factors. Visual acuity measured in the better eye improved by 0.14 logMAR (1.4 lines), implying an overall functional gain for the patient. *Ophthalmology 2000; 107:1125–1131 © 2000 by the American Academy of Ophthalmology.*

Keratoconus is a common indication for penetrating keratoplasty.[1,2] The success of penetrating keratoplasty for keratoconus has been well established, with the rate of graft survival being high.[1,3]

We were interested in conducting a retrospective review of the factors influencing visual outcome after corneal transplantation for keratoconus. Although encouraging visual results in terms of postoperative visual acuity have been reported previously,[3–10] visual rehabilitation is often slow and complicated. Given that grafts for keratoconus are performed to improve vision and to reduce visual disability and dissatisfaction with contact lenses, we considered it important to determine whether keratoplasty for keratoconus is of overall functional benefit to the patient. Functional benefit was estimated by comparing the visual acuity of the better eye before and after keratoplasty.

Because a stable visual outcome after penetrating keratoplasty may take several years to achieve, we reviewed patients who had received a corneal graft several years previously and for whom the surgery, postoperative care, and visual rehabilitation were consistent. Penetrating keratoplasty for keratoconus is associated with a high degree of graft astigmatism that may limit or delay visual rehabilitation for the patient. We aimed to examine whether postgraft astigmatism could be predicted from preoperative factors hypothesized to influence astigmatism, such as preoperative astigmatism and donor age.

Patients and Methods

A retrospective review was conducted of patients with keratoconus who received a penetrating keratoplasty by one surgeon (DJC) from January 1988, to May 30, 1995. The sources of information were the Australian Corneal Graft Registry database, hospital records, and, where applicable, the records of optometrists and ophthalmologists who referred these patients. The data collected included patient demographic information, age at which penetrating keratoplasty was performed, surgical variables (including graft diameter and suture technique), preoperative and postoperative refraction and keratometry, time of graft suture removal, method of correction, and length of time to stable visual outcome.

In total, 163 penetrating keratoplasties in 141 patients were performed at the institution during the study period. Of these cases, 78 patients (93 eyes) were under the care of one surgeon and remained in our center for follow-up and visual rehabilitation. There were 43 men and 35 women, and the mean age at the time of penetrating keratoplasty was 32 years (range, 13–70 years). There were 44 right eyes and 49 left eyes. Twenty-five patients had a history of allergic disease, such as atopy, hayfever, or allergic conjunctivitis, before penetrating keratoplasty, one patient had a pre-existing cataract, and three patients had limited visual potential caused by amblyopia (two cases) or macular degeneration (one

Originally received: September 16, 1999.
Accepted: February 29, 2000. Manuscript no. 99646.

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Supported by the Ophthalmic Research Institute of Australia.

The authors have no proprietary interest related to this article.

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ISSN 0161-6420/00/$–see front matter
PII S0161-6420(00)00112-3

Table 1. Indications for Keratoplasty

Indication	Number	Percentage
Contact lens intolerance	48	51.6
Poor best corrected vision	34	36.6
Apical scarring (including hydrops scar)	11	11.8

case). One patient had Down syndrome. Fifteen patients had bilateral penetrating keratoplasties performed during the study period; the mean time between the grafts was 28 months (range, 12–62 months). Sixteen other patients had had penetrating keratoplasty performed on the other eye before the period of our analysis. Indications for penetrating keratoplasty in this series are shown in Table 1.

Penetrating Keratoplasty

A standard technique was used throughout. The donor corneal button was trephined from the endothelial surface of the corneoscleral button. The diameter was 0.25 to 0.5 mm larger than that of the recipient bed. Standard surgical technique was used, and the donor cornea was sutured in place with 10-0 nylon using a running suture, the preferred technique in most cases. When vascularization of the recipient cornea was significant, interrupted sutures were placed in anticipation of increased postoperative inflammation and the subsequent need for early suture removal. Penetrating keratoplasty to a second eye was usually not undertaken for at least a year after the first keratoplasty. Donor age ranged from 15 to 83 years, with a mean of 58 years. The mean diameter of the donor corneal button was 8.0 mm (range, 7.5–8.5 mm), and the mean diameter of the recipient bed was 7.5 mm (range, 7.0–8.0 mm). A single continuous suture was used in 88 of 93 eyes (95%), and interrupted sutures were used in 5 of 93 eyes (5%). The mean time for suture removal after keratoplasty was 15 $\pm$ 4 months.

Postoperative Management

Patients were reviewed in the clinic at 1 day, 1 week, 3 weeks, 6 weeks, and thereafter at 3-month intervals. All received topical antibiotic eyedrops four times/day for a week and topical prednisolone phosphate (0.5%) eyedrops four times/day for up to a year, with gradually tapering doses. Visual acuity, keratometry, corneal topography, and refraction were charted.

Graft rejection was diagnosed in the presence of ciliary injection, corneal edema with keratic precipitates, Khodadoust lines or Krachmer's spots, and anterior chamber activity. The usual management of graft rejection was administration of intensive topical glucocorticosteroid eyedrops (0.5% prednisolone phosphate). The steroids were gradually tapered according to the clinical response.

The preferred time of removal of sutures was between 12 and 18 months after surgery. Patients had all sutures removed at 12 months if the keratometric astigmatism was more than 5 diopters (D). If the keratometric astigmatism was less than 5 D, the sutures were left in place for a further 3 to 6 months. Earlier suture removal was performed in cases of loosening of the sutures and increased vascularization of the host cornea.

Refraction was first performed 6 weeks after suture removal. Spectacles or a contact lens was prescribed according to need and the patient's individual preference. If astigmatism was excessive, incisional refractive surgery was performed at the slit lamp. This involved placement of two incisions of three clock hours 180 degrees apart in the steep meridian. This was done no less than 3 months after suture removal. Incisions in the graft-host interface were to a depth of approximately 90% of the corneal thickness.

Table 2. Complications after Keratoplasty

Complication	Number of Eyes
Graft failure	1
Corneal vascularization	8
Rejection	4*
Loose suture	3
Resuturing	2
Cataract	3
Raised intraocular pressure	3
Astigmatism requiring graft refractive surgery	21

*Two eyes had more than one rejection episode.

Patients were reviewed the next day, and resuturing of the relaxing incisions was performed in the operating theater if excessive wound gape, leaking corneal perforation, or gross overcorrection with increased astigmatism on keratometry were observed. If astigmatism on keratometry remained greater than 5 D after two reviews, further relaxing incisions and/or augmentation with compressive sutures at the flatter meridian were performed. Selective suture removal was performed 3 to 6 months after compressive suturing. The target of treatment was to reduce the cylinder power as much as possible to allow for spectacle or contact lens correction. No effort was made to alter the axis because all surgery was carried out centered on the axes of the preoperative cylinder. Any residual cylinder power of less than or equal to 4 D was regarded as an acceptable result.

Statistical Analysis

The influence of preoperative astigmatism, recipient age and gender, donor age, diameters of host corneal trephination and donor corneal trephination during penetrating keratoplasty, type of suture technique (continuous versus interrupted), time of suture removal after penetrating keratoplasty, time of graft refractive surgery after penetrating keratoplasty, and time of suture removal after graft refractive surgery on final postoperative astigmatism was analyzed by linear regression, using SPSS for Windows (SPSS Inc, Chicago, IL).

Results

Outcome was assessed in terms of graft survival, postoperative complications, and visual rehabilitation as measured by Snellen and logMAR acuity, keratometry, residual cylinder, and method of correction.

Graft Survival

There was one graft failure encountered in this series, with a mean follow-up of 46.5 months. This was due to traumatic wound dehiscence.

Postoperative Complications

Complications noted after keratoplasty are summarized in Table 2. There was one graft failure (1.08%) encountered in this series, with a mean follow-up of 46.5 months (range, 17–120 months). This was due to traumatic wound dehiscence with resultant graft edema, despite wound resuturing. A repeat graft was performed 9 months after the first graft. Of the eight patients with increased

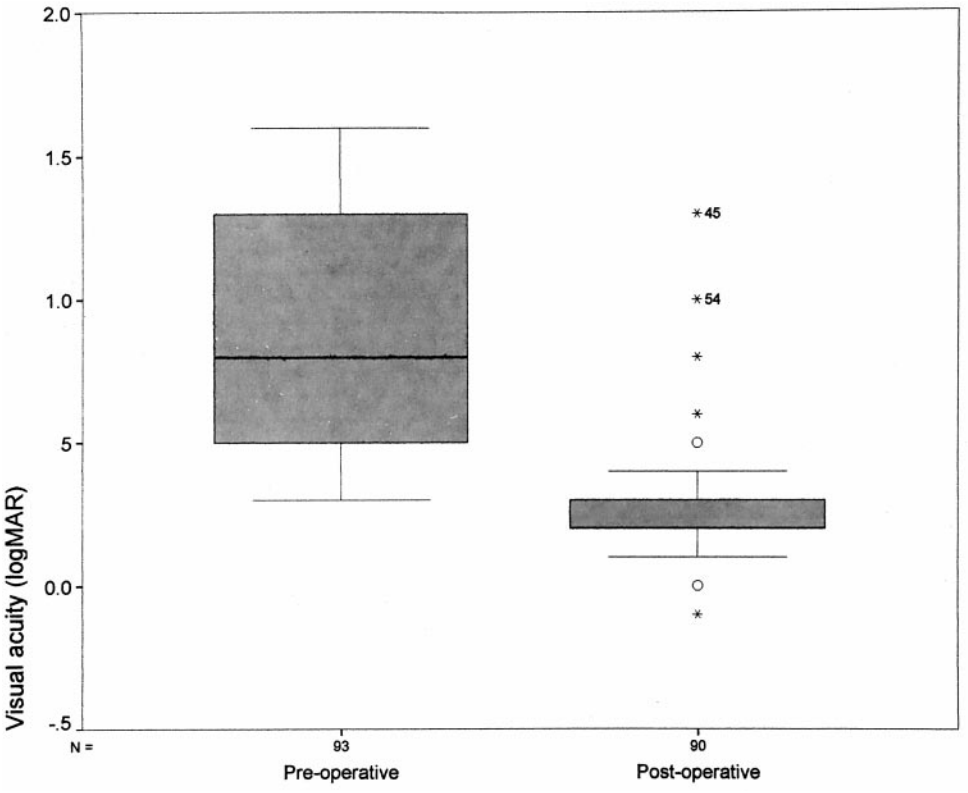

Figure 1. Boxplots illustrating the preoperative and postoperative visual acuity.

corneal vascularization after keratoplasty, three cases were associated with postoperative contact lens wear, one with a history of atopy, and four with premature loosening of the graft sutures. All four eyes with graft rejection exhibited increased corneal vascularization before graft rejection, and in three cases this was associated with contact lens wear after keratoplasty. Rejection episodes occurred at a mean of 24 months (range, 18–27 months) after keratoplasty and resolved without graft failure. Three patients (four eyes) had significant cataract develop, requiring cataract surgery and intraocular lens implantation. Raised intraocular pressures developed in four eyes, and control of intraocular pressure was achieved with antiglaucoma medication alone. In two eyes, the intraocular pressures returned to normal levels on cessation of topical steroids. None of the eyes had visual field loss from raised intraocular pressure.

Visual Rehabilitation

The mean preoperative visual acuity of the operated eye was 0.9 (20/160) logMAR (range, 0.3 (20/40) to 1.6 [hand movement]) (Fig 1). The preoperative methods of correction for the index eye and the other eye are shown in Figure 2. Before graft, 45% of index eyes were uncorrected because of advanced keratoconus and inability to fit a contact lens. Preoperatively, 78 eyes (83%) had a corneal power of >52 D (beyond the scale of the keratometer), and the remaining 15 eyes had a mean keratometry reading of 48 ± 2 D (range, 44–51 D) and a mean keratometric astigmatism of 6 ± 3 D.

The mean postoperative visual acuity of the operated eye was 0.24 logMAR (20/32-2) (range, −0.1–1.3) (Fig 1) and of the other eye was 0.34 logMAR (20/40-2) (range, −0.1–1.3). In five eyes,

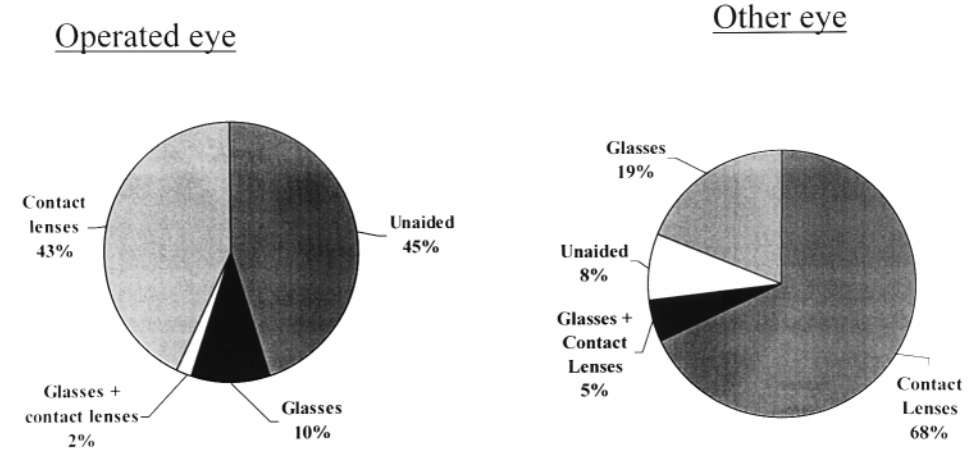

Figure 2. Type of preoperative correction in the operated eye and other eye.

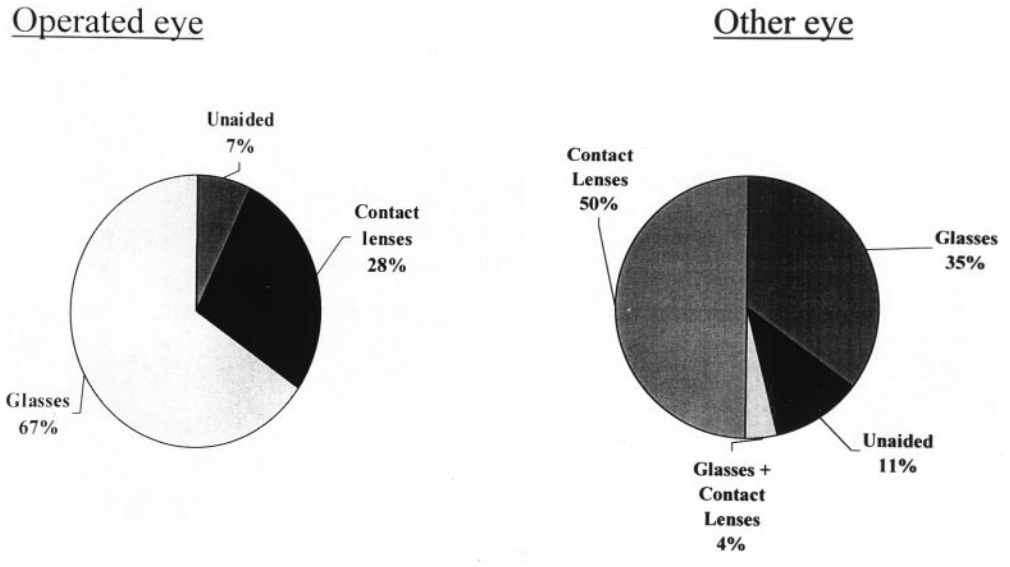

Figure 3. Type of postoperative correction in the operated eye and other eye.

visual acuity was worse than 0.8 logMAR (20/125); one patient had associated Foster-Fuch macular disease, one had amblyopia, one had Down's syndrome, and two had uncorrected high cylinder. Excluding the three eyes in which other pathologic conditions accounted for visual loss, 87% of eyes obtained a visual acuity of 0.3 logMAR (20/40) or better at the latest follow-up. Methods of postoperative correction in the grafted eye and contralateral eye are shown in Figure 3.

The postoperative visual acuity measurements were made with the patient wearing the correction, that was tolerated and worn on a daily basis. The preoperative assessment was taken as that which could be achieved under the best possible circumstances. Some patients could see well preoperatively but could not tolerate the correction required to achieve their best-corrected vision. This conservative correction has been observed in our clinic to encourage a conservative attitude to surgical assessment and the assessment of visual outcomes. Bearing this in mind, the visual benefit of keratoplasty for keratoconus may well be greater than measured in this study.

The mean postoperative keratometry reading was 45 ± 2 D, and the mean sutures-out keratometric astigmatism was 5 ± 3 D. The mean postoperative spherical refraction in the 22 eyes for which data were available was −0.33 ± 3.87 D. Of 93 eyes, 21 underwent graft refractive surgery for astigmatism at a mean of 26 ± 17 months after keratoplasty. After graft refractive surgery, the mean astigmatism was 4 ± 3 D.

Linear regression analysis for predictors of the amount of keratometric postgraft astigmatism yielded no factor of significance among those tested, including age and gender of patient, donor age, diameter of host corneal trephination and donor corneal trephination during penetrating keratoplasty, type of suture technique (continuous versus interrupted), preoperative astigmatism, time of suture removal after penetrating keratoplasty, time of graft refractive surgery after penetrating keratoplasty, and time of suture removal after graft refractive surgery.

The average time taken after penetrating keratoplasty for stabilization of refraction and for the patient to obtain useful vision in the operated eye was 19 ± 7 months. To investigate whether penetrating keratoplasty had been of overall functional benefit to the patient and bearing in mind that disability is related to the acuity in the better eye, the visual acuity of the better eye before and after penetrating keratoplasty was compared. The mean visual acuity in the better eye before penetrating keratoplasty was 0.32 (±0.29) logMAR (20/40-1) and that after penetrating keratoplasty was 0.18 (±0.18) logMAR (20/32+1) (Fig 4), $P < 0.001$.

Graft Refractive Surgery

Of 93 eyes, 21 underwent graft refractive surgery to reduce astigmatism. The average duration after keratoplasty when this was performed was 26 months (±17). Eighteen of these eyes in 17 patients had a minimum of 1 year follow-up after graft refractive surgery. Keratometric measurements were carried out before and after graft refractive surgery and were, therefore, available for analysis. Of the 17 patients, 10 were women and 7 were men, and the mean age at the time of graft refractive surgery was 39 years. Of the 18 eyes, 10 were right eyes and 8 were left eyes.

Preoperatively, the mean keratometric cylinder was 8.07 D (±3.06, range, 3.87 D–11.63 D). Postoperatively, the mean cylinder was 4.42 (±2.12). The target in these eyes was to reduce the cylinder as much as possible. No effort was made to alter the axis because all surgery was carried out centered on the axes of the preoperative cylinder.

Discussion

Penetrating keratoplasty for keratoconus was performed in relatively young patients (mean age, 31.6 years at the time of keratoplasty) with a slight male predominance of 55%. Thirty-two percent of our patients had a history of atopy.

Contact lens intolerance was the main indication for keratoplasty, and this is comparable to other series.[11,12] Forty-five percent of eyes were intolerant of contact lenses, and these patients depended on vision in the other eye before keratoplasty.

For bilateral grafts, the mean period between grafts was 28 months. Malbran and Fernández-Meijide[9] demonstrated that a graft reaction was more likely in the second eye if it were performed within a year of the first graft. The mean duration for suture removal after keratoplasty was 15 months (±4). It is prudent not to remove sutures less than 6 months after keratoplasty unless necessary, for example in the case of graft vascularization and stitch abscesses, be-

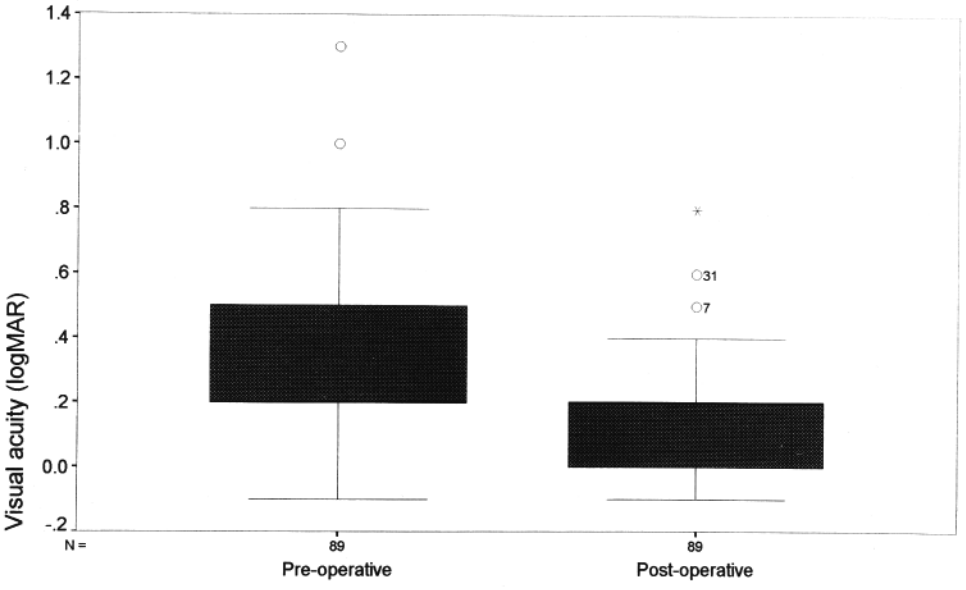

Figure 4. Boxplots illustrating the preoperative and postoperative best-eye visual acuity.

cause early suture removal is known to be associated with an increased risk of graft failure.[1]

Graft Survival and Complications

Penetrating keratoplasty for keratoconus is associated with a low graft failure rate in most series.[1,3–8,13] There was one graft failure encountered in our group of patients with a mean follow-up of 46 months, and this was due to wound dehiscence with resultant graft edema. Four of 93 eyes (4.3%) had rejection episodes not amounting to graft failure. This is a lower rate than other series, which reported a rejection rate of 18.5%[4] and 11.6%[6], respectively.

Eight patients had increased vascularization after keratoplasty; of these, three were associated with contact lens wear and one with atopy. Graft vascularization has been associated with an increased risk of allograft rejection.[14] In our series, half of those eyes with graft vascularization resulted in allograft rejection, occurring at a mean of 24 months after keratoplasty and resolving without failure. It has also been demonstrated that loose sutures are a risk factor for allograft rejection episodes.[14] In our series, three eyes had graft vascularization and loose sutures and one required resuturing because it occurred less than 6 months after keratoplasty. With prompt removal of the loose sutures and prophylactic use of topical steroids and antibiotics, allograft rejection episodes were circumvented.

Three patients (four eyes) had significant cataract develop after keratoplasty, and cataract surgery was subsequently performed. Of these, only one patient had a history of atopy with cataract already present before keratoplasty. Cataract formation after keratoplasty was thought to be a result of surgical trauma and postoperative steroid treatment. Steroid treatment probably also contributed to the raised intraocular pressure after keratoplasty in four eyes.

Visual and Refractive Results

Postoperatively, 86.2% of eyes obtained a corrected acuity of 20/40 or better at the latest follow-up (excluding three eyes with other pathologic conditions accounting for visual loss). This compared favorably with previous reports.[3–11]

Although the visual results are encouraging, it is also important to establish whether penetrating keratoplasty is of overall functional benefit to these patients. The ideal way would be to record the binocular visual acuity of these patients before and after keratoplasty, but this is not often performed in most centers. As an alternative, we compared the visual acuity of the better eye before and after keratoplasty (best-eye acuity). We found that the mean best-eye acuity before keratoplasty was 0.32 (±0.29) logMAR (20/40-1) and that after keratoplasty was 0.18 (±0.18) logMAR (20/32+1), and the difference between the two was statistically significant by analysis of variance ($P = 0.001$). Hence, the use of best-eye acuity effectively illustrates the functional benefit of keratoplasty in our series.

Postoperatively, most eyes (66.7%) achieved functional acuity with glasses. This differed from other series in which contact lenses were the preferred method of visual correction for 55% of patients.[15]

Factors influencing postgraft astigmatism were analyzed by linear regression using SPSS for Windows. None of the factors was a significant predictor of postgraft astigmatism, including age and sex of patient, donor age, age of patient when keratoplasty was performed, diameters of host and donor cornea trephinations suture technique (continuous versus interrupted), preoperative astigmatism, and time of suture removal after keratoplasty. Most of the grafted eyes (83%) had advanced keratoconus before grafting, as evidenced by the high preoperative keratometry (>52 D); however, their graft astigmatism is not statistically different from that of the remaining group (17%), with a mean preoperative astigmatism of 47.86 D (±2.17). These results

indicate that hypotheses such as patients with more preoperative astigmatism will have more postoperative astigmatism, or that older donor material is stiffer and thus leads to less postoperative astigmatism, cannot be substantiated. We can only conclude that postgraft astigmatism is caused by factors not included in our analysis, such as trephination of donor and recipient cornea and symmetry of suture forces.

The mean postoperative sutures-out astigmatism was 5 D (±3), and after graft refractive surgery in 21 eyes, the mean group astigmatism was 4 D (±3). This is comparable to other series reporting 4 to 5 D of sutures-out astigmatism after keratoplasty for keratoconus.[6,16]

Oversizing of the donor button is advocated to reduce the incidence of wound leakage because donor corneas cut from the endothelial surface are smaller than the opening produced by the same size trephine on the epithelial surface of the host cornea.[17,18] However, there are several reports advocating the use of the same size host and donor trephine in penetrating keratoplasty for keratoconus to reduce the amount of postoperative myopia.[19–22] Although our donor corneas were oversized by 0.5 mm, we did not encounter excessive myopia in our patients, the mean postoperative spherical refraction being −0.33 D (±3.87) in 22 eyes with available data. This supports a previous report that the increased axial length and resultant myopia in keratoconus was mainly the result of elongation of the posterior segment of the globe, with a small contribution from an increased anterior chamber depth.[15]

Graft Refractive Surgery

In our series, 22.5% (21 of 93) of eyes had intolerable postgraft astigmatism (mean 8.07 D ±3.07 in 18 eyes), which required graft refractive surgery. This is comparable to a report by Kirkness et al,[23]in which 18% of patients had graft refractive surgery performed after penetrating keratoplasty for keratoconus.

Various surgical methods of correcting postkeratoplasty astigmatism (all sutures-out astigmatism) have been described. These include relaxing incisions, compressive resuturing, relaxing incisions with counter-quadrant augmenting compressive sutures (known as augmented relaxing incisions), wedge resections, trapezoidal keratectomy, and, more recently, excimer laser photorefractive keratectomy.[24–29] Trapezoidal keratectomies are technically difficult, and the results are unpredictable,[27] so relaxing incisions, compressive resuturing, and augmented relaxing incisions are the more popular techniques currently used.[23,26,28] Previous studies on graft refractive surgery report a 3.5 to 15 D reduction of astigmatism using various techniques, such as relaxing incisions, augmented relaxing incisions, and compressive resuturing.[23,25,28] In our series, relaxing incisions were initially performed because we have found that, although there is a lesser chance of full correction with relaxing incisions alone, they offer a more rapid visual rehabilitation; this is similar to the report by Kirkness et al.[23] If the cylinder correction was inadequate with relaxing incisions alone, this was followed by counter-quadrant augmentation with compressive resuturing.

Of 93 eyes, 21 eyes underwent graft refractive surgery for intolerable astigmatism (mean 8.07 D ±3.06). Postoperatively the mean cylinder was 4.42 D (±2.12).

In conclusion, our series, penetrating keratoplasty for keratoconus is associated with an excellent graft survival rate (98.92% success rate at a mean of 46 months of follow-up). Contact lens intolerance is the main indication for keratoplasty. A good visual outcome is obtained postoperatively, with 86.2% of eyes achieving a visual acuity of 20/40 or better at the latest follow-up. Best-eye acuity improved from 0.32 (±0.29) logMAR (20/40-1) to 0.18 (±0.18) logMAR (20/32+1). Delay in visual rehabilitation caused by graft astigmatism can be successfully treated with graft refractive surgery (relaxing incisions with or without augmentation with compressive resuturing) with a reduction of mean graft cylinder from 8.07 D (±3.06) to a mean graft cylinder of 4.42 D (±2.12). Postgraft astigmatism cannot be predicted from pregraft factors.

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