Deep lamellar keratoplasty on air with lyophilised tissue

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Abstract

Deep lamellar keratoplasty on air involves injecting air into the corneal stroma to expand it to several times its normal thickness. This method has been used to facilitate dissection of the deep stroma and separate Descemet's membrane from the donor stroma.

The technique of deep lamellar keratoplasty on air was first reported by Archila in 1985. Since then, it has been used in a variety of clinical settings, including the treatment of keratoconus, pterygium, and herpes zoster ophthalmicus.

The advantages of deep lamellar keratoplasty on air include the following:

1. Reduced surgical stress on the donor cornea, as the endothelium remains intact.
2. Improved wound healing and reduced rejection rates.
3. Improved optical outcomes, as the deep stroma is more accessible for dissection.

The technique involves injecting air into the corneal stroma, which expands and becomes temporarily opaque. This makes it easier to dissect the deep stroma and separate Descemet's membrane from the donor stroma.

The technique has been used in patients with a variety of corneal disorders, including keratoconus, pterygium, and herpes zoster ophthalmicus. In a series of patients with keratoconus, it was found that the technique resulted in improved visual outcomes and reduced rejection rates.

The technique has also been used in cases of pterygium, where the air injection helps to separate the stroma from the underlying tissue, allowing for better dissection and grafting.

In cases of herpes zoster ophthalmicus, the air injection helps to separate the stroma from the underlying tissue, allowing for better dissection and grafting.

The technique has been shown to be effective in a range of clinical settings, and it is likely to continue to be used in the future as a valuable tool in the treatment of corneal disorders.
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Figure 2. A patient's cornea with central stromal scarring is suitable for this technique. Air is injected and a lamella resected. Lyophilised tissue is sutured in place.

If the recipient patient subsequently were to undergo penetrating keratoplasty since the eye would not be pre-sensitised to donor antigens.

We present our experimental work on human cadaver corneas and the results of using the technique in a series of four patients with different corneal pathologies. The corneal material we used for grafting included both organ-cultured full thickness corneal tissue without endothelium, and lathed lyophilised lenticules.

Materials and methods

IN VITRO WORK

We initially carried out trials in six human cadaver corneas which did not have pre-existing corneal pathology. Two were simply injected with air, and in the others air was injected and experimental lamellar dissection carried out (Fig 1). These eyes were fixed in formalin and then slices were paraffin embedded and sections of 3 μm cut prior to staining with haematoxylin and eosin for assessment by light microscopy.

CLINICAL SERIES

The four clinical cases selected all had superficial stromal opacities over the visual axis. Two had moderate keratoconus with significant apical scarring rendering them unsuitable for epikeratoplasty, and both were intolerant of contact lenses. The third patient had extensive vascularised subepithelial scarring following herpes zoster ophthalmicus. In this case the corneal neovessels were shut down with an argon laser preoperatively. The remaining patient had a large nasal pterygium with subepithelial scarring extending across the visual axis.

Surgery was performed by one surgeon (CKR) using a method similar to that described by Archila. A 26 gauge needle was inserted obliquely into the stroma in the mid-periphery of the cornea and air was injected until the whole stroma became insufflated if this was possible. Superficial trephination was made and the incision deepened with a diamond knife until Descemet's membrane was approached. Lamellar stromal dissection was carried out using a disposable lamellar blade. Out of the four cases, one patient (number 1) received a tissue-cultured full thickness donor cornea which had its endothelium removed by cellulose sponge. The other three patients received pre-lathed lyophilised lenticules cut to 100% of the donor tissue central corneal thickness (plano lamellar tissue, Keratec Eye Bank, St George's Hospital, London, UK). These lenticules were rehydrated with balanced salt solution just prior to grafting. The grafts were secured with interrupted monofilament sutures (Fig 2).

Results

Though complete insufflation of the cornea by air injection was relatively easy in cadaver eyes, it
was generally incomplete in our clinical cases leaving the area with most stromal scarring or pathology undissected. This occurred at the corneal apex in the keratoconus cases (Fig 3), and in the vascularised peripheral sector of the case of herpes zoster ophthalmicus. Complete air dissection of the cornea was achieved only in the case with the pterygium.

In every case air was found to enter the anterior chamber and, to a varying extent, to track into the subconjunctival tissues. In some instances it was necessary to aspirate the air from the anterior chamber by limbal puncture in order to reduce the intracorneal pressure, and it was these problems that prevented complete insufflation of the cornea.

Table I shows the results of the clinical cases including the preoperative and postoperative visual acuity, refraction, and keratometric values over the follow-up period of up to 4 years. The first patient with keratoconus only had a planned 30% lamellar dissection, and postoperatively there was some diffuse interface scarring with a contact lens corrected vision of 6/12. Because the patient was dissatisfied with the visual result he later underwent penetrating keratoplasty.

The second patient who had resection of a nasal pterygium developed small persistent epithelial defects in the first postoperative month, these healed eventually. Additionally, there were some small epithelial islands left at the interface away from the visual axis (Fig 4). The third patient with vascularised scarring secondary to herpes zoster ophthalmicus had previously undergone extracapsular cataract extraction with posterior chamber lens implantation. Incomplete air dissection was a problem particularly in the area of neovascularisation, and ultimately some deep stromal opacity remained, but this was away from the visual axis. Patient number four with keratoconus could not be fitted with contact lenses postoperatively, there was obvious central stromal opacity and so he was counselled aggressively. Postoperatively he achieved marked visual improvement to 6/9 with a contact lens. He had no significant complications.

Proprospective spectacles corrected vision ranged between 6/12 and counting fingers. All four patients achieved best corrected vision of 6/12 or better 1 year postoperatively. Considerable postoperative astigmatism was common in the early postoperative phase but tended to settle with time and selective suture removal. Both patients with keratoconus had marked corneal flattening after surgery.

Histopathology

IN VITRO WORK
Figures 5 and 6, stained with haematoxylin and eosin, show sections of human cadaver cornea following air insufflation. Nearly the whole stroma is occupied by small oval holes which are smaller superficially but become larger towards Descemet's membrane. The surgical emphysema of the cornea halts abruptly at the corneoscleral junction adjacent to the trabecular meshwork. The fine stromal structure immediately beneath Bouma's layer appears relatively unaffected, while there is good separation of Descemet's membrane from deep stromal fibres.

In no specimen was rupture of Descemet's membrane seen, although the possibility that rupture had occurred in a plane different from that of the sections examined was not excluded.

CLINICAL SPECIMENS
Histological examination of the excised lamellar dissections from the clinical cases revealed a

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Table I  Patient data

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<th>Patient number</th>
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<th>Pre-op refraction</th>
<th>Pre-op keratometry</th>
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<th>Post-op refraction</th>
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<td>54.00</td>
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<td>54.00</td>
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Clinical Specimens: Histological examination of the excised lamellar dissections from the clinical cases revealed a

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Figure 5. Cadaver cornea following air insufflation. The stroma is expanded by air spaces which extend only as far as the Descemet (haematoxylin and eosin, original magnification x 10).
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Discussion

The standard technique for lamellar keratoplasty is to resect the superficial host stroma and to replace the resected tissue with a partial thickness donor lamella. Problems with postoperative interface scarring have caused the technique to be largely discarded in favour of penetrating keratoplasty, which nowadays has a high success rate thanks to modern techniques of endothelial assessment of the donor corneas, and improved tissue handling by microsurgery. Nevertheless it must be remembered that in some conditions — for example, after trauma or ulceration, there may be vascularisation of the recipient cornea, and in these circumstances penetrating keratoplasty is not so successful because rejection problems are more frequently encountered.

Deep lamellar keratoplasty on air provides an enhanced visual contrast of the stroma to be dissected, allowing a more accurate assessment of the depth of incision. This helps to achieve resection of as much deep stroma as possible without perforating Descemet’s membrane. In practice, dissection actually at the level of Descemet’s membrane still carries a high risk of perforation, either through direct incision through the membrane, or by retracting or tearing of the membrane from indirect forces applied to it.

Because of this risk, in none of our clinical cases did we attempt to resect the full thickness of the recipient stroma, but rather aimed to achieve a near full thickness resection in the central optical zone of the cornea, but a less than full thickness resection in the periphery of the bed where the cornea is thicker. By limiting the near full thickness dissection to the central area alone it was thought that the risk of perforation would be minimised, and Descemet’s membrane was not in fact ruptured in any of the clinical cases.

By resecting less than the full thickness of the recipient cornea in the periphery of the graft bed, the risk of perforation by direct downward cutting with the diamond knife is minimised. The resultant graft bed thus has a contour that lies a uniform distance from the original corneal surface. In order to match the shape of this resected bed, the donor tissue used for the latter three patients in the series was pre-lathed to a uniform 100% of the donor tissue’s central thickness.

Air dissection was incomplete in each of our patients with stromal scarring, particularly in the area of maximal scarring. It is interesting to note that in cadaver corneas, air dissection is much more easily and quickly achieved than in living tissue, possibly owing to reduced adhesion between adjacent stromal fibre bundles from pre-existing corneal oedema.

We observed air in the anterior chamber in every case, and Price has advocated aspiration with a needle inserted into the anterior chamber to lower the intraocular pressure. In histological sections the air spaces above Descemet’s membrane extend extremely close to the trabecular meshwork (which is anatomically continuous with Descemet’s membrane). It is therefore possible that air gains access to the anterior chamber via the trabecular meshwork. If air had entered the anterior chamber through a rupture in Descemet’s membrane one would have expected corneal oedema to be present in this area postoperatively, or the possibility of a ‘double anterior chamber’ with aqueous tracking into the lamellar graft bed. However neither of these complications was observed in our series.
suggesting that the air dissection did not rupture Descemet's membrane.

Final spectacle corrected vision in all four patients was better than 6/18 and best corrected vision with a contact lens was 6/12 or better. While these visual results are less good than one would expect with penetrating keratoplasty they must be seen in the light of the reduced risks of lamellar keratoplasty. These include reduced risk of damage to anterior segment structures, the reduction in postoperative steroid treatment, and the lack of immunogenicity of lyophilised lenticules. This technique may thus be the treatment of choice where the aforementioned factors could be anticipated as problems if penetrating keratoplasty were to be undertaken, for example, in badly vascularised corneas, pre-existing glaucoma or steroid sensitivity, or where there is the likelihood of poor compliance with follow-up.

In summary our experience with deep stromal air injection is that it makes lamellar keratoplasty an easier and safer operation to perform with acceptable visual outcome using either tissue cultured or lyophilised donor material. Further work is needed to improve the surgical technique and define how injected air reaches the anterior chamber, as it would be helpful to avoid this complication. The use of lyophilised tissue should theoretically avoid sensitisation of the eye and this may be beneficial if subsequent penetrating keratoplasty needs to be undertaken.

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