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REVIEW

Managing Post Keratoplasty Astigmatism

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Abstract: Corneal transplantation, when used in the correct setting, can significantly improve visual acuity and therefore quality of life. One of the barriers to good vision following keratoplasty is residual post operative surgical astigmatism. Following a thorough literature search, we present the different options available to readers, with regards to how post-operative astigmatism can be approached and managed in order to improve vision. We present available data from the literature, which in some areas are scarce, with a view to collating all of this information in one place, allowing comparison between different modalities of treatment.

Keywords: penetrating keratoplasty, astigmatism, post graft astigmatism, corneal transplant astigmatism

Introduction

Penetrating keratoplasty is a surgical procedure that is designed to improve a patient's vision by replacing a diseased or damaged cornea with a healthy donor cornea. Despite the potential for clear grafts and improved visual acuity, post-operative astigmatism remains a common complication of this procedure. In fact, studies have shown that approximately one in five patients who undergo penetrating keratoplasty develop post-operative astigmatism of 5 dioptres or more, significantly impacting on the quality of vision and making post surgical visual rehabilitation challenging.[1–4]

There are several factors that can contribute to the development of post-keratoplasty astigmatism, including pre-operative, intraoperative, and postoperative factors. Preoperative factors may include the severity of the underlying condition prompting the need for surgery e.g ectasia,[5,6] while intraoperative factors may include those such as trephination size and location, donor graft size, corneal thickness, donor-recipient disparity, and poor suture placement.[7–9] Eye banking standards vary worldwide, but at present, there is no ability to exclude donor ectatic disease.[10] Similarly, donor corneas may have a preexisting amount of innate host astigmatism. Postoperative factors may include the use of post-operative medications to reduce inflammation, corneal vascularization, rejection, and wound dehiscence.[11] Some of the above factors are easier to control than others, and some are difficult to define, which can make it challenging to manage post-keratoplasty astigmatism effectively.

Method of Literature Search

A systematic search was performed using the PubMed database to identify relevant studies using the search terms penetrating keratoplasty and astigmatism. The search took place to include references up to January 2024. The initial search yielded a total of 1139 records, which underwent a screening process based on title and abstract relevance to the review's objective. Subsequent to this initial filtration, the remaining papers were subjected to a more detailed analysis, facilitating the creation of a refined subset of papers upon which this review is based. Please also see Table 1 for a summary of different interventions.

Discussion

Post penetrating keratoplasty (PK) astigmatism can be a challenging issue to manage. It is a common complication following corneal transplant surgery and can impact visual acuity and overall patient satisfaction. Conservative measures include correction by contact lenses or glasses,[12–16] depending on the degree or irregular astigmatism.

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Table 1 Quick-View Summary of Interventions

	Indications for treatment
Suture adjustment	During the initial postoperative period spanning 12 to 18 months, the strategic practice of selective suture removal is frequently used to modulate the healing process. Additional treatment modalities are typically initiated three months after the removal of all sutures.
Limbal relaxing incisions or compression sutures	Post suture removal these techniques provide a minimally invasive modality for addressing residual astigmatism when glasses or contact lenses are not providing satisfactory vision correction.
Excimer Laser based procedures	Topography-guided PRK or LASIK are both effective options for improving post-keratoplasty astigmatism. These procedures use advanced technology to map the irregularities of the corneal surface and guide the laser in reshaping it precisely. By customizing the treatment based on the corneal topography, these techniques can address the specific astigmatism present after keratoplasty, leading to improved vision outcomes for patients.
Intrastromal corneal ring segments	Intrastromal corneal ring segments have shown promise in improving post-keratoplasty astigmatism. These segments are inserted into the cornea to reshape its curvature. By altering the corneal shape, these segments can help address astigmatism following keratoplasty, offering patients another viable option for vision improvement.
IOL based treatment	IOL based treatments involve implanting special IOLs that can correct astigmatism along with addressing other vision issues like cataracts or refractive errors. They can be used in combination with the other options above to provide a comprehensive solution for patients with post-keratoplasty astigmatism.
Repeat corneal transplantation	In instances where alternative modalities for vision correction have proven ineffective, recurrent corneal transplantation may emerge as the ultimate recourse.

Medical Approaches

Medical approaches used to manage post-keratoplasty patients often include the use of anti-inflammatory medications to reduce inflammation and corneal vascularisation, and the use of topical steroids to help reduce rejection and wound dehiscence. This is important in providing corneal transplant stability prior to any further surgical approaches to managing post penetrating keratoplasty astigmatism.

Surgical Approaches

There are a variety of surgical options available to manage post penetrating keratoplasty astigmatism. These include corneal topography-guided selective suture removal,[17] relaxing incisions[18] or compression sutures,[19] intracorneal ring segments,[20] refractive laser surgery,[21,22] toric intraocular lenses,[23,24] small aperture optics,[25] and repeat keratoplasty.[26] The most appropriate option will depend on the specific circumstances of the individual case, including the type and severity of the astigmatism, the rationale for the transplantation (optical vs therapeutic vs tectonic graft), and the patient's visual needs and preferences. It is important to carefully evaluate the potential benefits and risks of each treatment approach and to consider the long-term stability of the results.

Interrupted Vs Continuous Sutures

In the immediate post operative period, astigmatism can be managed by manipulating the suture patterns in the cornea. For patients with interrupted suture patterns, selective suture removal can be used to influence healing and reduce astigmatism.[17,27] This can be done by systematically removing sutures that contribute to the astigmatism on a regular basis, starting at around 12 weeks post-operation. If the patient has a running suture pattern, it is more challenging to control astigmatism through selective suture removal because the entire suture must be removed if it is cut.[28,29] In some cases, it may be possible to rotate the sutures at approximately four weeks post-operation in order to loosen tight sutures and tighten loose sutures, although the effectiveness of this approach may vary.[30] The literature in general does seem to suggest that interrupted suture technique leads to higher astigmatism compared to continuous sutures in patients undergoing PK.[31] After complete suture removal it is usually more than one or two years post-operation, other options may need to be considered for the management of astigmatism. After complete suture removal it is recommended to delay further surgery until at least three months post-suture removal to allow for wound healing and refractive stability.

Incisional Surgical Techniques

The use of suture techniques, limbal relaxing incisions and compression sutures in the management of post-PK astigmatism has been thoroughly researched and documented in the literature. In particular the use of manual and laser assisted arcuate keratotomies and their nomograms which typically aim to improve around 5D of astigmatism.[32] In light of this, this paper aims to discuss the various options in the management of post-penetrating keratoplasty astigmatism that are available after these initial options.

Intra-Stromal Corneal Ring Segments

Intra-stromal corneal ring segments (ISCRS) have been demonstrated to be a viable option for reducing astigmatism in patients who have undergone PK. Coscarelli et al conducted a study of 59 eyes that received ICRS after PK using a manual trephine technique, found that astigmatism was reduced from a mean of −6.34 ± 3.4 dioptres (D) to −2.66 ± 2.52D, and at least one line of improvement in corrected distance visual acuity (CDVA) was observed in 73% of patients.[33] The ISCRS were implanted at least two years post-surgery and at least three months after complete suture removal, placed at 80% corneal thickness using an optical zone of 5mm with the aim to minimise the risk of complications related to neovascularization and wound dehiscence.

Another study by Arantes et al of 25 eyes that received ISCRS after deep anterior lamellar keratoplasty (DALK) reported a reduction in topographic astigmatism and spherical equivalent, as well as an improvement in CDVA.[34] The use of a femtosecond laser to create the corneal tunnel for ISCRS implantation has been shown to be safer than the manual technique, with a lower incidence of complications such as ring extrusion and perforation, with no complications in the femtosecond group compared to 13.09% in the manual group[35] A nomogram utilizing femtosecond laser assisted ISCRS implantation, in which the apical diameter and length of the arc are selected based on the amount of refractive astigmatism and the implantation axis is aligned with the flatter axis in the topography, has been proposed as a method to improve outcomes. Lisa et al conducted a study employing this nomogram in patients having ISCRS post PK and found that 32 eyes showed an improvement in mean uncorrected distance visual acuity (UDVA) (Snellen Decimal) from 0.16 ± 0.15 preoperatively to 0.43 ± 0.28 postoperatively and mean CDVA from 0.67 ± 0.22 to 0.80 ± 0.19.[36]

Excimer Laser Based Refractive Procedures

Topography-guided PRK, as, has been increasingly utilized in the management of aberrated corneas with irregular astigmatism in PK patients. In these cases, traditional wavefront-guided LASIK may not be feasible due to the quality of the wavefront map, rendering topography-guided PRK a more viable option.[37] One of the primary concerns with topography guided laser refractive surgery is its tendency to involve a greater amount of tissue ablation when contrasted with wavefront guided laser refractive surgery. It is worth noting that the maximum amount of astigmatism that can be treated with these procedures is typically limited to around 6D. One potential issue that may arise with refractive surgery in PK patients is the increased risk of corneal haze and the variable healing properties of transplanted corneas. In these cases, the use of mitomycin-C (MMC) may be beneficial in mitigating this risk.[38]

One of the largest studies in this area was conducted by Hardten et al. This was a retrospective review of 57 eyes from 48 patients who underwent LASIK for visual rehabilitation after PK.[39] The results showed that the procedure was effective in reducing ametropia, with a mean spherical equivalent of −0.61D and mean astigmatism of 1.94D at 2 years after surgery. However, the results of LASIK after PK were not as good as in eyes with naturally occurring myopia and astigmatism, and complications were more frequent, with 9 eyes (16%) developing epithelial ingrowth and 5 eyes (9%) requiring repeat corneal transplants. All of the patients with epithelial ingrowth had override of the donor wound over the host before the LASIK. The 5 eyes that required repeat corneal transplant, 2 had early loss of graft clarity due to low endothelial cell counts, 1 patient had a rejection episode 2 years after LASIK, and 2 for persistent irregular astigmatism that existed prior to LASIK.

Malecha et al conducted a retrospective review of medical records of patients who underwent LASIK following PK at the University of Minnesota between January 1999 and March 2000.[40] Of the 20 eyes in the study, 73.7% had undergone PK for keratoconus. Anisometropia and/or contact lens intolerance was the indication for LASIK following PK. The mean sphere was reduced by 3.93D (80.0%) and the mean cylinder by 2.83D (69.9%) from preoperative values at the last follow-up visit. UDVA became 20/40 or better in 73.7% of eyes after LASIK.

Kavoor et al conducted a study of 23 keratorefractive procedures on 16 eyes of 16 consecutive subjects between 2002 and 2008.[41] The study found that photorefractive keratectomy (PRK) and LASIK were effective in reducing surgically induced astigmatism after PK in most patients. There were two episodes of acute graft rejection in the study, one of which resolved with corticosteroids and the other requiring a repeat corneal transplantation.

Spadea et al conducted a study on 12 eyes from 12 patients with highly irregular astigmatism after PK for keratoconus who underwent a single-step topography-guided trans-epithelial ablation.[42] The results showed significant improvements in UDVA and CDVA, as well as a significant decrease in spherical equivalent and subjective and keratometry astigmatism. The corneal morphological irregularity index also significantly decreased. There was one episode of graft rejection, which was successfully treated with topical steroids, and two eyes (16.7%) showed mild corneal haze at 3 months post-PRK, which did not regress at 12 months. Overall, the study demonstrated the safety and long-term effectiveness of topography-guided trans-epithelial ablation in the treatment of highly irregular astigmatism after PK.

Donoso et al conducted a retrospective study where 14 patients (19 eyes) underwent LASIK after PK for keratoconus.[43] The results showed that CDVA remained stable throughout the study, but the spherical equivalent decreased from −2.6 D before surgery to −0.36 D at the shorter follow-up period (average 9 months post procedure) and −1.28 D at the longer follow-up period (average 6.8 years post procedure). The refractive cylinder was reduced from −3.43 D preoperatively to −1.37 D at the shorter follow-up period but increased to −3.21 D at the longer follow-up period. These results suggest that LASIK may not be an effective long-term surgical treatment for residual refractive errors after PK for keratoconus.

In summary the above studies have shown promising visual and refractive outcomes post-topography-guided PRK or LASIK following PK. Large retrospective reviews have demonstrated the effectiveness of LASIK post-PK in reducing ametropia, though complications such as epithelial ingrowth and the need for repeat corneal transplants are more frequent. Additionally, studies have explored the efficacy of PRK and LASIK in reducing surgically induced astigmatism after PK, with some reporting favourable outcomes but also instances of graft rejection and corneal haze. Long-term studies suggest that while LASIK may initially reduce refractive errors post-PK, it may not provide lasting effectiveness, highlighting the need for further comparative studies to fully assess the superiority of these approaches over other surgical options.

Combined PRK and Intra-Stromal Corneal Ring Segments

Bertini et al conducted a study aimed to evaluate the refractive and topographic outcomes of combining ISCRS with PRK for the correction of high PK astigmatism.[44] This was a prospective interventional study that included 30 eyes of 29 patients with PK astigmatism who were intolerant to contact lens fitting and had corneal astigmatism higher than 6.0 D. The participants underwent femtosecond laser assisted ICRS implantation to reduce and regularise corneal astigmatism and, 3 months later, underwent PRK for the residual astigmatism. Outcomes were assessed 12 months after PRK. The results demonstrated a significant improvement in UDVA, spherical equivalent, topographic astigmatism, and refractive astigmatism following the ISCRS/PRK combination. However, the procedure was associated with several complications, including clinically significant corneal opacification in 8% of cases, endothelial rejection in 4%, infectious keratitis in 4%, and ISCRS extrusion after corneal melting in 4%. Despite these adverse events, the authors concluded that the combination of ISCRS and PRK was an effective treatment for high PK astigmatism, resulting in a high correction index for both corneal and refractive astigmatism. However, the safety of this approach warrants further investigation.

Intraocular Lens Based Procedures

Toric Pseudophakic Lens Implantation

Toric intraocular lenses (IOLs) are a potential treatment option for patients who have undergone PK and developed astigmatism. These lenses can be used in both phakic and pseudophakic patients and have been shown to be effective in correcting large spherical errors and astigmatism up to 15D with customized IOLs.[45] The use of toric IOLs has the advantage of minimal manipulation of the cornea, which helps to maintain its structural integrity and predictability of results. However, toric IOLs may not be effective in fully correcting irregular astigmatism with non-orthogonal axis and are therefore more suitable for patients with minimal irregular astigmatism who can typically achieve satisfactory correction with spectacles. While some studies have suggested that toric IOLs may be effective in patients with more irregular astigmatism, further research is needed to fully evaluate their benefit in these cases.[46] Alternatively, sulcus-supported IOLs may be used to correct residual refractive error in phakic patients, although these lenses may rotate postoperatively and compromise the outcome.[47] Phakic IOLs may be an option for younger patients with clear lenses, but they are generally limited in their ability to correct astigmatism up to 7.5D and may be associated with higher endothelial cell loss.[24,48]

Srinivasan et al conducted a study on the use of customized toric IOLs as a treatment option for patients with high astigmatism after PK.[49] The 3 types of toric lenses used in the study were the Rayner T-Flex(Raynor, Hove, UK), Raynor Sulcoflex(Raynor, Hove, UK) and HO PCIOL(Humanoptics, Erlangen, Germany). Nine eyes of nine patients were included in the study, six of which underwent simultaneous phacoemulsification and IOL implantation, while the remaining three received secondary “piggyback” toric IOLs. The results showed that the use of customized toric IOLs resulted in a significant improvement in UDVA and a reduction in corneal astigmatism. There was no significant change in CDVA and mean endothelial cell loss was 9.9%. These findings suggest that customised toric IOLs may be an effective option for the treatment of high astigmatism after PK.

Implantable Collamer Lenses

Alfonso et al conducted a study aimed to evaluate the efficacy, predictability, and safety of a phakic posterior chamber intraocular Collamer lens (ICL) in treating myopia and astigmatism after PK.[50] The ICL was implanted in 15 eyes that were unable to wear glasses or contact lenses, and corneal laser surgery was contraindicated. The lenses used were either the myopic ICMV4 Visian ICL or toric TICM4 Visian ICL(Staar Surgical, California, USA). Preoperative and 24-month postoperative data were collected, including UDVA, CDVA, refractive error, endothelial cell count, and safety index. The safety index was 1.58, and the mean UDVA and CDVA improved significantly postoperatively. The spherical equivalent was within ±1.00 D in 80% of eyes and within ±0.50 D in 66.6% of eyes, with minimal endothelial cell loss. The results showed that phakic intraocular lens implantation is a viable treatment option for myopia and astigmatism after PK in patients for whom glasses, contact lenses, or corneal refractive surgery are contraindicated.

Small Aperture Optics; Pinhole Lenses

The use of small aperture optics, such as the Xtra Focus(Morcher GmbH, Germany) and IC-8 IOL(Bausch and Lomb), has been demonstrated as a potential treatment option for irregular astigmatism in a number of studies.[51–53] The Xtra Focus, a sulcus fixated hydrophobic acrylic implant with a central hole, has been shown to improve UDVA, CDVA, near uncorrected and corrected visual acuities in patients with irregular astigmatism, including those with a history of PK. Similarly, the IC-8 IOL, a hydrophobic intraocular lens with a central pinhole mask, has been shown to improve CDVA and visual acuity at various distances in patients with severe corneal irregularities caused by conditions such as keratoconus, PK, and ocular trauma. However, the dioptric power range of these implants may be a limiting factor for their use in irregular corneas. Further research is necessary to fully understand the potential of these devices in the treatment of irregular astigmatism.

Trindade et al conducted a study on twenty-one patients with irregular corneal astigmatism caused by keratoconus, post-radial keratotomy, post-PK, or traumatic corneal laceration looking at the effectiveness of the Xtrafocus device in improving visual acuity in patients with irregular corneal astigmatism.[54] The results showed a statistically significant improvement in UDVA and CDVA, and subjective patient satisfaction was high. Manifest refraction remained unchanged, and only one case required an additional surgical intervention due to decentration of the device. The study concludes that the intraocular pinhole device is an effective treatment option for patients with irregular corneal astigmatism.

Ho et al conducted a study on eleven pseudophakic eyes of eleven patients using the Xtrafocus lens.[55] Within this patient population, six individuals were specifically recruited due to the presence of irregular astigmatism following PK. The research findings yielded highly encouraging outcomes, notably indicating that eight out of the eleven patients expressed satisfaction with their respective visual results. Haloes, poor vision in dim light, floaters and restricted field of vision have all been reported in the existing literature with these lenses.[54,56,57] Of particular significance, the present study disclosed that two patients ultimately necessitated explantation of the XtraFocus lens due to the onset of troubling symptoms, including worsening glare, and distressing floaters. These instances emphasise the need for thorough patient selection, recognizing that not all patients may achieve the desired outcomes, and complications can necessitate lens removal.

Tissue Adding Procedures

Microkeratome-assisted anterior lamellar keratoplasty (MALK) is a surgical technique used to correct high-degree post PK astigmatism. Gutfreund et al published a study looking at the outcomes of patients treated with MALK for post PK astigmatism.[58] The study comprised of four eyes of two patients with more than 10D of astigmatism post PK. The procedure involves a 250-micron lamellar keratectomy, followed by the placement of a donor graft secured with a double-running suture. MALK was found to be effective and safe in the treatment of high-degree post PK astigmatism, with improvements in CDVA and reduction in refractive astigmatism and surface asymmetry index observed in the four eyes of two patients studied for 3 years or longer after MALK.

Repeat PK may be considered as a treatment option for persistent or refractory astigmatism after initial keratoplasty.[26] However, this option should be approached with caution due to the higher risk of rejection and glaucoma, as well as other complications, associated with repeat transplantation. It is important to carefully weigh the potential risks and benefits of repeat keratoplasty in the management of astigmatism after initial keratoplasty, and to consider alternative treatment options whenever possible.

Conclusion

In conclusion, the management of post-keratoplasty astigmatism is a complex and challenging task that requires careful consideration of various conservative and surgical options. The available literature highlights several promising techniques that can improve visual outcomes following suture removal. However, it is important to acknowledge that the current evidence base is limited, and further research is needed to establish the efficacy and safety of these interventions. In additional, as with any surgical procedure, outcomes will vary according to surgical technique and experience, as well as inherent patient factors. What is clear is that there are now many options available to patients and clinicians that can help improve astigmatic outcomes. Proper patient counselling is paramount, as all treatment modalities carry inherent and varied risks. No doubt as the use of these techniques becomes more prevalent in clinical practice, we anticipate that additional studies will provide valuable insights into their long-term outcomes and help to further optimise patient care.

Disclosure

The authors report no conflicts of interest in this work.

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