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The Success of Penetrating Keratoplasty for Keratoconus

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Summary

We report the results, over a 20 year period up to 1989, of 201 penetrating keratoplasties in 198 eyes of 158 patients. The five year graft survival was 97%. A corrected visual acuity of 6/12 or better was attained by 91%. The mean spherical equivalent refraction on removal of sutures was −2.68 Ds and the mean cylindrical correction was −5.56 Ds. The cumulative time to dispensing final refractive correction was 38 months for 90% of patients. Rejection episodes occurred in 20% of grafts and were associated with loosening of sutures and bilateral grafts. Atopic patients (28%) were not at greater risk from rejection.

Graft refractive surgery was undertaken in 18% and, of these, 55% achieved 6/12 vision or better with an refractive correction which could be dispensed and tolerated within 6 months.

The introduction of modern microsurgical techniques has firmly established penetrating keratoplasty (PK) as a therapeutic measure for the visual rehabilitation of patients affected by keratoconus. Although in the United States of America the commonest indication for keratoplasty remains aphakic or pseudophakic bullous keratoplasty,[1] published figures show that, at Moorfields Eye Hospital,[2] keratoconus is the commonest indication for PK. The demography of patients undergoing keratoplasty suggests that keratoconus is particularly important in view of the fact that affected patients are likely to be young adults with a long working life ahead of them. That keratoplasty is successful in the management of keratoconus, in providing a clear graft and improvement of vision, has been established both by clinical experience and by a wealth of published material.[3–13] Although in these broad terms the success of keratoplasty is understood, the more detailed problems are less fully described. Paglen *et al*[6] published the cumulative results of over 300 keratoplasties performed from 1948 to 1975 by a single surgeon, Max Fine. They excluded every patient without at least five years follow-up and consequently eliminated more than half the patients operated on in that period. More than 100 keratoplasties were performed without the aid of the operating microscope and clearly might be expected to have more complications. These cases were not analysed separately so that, despite the wealth of detail, this series does not allow for assessment of the improvements made in surgical and postoperative care resulting from accumulated

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experience and improved operative techniques which followed the introduction of the operating microscope and associated fine instruments and suture materials. Nevertheless Paglen *et al* were able to report over 90% of grafts remaining clear and 73% of eyes achieving 6/12 vision or better. In order to continue to improve results and patient management, every aspect and risk factor involved in surgery and postoperative care needs to be considered. Transplantation in keratoconus has been associated, particularly, with relatively high degrees of astigmatism which may limit a patient's vision in spite of a clear graft and greatly delay visual rehabilitation. Moreover, since keratoconus is nearly always a bilateral, though asymmetric condition, bilateral transplants may be performed with additional consequential problems. The tendency to corneal astigmatism may lead to intolerable aniseikonia. Graft reactions have also been noted to be more common in eyes after bilateral transplants ie the second transplant may prejudice the health of the first. Only Epstein *et al*[9] have discussed actuarial survival of transplants in keratoconus and they demonstrate that keratoconus has one of the best prognoses of all the indications for corneal transplantation.

The aim of the present study was to consider these and other factors which appear to be germane to the outcome of surgery for keratoconus. In particular, we considered the survival of the transplants; their complications; the tolerance of astigmatism and anisometropia; the time taken for tolerable correction of vision; and the need for graft refractive surgery in this group and its effects on the grafts. We also sought to identify whether patients undergoing bilateral surgery were at particular risk.

We hoped by these means to present a balanced view of keratoplasty for keratoconus in the context of one clinical centre and to enable us to improve our advice to patients about to undergo this form of surgery.

Patients and Methods

A database of all patients under the care of the surgeons of the Corneal Clinic, Moorfields Eye Hospital was used to identify patients with keratoconus undergoing keratoplasty. Eyes without a minimum of 12 months follow-up from the time of keratoplasty were excluded and patients not seen in the clinic for more than 5 years were also excluded from the study. Patients were recruited over a 20 year period from 1969 to early 1989 averaging about 10 grafts per annum overall but, in latter years, the rate is higher. The results for individual grafts were analysed.

The surgery was performed by a large number of surgeons including residents in training but all cases were managed in a broadly similar fashion according to the following guidelines.

Prior to 1985, all donor material was from moist-chamber stored corneas (used within 24 hours of death) and after that date corneas stored in MK medium, (used within 3 days) K-sol, (used within 7 days) and a few in tissue support medium (used within 28 days) were used, but moist-chamber stored corneas continued to be used as well.

Donor ages ranged from 10 to 95 years, mean 61.73, median 65 years. Those stored as corneal discs were prepared for transplantation by punching from the endothelial surface. Whole eyes were cut with trephine, blade and scissors from the epithelial side and in these cases the cord length of host bed and donor button were measured and equated taking care not to undersize the donor, although in nearly every case the same size trephine was used.

The trephine was placed centrally on the cornea and the base of the cone was included within the button of excised corneal tissue. In the few cases that involved combined cataract extraction, the surgery was carried out using standard techniques.[14] The great majority of grafts were either 7.5 or 8 mm (host bed trephine size) in diameter (Fig. 1). In preparing the donor button care was taken to avoid undersizing it. The cord length of the host bed and the donor were measured and if necessary a larger trephine was chosen. When a corneoscleral disc was used and it was punched from the endothelial surface, the punch trephine was nominally 0.5 mm larger than that used for the host bed, although in practice, the actual cord lengths were almost identical. No deliberate attempt was made to alter the

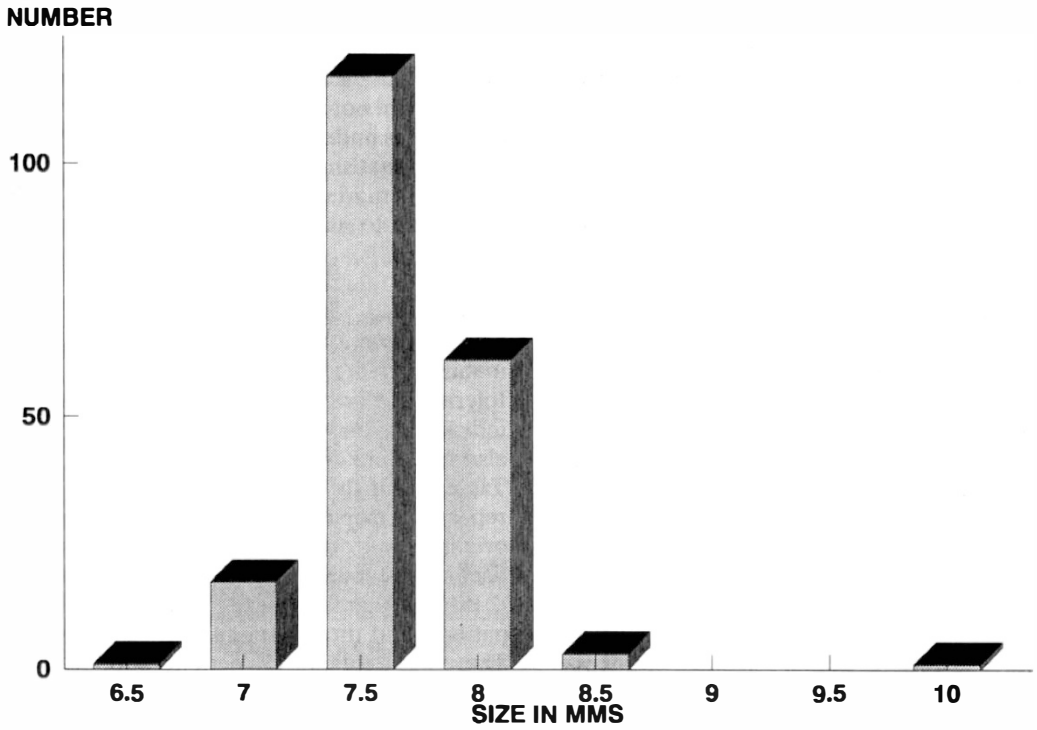

Fig. 1 *The size of individual grafts as measured by nominal trephine size of the host bed.*

refractive results by manipulating the donor size.

After 1982 the anterior chamber was reformed with viscoelastic material, either sodium hyaluronate or 2% hydroxypropylmethyl cellulose which was used to protect the corneal button during surgery. A peripheral iridectomy was not performed routinely. The donor buttons were sewn in place with 10/0 perlon (until c1980) or 10/0 nylon using a running suture in 93%. In 12 (6%) interrupted sutures were used, (12 sutures) and in 2 (1%) a combination of eight interrupted and a running 10/0 nylon suture pattern was employed. At the end of the procedure a subconjunctival injection of betamethasone 4 mg and genticin 20 mg or cefuroxime 125 mg was given.

Graft rejection was diagnosed in the presence of a ciliary flush, anterior chamber cellular activity or flare, keratic precipitates, (Kp), a Khodaoust line, or Krachmer's spots. Following diagnosis, the usual management was a subconjunctival injection of 4 mg betamethasone, followed by intensive topical steroids eg G. dexamethasone 0.1% every half hour. The steroid dosage was then titrated according to the clinical response. Sutures were not removed electively at a

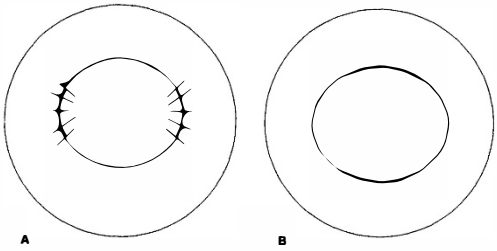

Fig. 2 *The two methods of graft refractive surgery used to correct high astigmatism. A.* Compressive resuturing. *The wound is incised deeply and symmetrically around the axis of the flatter meridian and resutured tightly with 9/0 or 10/0 interrupted sutures, initially overcorrected so that the flatter meridian becomes the steeper. Selective suture removal as the wound heals, allows a drift to sphericity. B.* Relaxing incisions. *More suitable for lower degrees of astigmatism. The wound is incised deeply around the steeper axis allowing it to flatten.*

specific time but rather where considered necessary by individual surgeons. Indications for suture removal included loosening of sutures, although, if this occurred early, then the graft was resutured. As a general rule, where there was little astigmatism with the suture *in situ* and tension lines could be observed removal of the suture was avoided. Where there was a high degree of astigmatism, there was a greater tendency to remove the suture early.

If the second eye required surgery, this was generally not undertaken for at least one year following the first keratoplasty, range 5 to 216 months, mean 36.4, median 22 months. Graft refractive surgery was carried out where there was intolerable astigmatism. This criterion is subjective based on the patient's response to refractive correction, trial of spectacles or contact lenses, or in tolerance of contact lenses.

The refractive procedures carried out were either relaxing incisions in the original wound, made around the steeper axis or compressive resuturing, performed following reincision of the wound in the flatter meridian followed by insertion of four or five sutures of 9/0 or 10/0 nylon as shown in Figure 2.

Intolerable anisometropia was diagnosed where the refractive correction of both eyes could not be tolerated simultaneously because of differences between the spherical equivalent of the two eyes.

Achievement of useful vision was (arbitrarily) defined as an uncorrected vision of 6/12 or corrected vision of 6/12 where the refractive correction (whether contact lens or spectacles) had been dispensed.

Visual results quoted are refracted visual acuities and not acuity achieved with a pinhole except where uncorrected acuity is specifically quoted. In dealing with astigmatism we have confined discussion to refracted values and not keratometric readings since for practical purposes it is this quality which will govern the patient's visual rehabilitation. Graft failure was considered when the graft was so oedematous, scarred or opaque that useful vision could not be achieved through it, or if a regraft was undertaken because of uncorrectable astigmatism.

The actuarial survival was calculated according to the methods of Kaplan and Meier.[15]

Table I *Indications for keratoplasty*

Contact lens related	100
Apical scarring	43
Scarring after hydrops	23
Poor visual acuity	20
Combination of factors	10
Failed graft	4
Failed epikeratoplasty	1

Results

Contact lens related difficulties (including inability to fit, poor wearing time or poor tolerance) were the most common principal indications for keratoplasty, though many also had some degree of apical scarring (see Table I). Of the four eyes which underwent repeat keratoplasty following failure of the original graft, two had intolerable astigmatism unrelieved by graft refractive surgery.

Bilateral grafts were performed in 37 patients and three patients had three grafts. There was a total of 158 patients and 198 eyes in this series of 201 penetrating corneal grafts. Patients ages ranged from 13–80 years at the time of keratoplasty, mean 22.1 median 25 (Fig. 3). A number of eyes had related or coexistant disease. This included a history of atopy, educational subnormality, (four having Downs' syndrome), previous surgery, trauma or infections (see Table II). Eleven patients undergoing bilateral grafts had atopy which is the same proportion as those with unilateral grafts and atopy. Atopy, therefore, does not lead more frequently to the need for bilateral keratoplasty, $p=0.5$.

Graft Survival and Complications

Complications are summarised in Table III. The probability of graft survival for all grafts in the series was 97% at both five and ten years. The median follow-up was 48 months and the mean follow-up was 60.2 months. If only first, unilateral grafts are considered the probability of survival rises to 99% at five years (*vide infra*). Twenty-five (12.5%) of the grafts have been followed for more than ten years and all remain clear with no signs of graft failure (Fig. 4). There was one failure due to rejection in a unilateral graft, one due to infection in a repeat (unilateral) kerato-

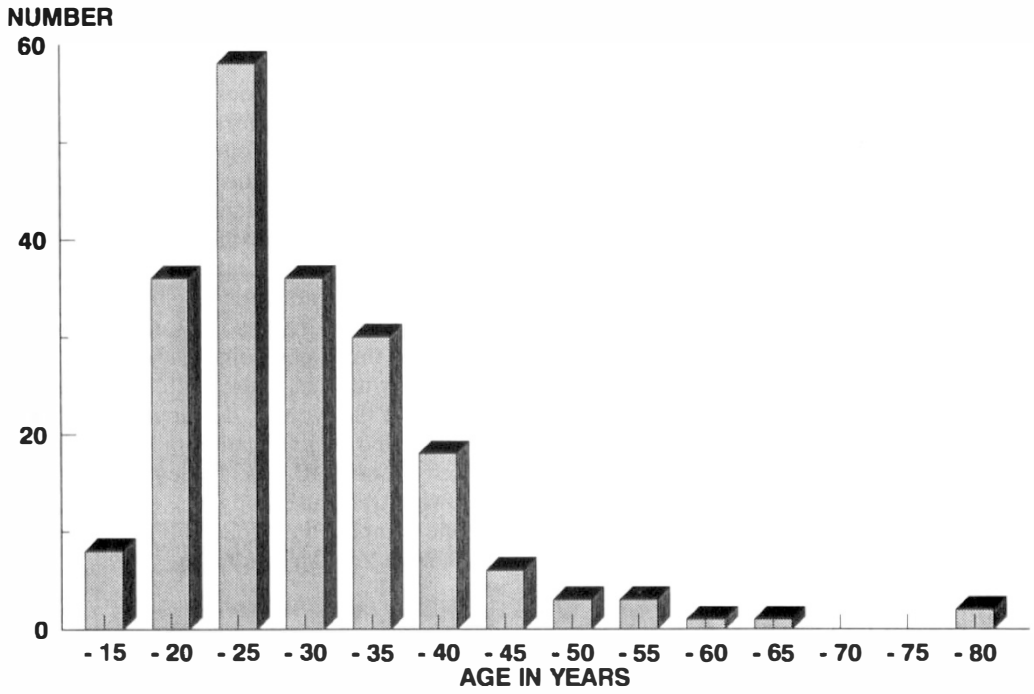

Fig. 3 *Age of patient at time of keratoplasty. Where bilateral grafts have been performed the age of patient at the time of each graft is entered.*

plasty; there were four failures in the second of a pair of bilateral grafts, which included another due to infection, one following failed retinal detachment surgery and phthisis in an eye which had undergone needling for congenital cataracts many years previously, one, a primary graft failure, and finally one which was regrafted though clear due to intolerable astigmatism unrelieved by refractive surgery. Although rejection was not the main reason for graft failure, the second eye of a bilateral pair was nevertheless much more likely to suffer graft failure, $p<0.005$. Rejection episodes were common. Altogether, 40 eyes encountered at least one rejection episode from one month to five years following keratoplasty.

Table II *Co-existing conditions (by graft not patient)*

Atopy	57
Educationally-sub-normal (Downs'syndrome)	6 (4)
Previous ECCE and IOL	1
Previous needling of cataract	3
Previous microbial keratitis	1
Previous trauma	1
Previous thermokeratoplasty	1

When bilateral grafts were performed, there was no difference in the incidence between the rejection rate in unilateral grafts and the rejection rate in the first eye until the time of the graft in the second eye, $p>0.05$. Once the second eye had been grafted, there was a significantly higher rate of graft rejection, $p<0.005$ but there was no difference in frequency between the first and second eyes $p=0.8$. Rejection episodes occurring in both eyes were slightly more common than unilateral episodes (12 vs 8) in bilaterally grafted eyes but the difference is not significant,

Table III *Complications encountered (several eyes had more than one complication)*

Rejection	40
Cataract	8
Microbial keratitis	4
Retinal detachment	2
Herpes simplex keratitis	2
Loose suture	11
Accidental Trauma	4
Glaucoma	4
Astigmatism requiring graft refractive surgery	36
Severe anisometropia	3

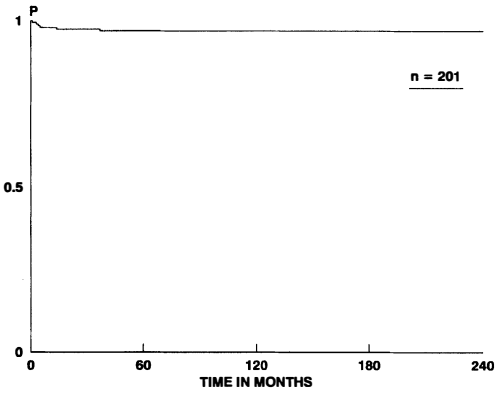

Fig. 4 *The overall survival probability of all grafts in the series. When only first, unilateral grafts are considered then the survival probability rises to 0.99.*

p=0.1. Graft rejection episodes were not more commonly associated with a history of atopy, p=0.4. Rejection episodes were not more common after graft refractive surgery, p>0.1.

Several eyes had more than one rejection episode. The type of reaction varied from a few keratic precipitates (Kp), widespread Kp involving the whole of the posterior surface of the donor button, a Khodadoust rejection line, Krachmer's spots and diffuse oedema responding to treatment with topical steroids (Table IV). With one exception, all the rejection episodes were reversed with intensive steroid therapy. Thus one graft out of forty (2.5%) with documented rejection episodes failed from rejection.

Other complications of a non-refractive nature were found. Eight eyes developed cataract following transplantation. Six have successfully undergone extraction and in the others surgery has been deferred for non-ophthalmological reasons. Atopes were not at greater risk of developing cataract, p>0.05. There were four instances of microbial keratitis in grafts, two of which led to graft failure. Two retinal detachments occurred in aphakic eyes and two eyes with no antecedent history developed Herpes simplex keratitis. Loosening or breakage of the running suture was found in 23 (11.5%) grafts. This was not more likely to occur in atopic eyes p=0.2. Rejection episodes were significantly more common in association with loose sutures p<0.05. The two herpetic ulcers were triggered by a broken suture. Two eyes developed severe 360° superficial vascularisation as a result of suture loosening.

Trauma of a serious sight threatening nature involving rupture of the graft host interface occurred in four eyes. All had been rendered aphakic by the trauma. Three eyes also had vitreous prolapse on presentation. All underwent successful primary repair of the trauma but on eye suffered a giant retinal tear three years after the original trauma.

Four eyes developed raised intraocular pressure, three controllable on medication but one, which had also suffered traumatic rupture of the wound, developed glaucoma, uncontrolled on medication or laser trabeculoplasty. The IOP was, however, controlled following trabeculectomy.

One complication which did not occur was the Urrets-Zavalia syndrome.

Visual and refractive results

Pre-operative visual acuity ranged from 6/9 to hand movement but most had 6/60 to counting fingers (Fig. 5).

By six months, 126 eyes (63%) could see 6/12 or better (Fig. 6). The best recorded acuity was 6/9 or better in 91% of cases and 97% could see 6/12 or better (Fig. 7). The final visual ie current acuity at this review is 6/9 or better in 85% and 91% achieve a vision of 6/12 or better (Fig. 8). No difference in spherical equivalent or cylindrical correction could be found between those eyes where the donor was obtained from a whole eye and those where the donor was obtained from a corneo-scleral disc, p>0.01, and the two groups will not be discussed separately.

The time to removal of sutures varied from one month to over 4 years, mean 15.8, median 17 months. Thirty four of the patients still have all the sutures in place. In those patients in whom the suture has been removed long enough for the vision to stabilise the uncorrected vision varied from 6/5 to counting

Table IV *Patterns of rejections—by individual episodes*

Few keratic precipitates (Kp)	2
Widespread Kp	14
Khodadoust rejection line	26
Krachmer's spots	3
Diffuse oedema	3

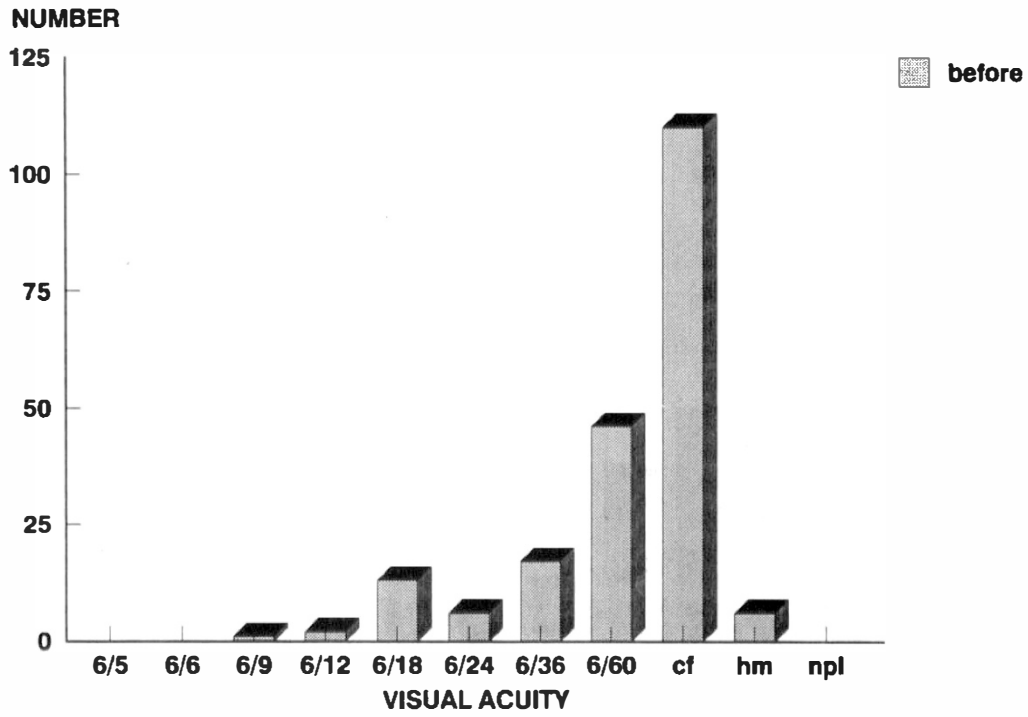

Fig. 5 *The best recorded visual acuity obtained prior to keratoplasty. Where contact lenses could not be fitted, this acuity is unaided otherwise the acuities are corrected.*

fingers, median 6/24, (Fig. 9). The mean spherical equivalent correction following suture removal was −2.68 Ds, range −16.00 to +4.00 Ds. The mean cylinder (all expressed in negative cylinders) was −5.56 Ds range −17.00 to plano. The time taken for eyes to achieve useful vision 6/12 unaided or wearing correction giving 6/12 or better is shown by the cumulative frequency curve in Figure 10.

The time to dispensing of refractive correction is shown in Figure 11. Of those patients with satisfactory correction, 83 wore spectacles, 42 contact lenses and 16 were unaided. The change in refraction from six months to that following removal of the sutures is shown graphically in Figures 12 and 13. From these graphs it can be seen that the change in spherical equivalents is less than ± 3 Ds in 77% and the 90% confidence limit is ± 5 Ds. The cylindrical change is ± 3 Ds in 74% and a 90% confidence limit of ± 5 Ds, although the figures are skewed towards a greater negative cylindrical correction.

Although the figures for individual surgeons are too small to allow comparisons when one considers the results of residents in training compared to those of experienced surgeons, the mean cylindrical correction is not significnatly different in the two groups $P>0.1$. Complications including rejection do not seem any more common when surgery is performed by residents $p=0.4$.

Complications

The most troublesome refractive complication was intolerable astigmatism which could not be adequately corrected with spectacles or contact lenses. This was no more likely to occur after early suture loosening than in the rest of the group $p>0.1$. In most cases these patients were offered graft refractive surgery. Graft refractive surgery consisted either of relieving incisions or compressive resuturing. The results below are given after stabilisation of the refraction in the case of relieving sutures and after suture removal in the case of compression sutures. Although 36 eyes met these criteria. These 36 eyes underwent the refractive surgery, in one to four separate

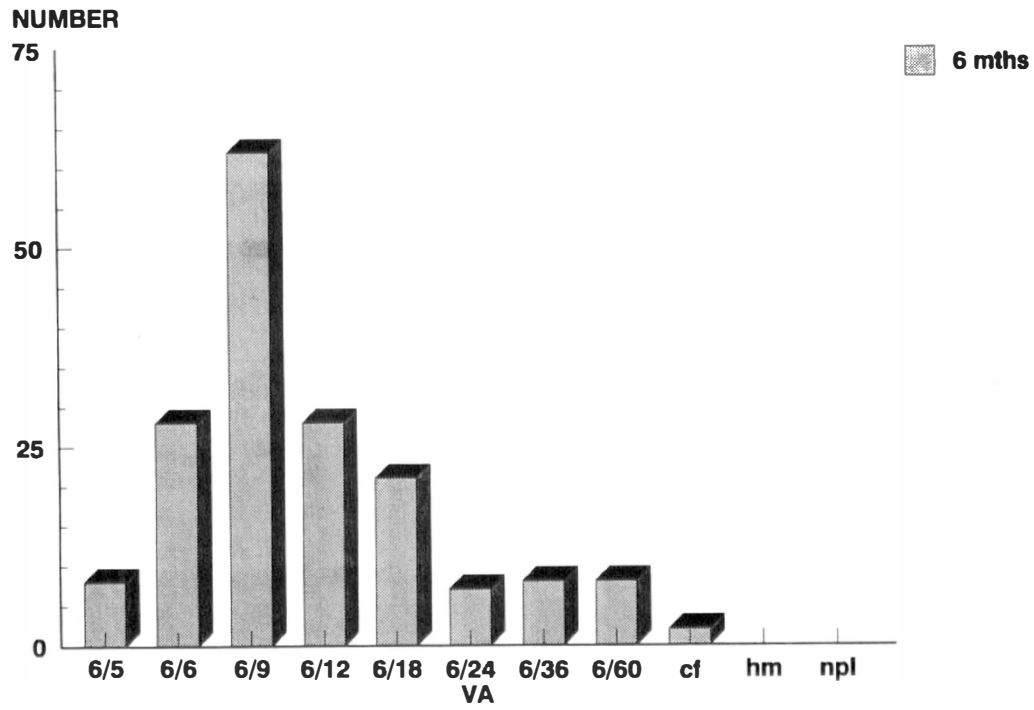

Fig. 6 *The refracted visual acuity at six months following keratoplasty. Because of timing of out-patient visits this time may vary by ±6 weeks.*

operations. The spherical equivalent changed very little (90% were within 2 Ds) following refractive surgery. The cylindrical correction element was reduced from a mean of −8.92 Ds to a mean of −4.11 Ds that is a reduction of 4.81 Ds. Three cases showed an increase in cylinder after relieving incisions. Prior to refractive surgery only one patient had a cylinder less than 5 Ds, afterwards 29 were less than 5 Ds. The change achieved is shown in Figure 14. More detailed analysis is beyond the scope of this paper.

The degrees of astigmatism were analysed according to groups of years when the surgery was performed *viz* 1971–1975, 1976–1980, 1981–1985 and 1986–1989. We could demonstrate no significant difference between any of the groups, $p>0.05$.

In only three patients who had undergone bilateral corneal graft surgery was aniseikonia a problem. In all the spherical equivalent differed by more than five dioptres although, curiously the cylindrical element was similar between both eyes. One ultimately tolerated spectacles despite a difference of 8 Ds (spherical equivalent). One tolerated contact lenses but the remaining patient, an atope could not be fitted with contact lenses and cannot be made comfortable binocularly.

Over 40 of the eyes (30% of all those wearing a refractive correction) in the series have been refitted with contact lenses following keratoplasty and are wearing them satisfactorily.

Discussion

There have been many reports on individual aspects of corneal transplantation in keratoconus generally showing that keratoplasty carries a good prognosis of graft survival, a relatively good prospect of recovery of vision and indicating that astigmatism is a problem which is amenable to treatment.[3–13,17–19,23,25,26,29]

Suvival of grafts

Paglen *et al*[6] presented the results of PK in keratoconus of an impressive series of over 300 patients with a mean follow-up of 11.3 years, but of these only 110 grafts were per-

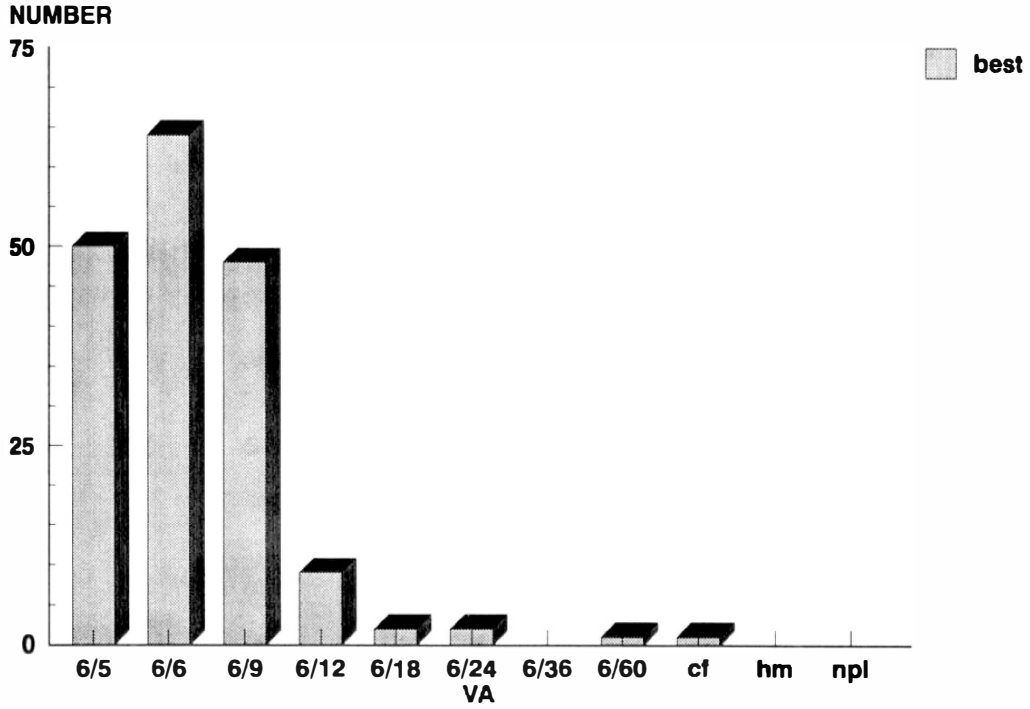

Fig. 7 *The best refracted acuity obtained at any time after keratoplasty.*

formed using modern microsurgical techniques including the use of monofilament nylon suture. Even so, the results of this impressive series are excellent. Ninety per cent of the grafts were clear and a further 3% had haziness compatible with 6/12 acuity. Although actuarial survival figures are not quoted it is quite evident with only five late failures in a study of this size and length of follow-up that late graft decompensation is not a substantial problem. In addition, the authors analyse separately 67 eyes with a minimum follow-up of 15 years. In this group there were six late failures but the individual reasons for failure are not given. Anseth and Palm,[3] Pouliquen *et al*,[4] Keates and Falkenstein[5] de Lavalette[7] and Pouchkowskaya[8] all presented smaller series of grafts suggesting a similar good prognosis for keratoplasty in keratoconus.

More recently Epstein[9] *et al* published the results of 345 transplants for keratoconus. To our knowledge this is the first paper to give survival curves for this condition. Included are 33 second grafts (9.5%) and 14 further grafts (4.5%), a figure much higher than the present series which had only 1.5% regrafts. The probability of graft survival in first grafts was 91.3% at four years which represents a total follow-up of one third of their patients due to censoring. Second grafts had a similar survival but that of further grafts was significantly reduced. The four year survival of the present series was 97% which compares well with Epstein's. His four year survival probability corresponds to the median survival probability—ie the probability of survival at the time when exactly half the grafts are still clear and have not been censored. Because of Epstein's short follow-up, his series and the present study are comparable in size at the four year point. Epstein suggests a continuing decline in graft survival to approximately 86% at seven years but our study did not support this concept with no failures later than four years. We found no failures in 25 patients followed for more than 10 years and conclude that if late failure does occur, then it is either not common or will only occur at follow-up times greater than we have so far achieved.

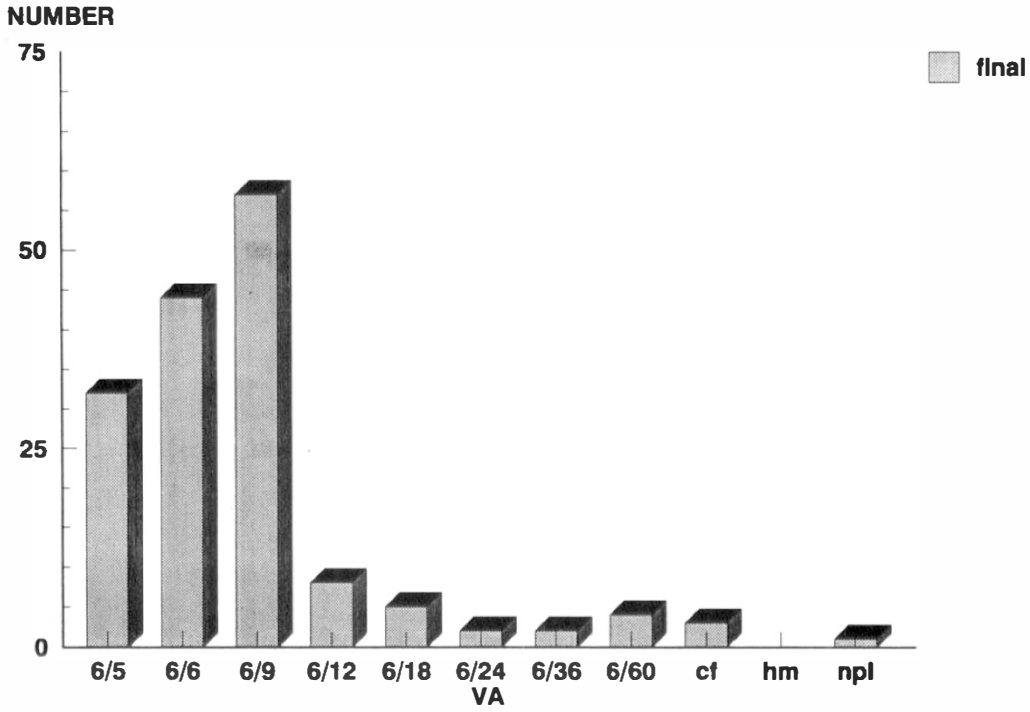

Fig. 8 *The final visual acuity shows the corrected visual acuity at the time of this review.*

The question of late donor failure was comprehensively examined by Linn *et al*[16] who were unable to demonstrate a correlation with endothelial cell loss and donor age. They found an association of declining endothelial cell numbers with length of time that the graft had survived but the most important determinant of endothelial cell survival was recipient age, ie the younger the patient at the time of keratoplasty the less the endothelial cell loss. This observation is certainly consistent with the findings in many series of prolonged graft survival and very few late failures in keratoconus.

As as result of modern microsurgical techniques, and critical evaluation of donor material, patients with keratoconus can therefore expect to keep a clear graft in a very high proportion of cases, a figure approaching 100% in first grafts.

Rejection

Rejection episodes were relatively common in a group of patients with little history of ocular inflammation. It might have been expected, however, that the atopic group, with greater release of inflammatory mediators, would have been at greater risk from this complication. This was not the case. Presumably the trauma of surgery was sufficient inflammatory stimulus to enable sensitisation to be induced in all cases.

The fact that so few grafts were lost as a result of rejection episodes may demonstrate the benefit of the aggressive approach to patient awareness, diagnosis and management of early graft rejections. Patients are encouraged to report immediately the development of any symptoms suggesting rejection. Any signs consistent with early rejection (we do not wait for the presence of a rejection line) and rejections are treated with intensive topical and subconjunctival steroids, titrating the dosage against the clinical response. The problem of an increased rejection and failure rate in bilateral grafts (as well as regrafts) has been addressed by Chandler and Kaufman[17] who suspected this problem but their figures (less than 100 transplants) did not indicate a greater risk in bilateral grafts.

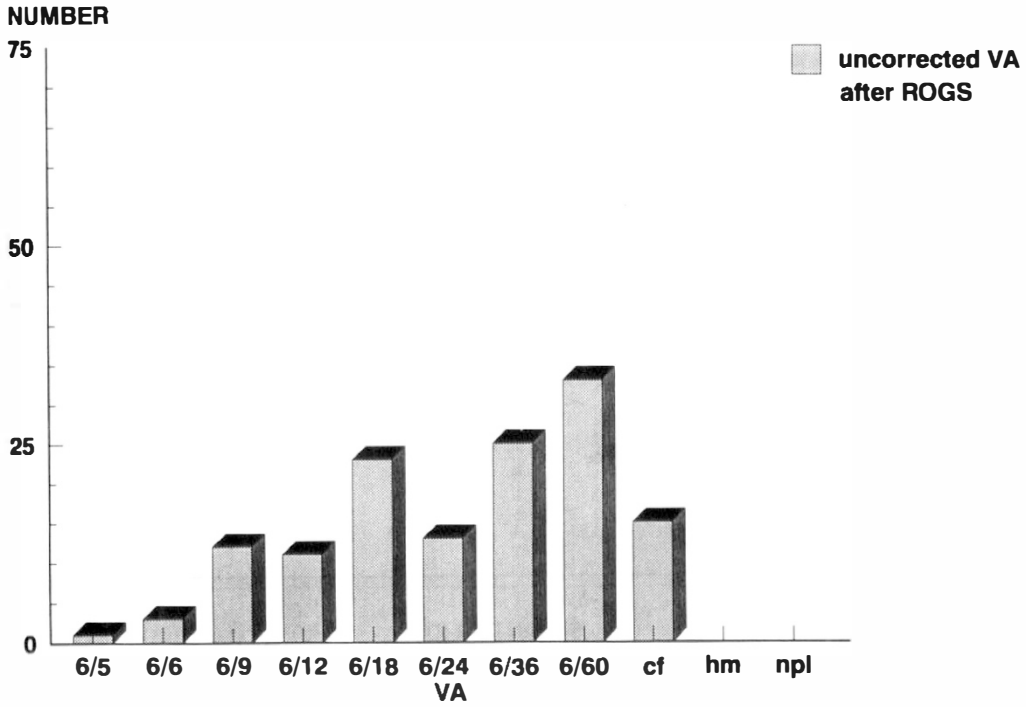

Fig. 9 *The uncorrected acuity after removal of all graft sutures. Where graft refractive surgery was subsequently undertaken, the acuity, berfore this was done, is shown.*

The overall incidence of graft reactions in their series of 35% was higher than our figure of 20%. Whether this difference is real or apparent is difficult to elaborate but it may reflect either improvements in surgical technique or more likely it may be due to our increased use of steroids in the post-operative period.

Steroid regimes are difficult to quantify since, at best, they tend to be variable but our tendency to use steroids for at least six months in decreasing dosage probably represents a greater overall dosage than would be used in most American centres.

Malbran[18] demonstrated that the second eye was more likely to suffer a graft reaction if the second graft was performed within one

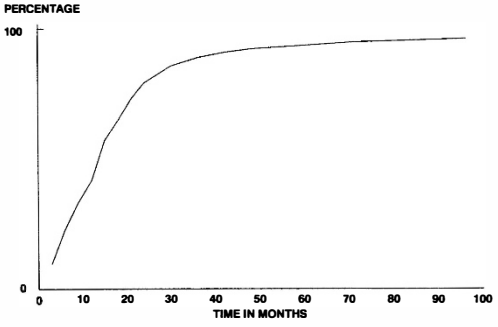

Fig.10 *Cumulative percentage curve of time taken for eyes to achieve 6/12 acuity either unaided or with refractive correction.*

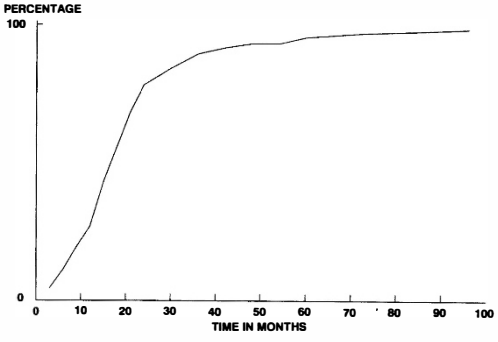

Fig. 11 *Cumulative percentage curve of time taken for dispensing of refractive correction. Where no correction was required the time taken to reach 6/12 vision was entered.*

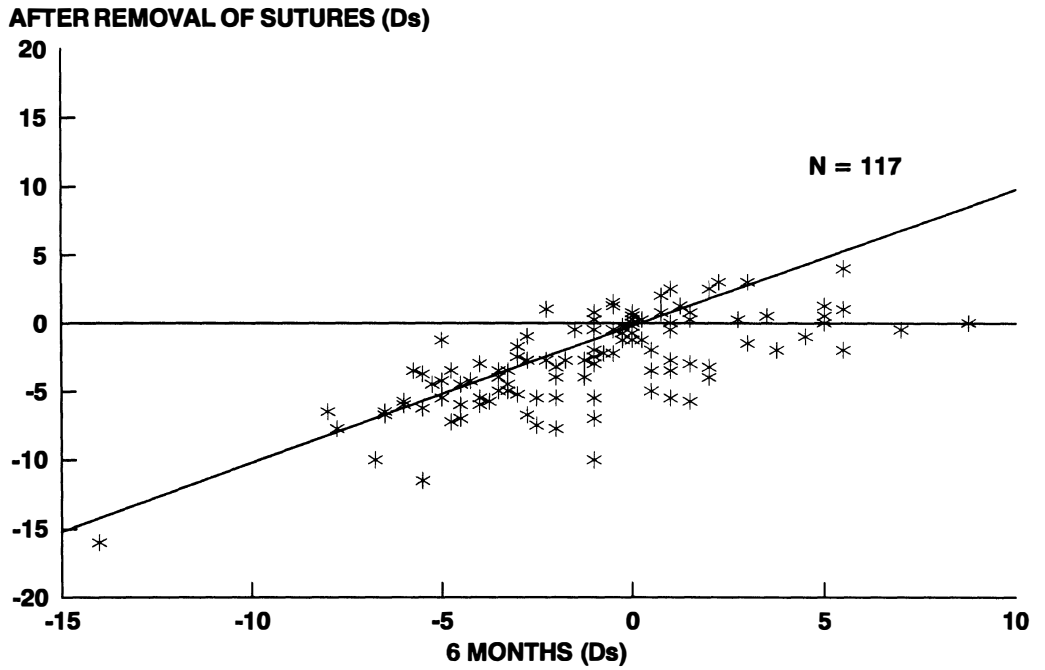

Fig. 12 *Scattergram showing the change in spherical equivalent, in dioptres (Ds), from 6 months following keratoplasty to that following suture removal. Where several points coincide only one point is shown. The oblique line indicates no change.*

year of the first. Buxton *et al*[19] were unable to demonstrate statistically significant increased rates of rejection after bilateral keratoplasties but the numbers were slightly smaller than the present study with 32 out of 134 being bilateral cases. The present data reveal that graft reactions are more common in either eye, once both eyes have been operated but that neither appears to be more at risk than the other. The second operation does therefore appear to put the first graft at risk even several years after the surgery. Since only two patients underwent bilateral keratoplasty within 12 months, no comment can be made on the increased likelihood of inducing graft reactions as a result. Even if rejection does not lead to failure, the second of the two eyes to be grafted remains at greater risk of failure and we have no simple explanation for this curiosity. The implication must be, however, that whenever a graft is undertaken in the second eye, particular care needs to be taken in the supervision of both grafts.

Complications

Ficker *et al*[20] demonstrated that loose sutures are a risk factor for rejection episodes in Herpes simplex keratitis, where 36% of transplants suffered loose sutures. Although the incidence of loose sutures was lower in the grafts in keratoconus (11.5%), they remained a significant factor in association with allograft rejections. Bates[20] further highlighted the danger of loose sutures predisposing to microbial keratitis. We, therefore, wish to emphasise the importance of prompt attention to loose sutures and recommend removal of loose sutures immediately they are observed. If it is felt that the wound is not secure, we recommend resuturing. In either case, prophylactic topical antibiotics and steroid drops should be used.

In only one case, a young atope, where cataract developed was there evidence of lens change prior to keratoplasty. Atopes are not at greater risk of developing cataract post-operatively. In the others, cataract developed up to eight years following keratoplasty. The trauma of surgery and post-operative steroid therapy may have increased the risk of cataract developing. Steriod therapy may also have contributed to raised intraocular pressure but

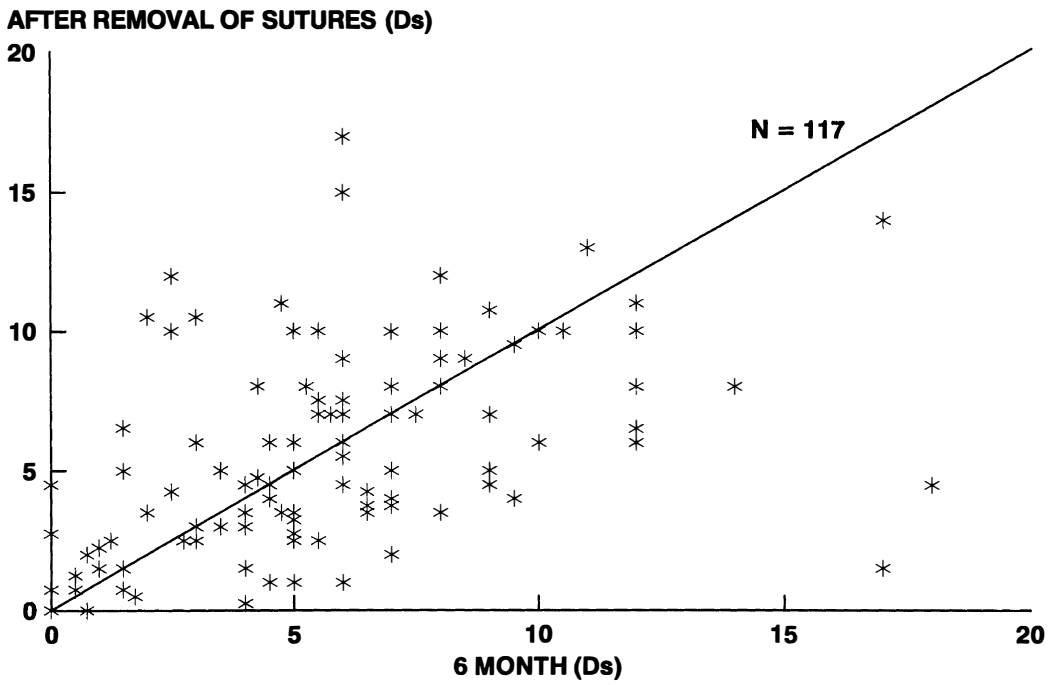

Fig. 13 *Scattergram of change in cylindrical value (dioptres—Ds) from six months after keratoplasty to that following suture removal. All values are refracted and not keratometric. Although all were recorded in minus cylinders only the arithmetical value has been plotted. Where several points coincide only one point is shown. The oblique line indicates no change.*

one case was associated with microbial keratitis and regraft and a second with trauma to the graft. All have been controlled adequately. Trauma to the graft wound was potentially the most damaging of all the complications encountered. Two were as a result of assaults and two accidental. In each case the injury was sustained several months post-operatively but the graft—host wound was ruptured and intraocular contents were lost. One case has subsequently suffered a giant retinal tear. This emphasises the delicate nature of transplanted corneas and patients should be aware that a transplant is never as secure as their original cornea. It also supports the development of epikeratoplasty in the management of suitable candidates since epikeratoplasty does not breech ocular integrity. A relatively large number of incidents occurred in otherwise healthy eyes undergoing comparatively uncomplicated surgery. The consequence of these incidents was, however, favourable. This was achieved partly as a result of patient awareness leading to prompt presentation on development of adverse symptoms.

Visual acuity

The visual results obtained after keratoconus are encouraging. Although the best refracted results appear excellent it is perhaps more realistic to consider the current visual results, since these may reflect practical on-going difficulties or complications that the patients have suffered. Even so, 91% have a current corrected acuity of 6/12 or better. These figures compare favourably with previously reported series.[3–13,17–19,22–29] Reasons for loss of best acuity include trauma, cataract, glaucoma, and other ocular conditions not necessarily related to keratoconus or the surgery.

At six months post-operatively, only 63% of eyes were correctable to 6/12 or better reflecting the protracted recovery period that such eyes demonstrate. Continuing resolution of graft stromal oedema and folds, and possibly high astigmatism contribute to this delay.

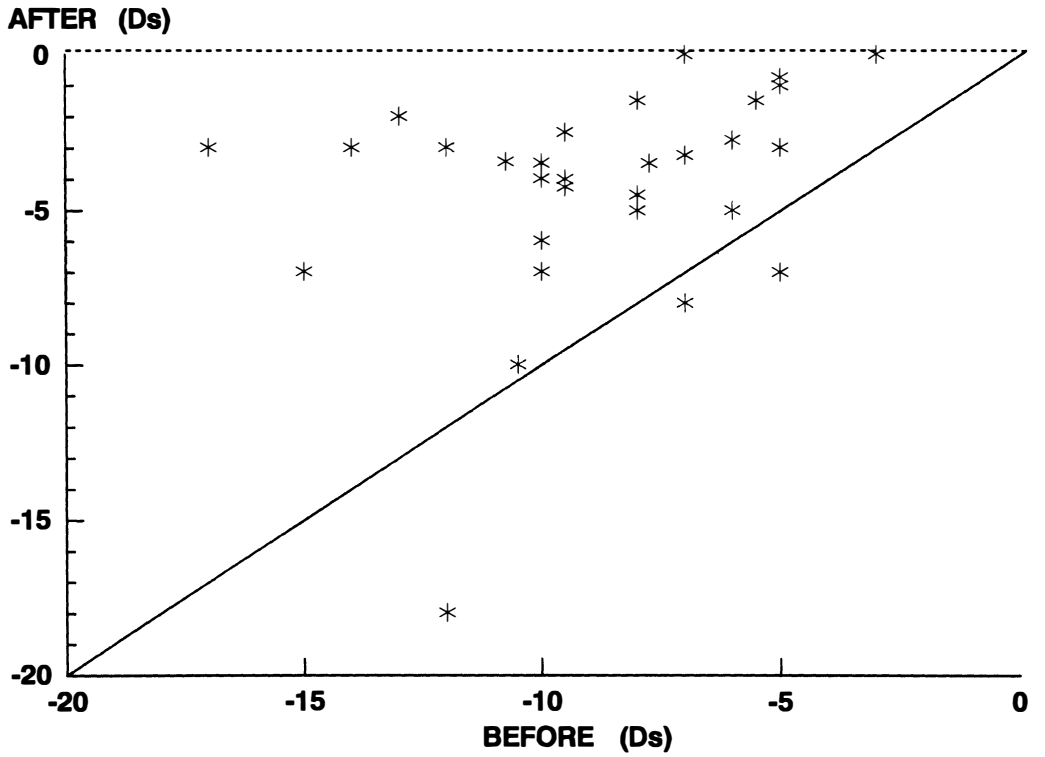

Fig. 14 *Scattergram showing the change in astigmatism produced by graft refractive surgery. Again where several points coincide only one is shown. The oblique line indicates no change and all points above it show reduction in astigmatism.*

This in turn highlights the prolonged period before patients achieve useful vision.

Although many patients whose vision has not yet recovered to 6/12 corrected or who still have not had correction dispensed might consider that their vision was useful, we adopted 6/12 as a practical endpoint since this approximates to the visual requirement for driving. This level also represents the 90% confidence limit of visual improvement. It took three years for 90% of patients to reach this level of corrected acuity and a similar time (38 months) until the appropriate refractive correction was dispensed. Reasons for this prolonged recovery period may include high astigmatism where refractive surgery was necessary, lack of concern by the patient because the other eye had good vision and in many cases the delay was necessary because it was desirable for the graft sutures to be removed before the patient could be fitted with a contact lens. Although the levels of vision reached are excellent, the delay is large and clearly represents one area where potential improvements in patient management may be made either by earlier suture removal, earlier graft refractive surgery or by fitting of contact lenses sooner. Thirty per cent of patients were eventually fitted with contact lenses after keratoplasty and none developed any serious complications as a result. In particular, rejection episodes did not appear more common in these patients.

Astigmatism

Graft astigmatism has always been recognised as a major barrier to easy visual rehabilitation of keratoconus patients. Troutman[11] reporting 82 out of 94 transplants found an average of four dioptres by keratometry but found no significant difference before and after suture removal. Stainer *et al*[22] recommend a combination of running suture and interrupted sutures to reduce astigmatism and permit

selective suture removal to reduce initial high degrees of astigmatism encouraging the cornea to assume a more regular shape. The average astigmatism by this technique was 3.4 dioptres by keratometry. Only 18% of the series however were patients with keratoconus. Binder,[24] again in a mixed series confirmed the benefit of selective suture removal. Other relevant factors in the generation of astigmatism include the position of the trephine *vis à vis* the cone[23] and the degree of tilt of the trephine at the time of cutting the host bed.[27]

Despite our awareness of the problem and paying particular attention to the care in cutting the host and donor, astigmatism remains a problem for many of the patients in this study. Although the numbers in individual years are too small to analyse, taking the figures in groups of five years eg 1971–1975 etc showed no significant improvement until the present time, $p>0.05$.

Aniseikonia was a significant problem in only one patient (0.5%) with bilateral grafts.

Following removal of the graft sutures, the overall refractive results are skewed towards myopia. This reflects, in part, the tendency for keratoconic eyes to be myopic in any case, but also reflects the tendency in keratoconus for slight oversizing of grafts to produce myopia recently described by Perry,[25] Duran[28] and Wilson.[29] While reducing the size of donor slightly may counteract this tendency, it is doubtful whether this is to be recommended since any degree of graft host disparity requires greater compression of the wound to achieve watertight closure. This in turn tends to compress the drainage angle and may predispose the eye to glaucoma.

Graft refractive surgery has been described widely and in many forms[23,30–32] but the surgery in this series was confined to relieving incisions and compressive resuturing. Because of the varying indications for refractive surgery and differing preferences of a number of surgeons, analysis of the relative success between the two techniques is not possible. Refractive surgery was, however, successful in reducing the astigmatism to less than five dioptres in 80%. The mean reduction achieved was 4.81 dioptres. Fifty-five patients attained useful vision within six months of refractive surgery and 90% within 18 months. The refractive surgery not only reduced astigmatism but also enabled visual rehabilitation in a reasonable time in the majority of the patients. Since we have shown (*vide supra*) that 77% of eyes change by no more than three dioptres between six months and the time that the graft suture is fully removed, consideration might be given to the possibility of planning graft refractive surgery at a much earlier date.

The role of epikeratoplasty in the management is currently under investigation and initial reports indicate that it may be useful where there is good visual acuity with a diagnostic contact lens but where a contact lens is not tolerable.[12,32,33] compared to penetrating keratoplasty, epikeratoplasty offers the advantages of maintaining an intact globe in a young, population, while avoiding potential immune rejection. The major disadvantage is a prolonged healing period. As yet, the limits of the extent of the corneal ectasia that would be suitable for epikeratoplasty remain to be identified. From our indications for surgery, it would appear that this figure accounts for less than a third of patients undergoing keratoplasty. The visual results, nevertheless, would seesm to justify further work in this area.

Our data lead us to conclude that keratoplasty provides good visual rehabilitation for patients with keratoconus with an excellent prospect of maintaining a clear graft. Full rehabilitation may be a prolonged process but if astigmatism is the cause of delay it may be satisfactorily treated by graft refractive surgery. Major improvements in the future may be aimed at reducing initial astigmatism and by earlier intervention where severe astigmatism exists.

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