• Brief Report •

Simultaneous tectonic Descemet stripping endothelial keratoplasty and tectonic Bowman layer transplant for the management of corneal perforation

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Abstract

• **AIM:** To report the outcomes of three cases of corneal perforation managed with simultaneous tectonic Descemet stripping endothelial keratoplasty (t-DSEK) and tectonic Bowman layer transplant (t-BLT) as an alternative to tectonic penetrating keratoplasty (t-PKP).

• **METHODS:** Three eyes of three patients receiving simultaneous t-DSEK and t-BLT for corneal perforation were included. The technique for DSEK was modified depending on individual requirements. The t-BLT technique was standardised using an 8 mm graft and fixated with a running suture. Success was measured by the ability of this procedure to close a corneal perforation.

• **RESULTS:** All three cases achieved tectonic eye globe restoration and remained stable during the minimum 3-month observation period. Reinterventions were relatively common: 2 cases required amniotic membrane transplant for persistent epithelial defects. One case required DSEK rebubbling. One case developed angle closure glaucoma requiring surgical peripheral iridectomy.

• **CONCLUSION:** Simultaneous t-DSEK and t-BLT may be a useful strategy for the management of corneal perforation as an alternative management to t-PKP for selected cases.

• **KEYWORDS:** tectonic corneal graft; Descemet stripping endothelial keratoplasty; Bowman layer transplant; penetrating keratoplasty
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INTRODUCTION

Corneal perforations can be an unfortunate complication secondary to a number of pathologies posing a considerable challenge for ophthalmic surgeons. The ultimate aim remains restoring the anatomical integrity of the eye while simultaneously attempting to preserve as much visual function as possible. Current approaches to tackling these complex cases vary, depending on the size, location, and cause of the perforation[1]. Commonly, these include the placement of cyanoacrylate glue, conjunctival flaps, amniotic transplants, and in extreme cases, tectonic grafts. The most commonly performed corneal grafts in these complex scenarios are either tectonic anterior lamellar keratoplasty, tectonic penetrating keratoplasty (t-PKP), or lamellar patch grafts, all involving sutures. We recently reported the outcomes of managing such a scenario with tectonic Descemet stripping endothelial keratoplasty (t-DSEK) grafts[2]. Nonetheless, in many cases of perforation, particularly those with melting surrounding the perforation, or if the perforation is large, a t-DSEK may need to be assisted with a glue patch to help keep the t-DSEK graft in place. However, if the perforation is large enough, a glue patch may not serve for the purpose of supporting a DSEK graft to be held in place.

In a previous case series of our group, we discussed how a deep anterior lamellar keratoplasty (DALK) over DSEK could be performed on cases in which, after the tectonic DSEK, the eye was considered to still have visual potential[2]. On the other hand, recent reports have shown Bowman layer transplant

(BLT) as an effective strategy to treat corneal diseases leading to ocular surface irregularity, such as superficial herpetic leukomas[3], or radial keratotomy[4]. This raises the question whether for some selected cases, a simultaneous t-DSEK and t-BLT may be performed in the same setting, with both grafts obtained from the same donor cornea.

We herein present a case series of patients with corneal perforation deemed unsuitable for t-PKP, in which the perforation/melting around the perforation was too large to be managed with t-DSEK alone, and an overlying glue patch was deemed unsuitable; which were managed with simultaneous t-DSEK with overlying t-BLT (to provide further support to the underlying t-DSEK as an alternative to an overlying glue patch).

SUBJECTS AND METHODS

Ethical Approval Written informed consent was obtained from the patient for the use of their medical records in writing this case report. The individual patient consent form is available on request. Given the urgent nature of these cases, and considering this option as the option to be offered in patient's best interest (taking into consideration all other ocular and extraocular co-morbidities, as well as social and other related factors), institutional ethics approval was deemed not necessary prior to these operations as it would only delay the necessary care; and after as it is a retrospective study. Nonetheless, patients were informed of all potential surgical options and the rationale for offering combined t-DSEK and t-BLT, and despite of the relative urgency, all patients had a minimum of 24h to think of all options offered (which was the time it took to procure an urgent cornea for surgery). After patient's agreement to this approach, this was appropriately reflected in an informed consent.

This retrospective case series study has been undertaken at the Royal Gwent Hospital, Wales, UK. Three eyes of three patients whom presented *via* eye casualty department with corneal perforations from different aetiologies were included. These three cases were deemed unsuitable for t-PKP for various reasons. The main reasons for such an approach over PKP would mainly be a combination of factors that would render the case of high risk of expulsive haemorrhage if an open–sky PKP was attempted. First, these cases presented with large and/or complex cases of relatively longstanding perforations and a very soft eye. Second, some of these cases presented with a concomitant choroidal detachment. Third, some of these cases presented breathing problems whilst lying flat and were deemed unsuitable for general anaesthesia (GA) making the risk of expulsive haemorrhage even greater. Fourth, some of these cases did not have visual potential, or it was unclear whether they had any visual potential, so the main goal was restoring the eye globe, not necessarily *via* PKP. Further individual details will be disclosed later on in this manuscript. They were therefore scheduled for urgent t-DSEK with simultaneous t-BLT as the closest treatment option to a PKP.

Our technique for manual DSEK graft[2,5] and Bowman layer (BL) graft[6-7] harvest have been previously reported. Briefly, the donor cornea is soaked for 30min in balanced salt solution (BSS), which would thicken the stroma up in order to facilitate tissue dissection for the manual DSEK lenticule harvesting (this tissue swelling is not expected to affect BL). Then, the donor cornea is mounted in an artificial anterior chamber (AC) (Katena) filled in with air. Since two grafts need to be obtained from the same cornea, we first harvested the BL graft, as it doesn't affect the harvesting of the subsequent DSEK graft; while harvesting the DSEK graft first could certainly impair the safe harvesting of the BL graft, as it would involve a limbal deep incision through BL, whereas the first step in BL harvest requires only a superficial scoring.

The epithelium is debrided from the donor cornea with a Weck-Cel sponge, then a superficial scoring with a 30 gauge needle is performed 360 degrees at the periphery. The edges of the scoring mark are then lifted by scraping with the short end of a Morlett spatula (Duckworth and Kent) in order to lift a BL "flap". Then the same scraping manoeuvre is continued 360 degrees. While for previous cases we then switched to a peeling technique with a Moorfields forceps, we recently modified the technique and we now complete the full detachment of the BL graft by scraping with the short end of a Morlett spatula. This results in comparable grafts (based on intraoperative behaviour with the obtention of a Bowman roll) with a much lesser incidence of BL graft tears. The BL graft is then marked with an "F" stamp at the epithelial side, stained with trypan blue (vision blue) and punched to the desired size (8 mm). The graft is finally kept in either BSS or culture medium, forming a Bowman's roll untill the time of implantation.

The remainder donor corneoscleral rim is kept on the artificial AC to harvest the manual DSEK graft. A peripheral 3-4 clock hour 400 μm depth incision with a calibrated diamond blade is performed, then a DSEK graft is manually dissected using the Morlett spatula. Since this graft aims a tectonic purpose, the DSEK lenticule is intentionally thicker than a standard DSEK graft with pure visual purposes. The graft is finally punched to the desired size (in our cases 8.5 mm, but can be tailored to each patient's needs) and kept in culture medium solution till the time of insertion.

We've already described our technique for both t-DSEK and BLT[2,6-7], although in this occasion BLT would be placed as an onlay. Briefly, the t-DSEK can proceed as close to normal fashion in small perforations or perforations plugged with a glue patch. Viscoelastics may be needed to keep a formed AC

in larger perforations. Once the perforation has been plugged by the DSEK, then the t-BLT can proceed as for a standard BLT onlay technique[3], although we'd recommend in this scenario the BLT to be fixed with a running suture.

Follow up visits were performed routinely at 1d, 1wk, 1 and 3mo postoperative, with as many visits in between as deemed necessary for each individual case. Optical coherence tomography (OCT) scans (Heidelberg) were performed whenever deemed necessary.

RESULTS

Case 1 A 79 years old female presented to eye casualty with a herpetic trophic corneal perforation in the left eye. Her past ophthalmic history was cataract in the right eye; and in the left eye a dense white cataract, macular scar, deep amblyopia and previous episodes of herpetic keratitis causing corneal scarring. She refused several times to have an elective PKP with cataract extraction and lens implant as she was aware that the left eye had always very poor visual prognosis.

On presentation, a trophic 2-3 mm corneal perforation with completely shallow AC was seen. There was melting and scarring of the cornea in the 2-3 mm radius surrounding the perforation, hence details of the iris or the lens were not visible. Visual acuity (VA) was perception of light (PL). A glue patch was performed whilst waiting for a donor cornea, in order to perform an urgent t-PKP under GA. Unfortunately the glue patch didn't hold and the eye remained hypotonic for several days until a donor cornea was delivered.

For logistic reasons, the anaesthetic department was not willing to proceed with GA, and the risks of performing such a case under local anaesthesia possessed a theoretically increased risk of expulsive haemorrhage. Hence, this patient was offered a simultaneous t-DSEK and t-BLT from the same donor cornea under local anaesthesia, as the closest option possible to a t-PKP. The procedure (particularly the DSEK part) was technically challenging due to poor intraoperative view and presence of fibrin in the AC. Nonetheless it was performed with our standard DSEK technique[5], with the main difference that the AC was reformed and maintained with viscoelastic substance (Healon 10). The subsequent tectonic BLT was placed on the surface after ensuring de-epithelialisation of host cornea (except for the limbal area) and secured with a 10-0 nylon running suture. The procedure was completed with no adverse events and a bandage contact lens was placed at the end of surgery. After surgery, treatment was started with aciclovir 400 mg 3 time per day (TD), maxitrol hourly, and intense lubrication.

On postoperative day 1 the patient presented with acute angle closure glaucoma. Peripheral laser iridotomies (PIs) failed to resolve the situation and the patient was taken to theatre for a surgical PI. Intraoperative examination revealed seclussio pupillae (not fully visible through the corneal opacity in previous clinic assessments) which resulted in iris bombe, with a second ring of synechiae from the iris to the edge of the DSEK (which again, was not fully visible on slit lamp). A surgical PI was performed as well as breakage of both rings of synechiae, with intraocular pressure (IOP) returning to normal levels. A subsequent persistent epithelial defect, with swelling of the BL graft (resulting in initial equatorial retraction and central thickening of the BL graft), was treated with amniotic membrane transplant (AMT) and allogeneic serum drops. The dosage of oral acivclovir and maxitrol was tailored depending on the evolution of the case. The cornea showed finally full epithelialisation, at which point sutures were removed. AC remained deep, nicely formed, and stable thereafter during the 6mo follow up period. VA improved to hand movements (HM).

Case 2 An 88 years old female presented to eye casualty with a right eye corneal trophic perforation of unknown cause. She had a background of rheumatoid arthritis, however with no signs of dry eye in the fellow eye. She had a past ophthalmic history of bilateral cataract surgery with lens implant several years back. She presented reporting a few weeks history of painless blurred vision, which then evolved into a painful eye a few days before presentation to us.

On presentation there was a central 2 mm corneal perforation with surrounding area of corneal melting. AC was completely flat and the eye was soft. VA was PL. Visualization of AC details was within reasonable limits. It was decided that it would be less invasive to tackle this perforation with t-DSEK[2], nonetheless the larger area of melting could compromise the t-DSEK attachment. A glue patch may have shown difficulty to attach on a rather wet surface. However, opting for a PKP with the uncertainties around the cause of the perforation, would possess additional risks and an uncertain prognosis. Hence a t-DSEK and t-BLT were performed to both plug the corneal perforation as well as provide further tectonic support to the t-DSEK. Both procedures were performed simultaneously under local anaesthetic, with hardly any modifications from our standard thin manual (TM) DSEK[5] and BLT onlay technique (as mentioned for case 1), with no adverse events to report. A bandage contact lens was placed at the end of the procedure. Treatment with aciclovir 400 mg TD, Maxitrol hourly and intense lubrication was started (Figure 1).

One week after surgery there was a persistent epithelial defect as well as a partial DSEK detachment. The partial DSEK detachment involved the perforation area, which remained plugged by the tectonic BLT. The BL graft showed swelling resulting in initial equatorial retraction and central thickening of the BL graft. The AC remained formed and the DSEK detachment was treated with an air injection at the slit lamp.

(Figure 2). Allogeneic serum drops were introduced to the treatment with rather quick resolution of the epithelial defect (at which point sutures were removed). Aciclovir and Maxitrol dosage were tailored depending on the evolution of the case. The patient achieved a well formed globe and remained stable thereafter during the follow up period of 3mo, with VA improving to counting fingers (CF).

Case 3 A 76 years old male presented to eye casualty with a corneal perforation of unknown cause on the left eye. He had previous history of cataract surgery with lens implant to the same left eye a month prior. He had vague on and off symptoms since, and presented to his optician for a routine one-month post cataract surgery check up. At optician's examination, a large area of corneal melting with central corneal perforation was detected, hence an urgent referral to eye casualty.

Examination revealed a central 2 mm perforation with a surrounding area of corneal melting. VA was PL. Screening for autoimmune/rheumatological disorders was negative, hence it was suspected the cause of the perforation to be herpetic. Patient was deemed unfit for GA, plus, with the uncertainties around the cause of the perforation, made the prognosis of a PKP very guarded. A t-DSEK with t-BLT and AMT was performed on an urgent basis. The decision for doing an AMT on the same setting was due to the previous experience of persistent epithelial defects post operatively in the previous two cases. The DSEK surgery was again challenging due to the presence of some anterior synechiae towards the area of the perforation, and increased vitreous pressure with shallow AC throughout surgery. BLT and AMT were performed with no adverse events to report. A bandage contact lens was placed at the end of the procedure. Aciclovir 400 mg TD and Maxitrol hourly were started. The AMT was dislodged on day 7, and the membrane was resutured in theatre. Allogeneic serum drops 6 times per day were requested and started as soon as they were available, which took a few weeks.

The DSEK graft was almost fully attached except for a small area superiorly of partial detachment. The BLT graft remained properly positioned initially, however later on showed shrinking in the equatorial diameter with increase in central thickness, along with a few pockets of fluid within the interface, resembling a post-laser *in situ* keratomileusis (LASIK) fluid interface syndrome. This was treated with latanoprost 0.05% OD, with final resolution of the fluid pockets (Figure 3). The eye showed then a nicely formed AC with tectonic restoration of the globe. The eye remained stable for 3mo, at which point the patient decided not to come for further follow up as he felt the eye was comfortable. VA improved to CF. We continue liaising with patient's local optometrist who reported a stable eye and patient still reporting a comfortable eye.

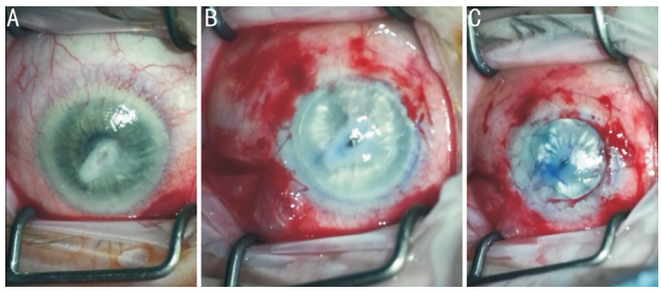

Figure 1 Intraoperative images A: Perforation on presentation; B: Immediately after tectonic DSEK; C: Immediately after tectonic BLT. DSEK: Descemet stripping endothelial keratoplasty; BLT: Bowman layer transplant.

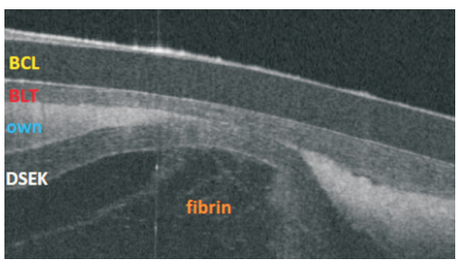

Figure 2 Corneal OCT following tectonic DSEK and tectonic BLT Note uneven graft thickening adapting in a "lock and key" fashion with underlying irregularities (possibly due to tissue expansion and new collagen formation). Own: Patient's own host stroma; DSEK: Tectonic DSEK tissue; Fibrin: Fibrin in the AC; BCL: Bandage contact lens; OCT: Optical coherence tomography; DSEK: Descemet stripping endothelial keratoplasty; BLT: Bowman layer transplant; AC: Anterior chamber.

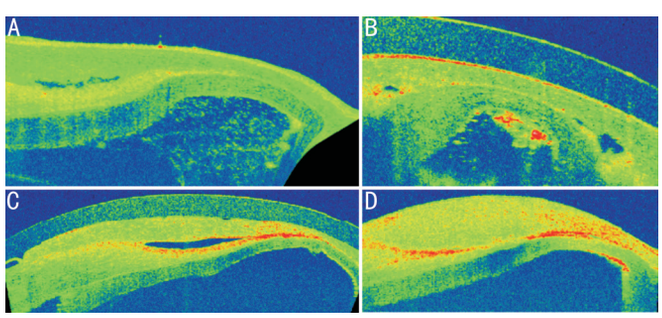

Figure 3 Serial OCT monitoring of early postoperative period A: 1wk postoperative OCT showing DSEK attachment and overlying BL graft with fibrin in the AC and a small pocket of fluid; B: 1mo postoperative with additional pocket of fluid forming; C: Equatorial shrinking with anterior to posterior expansion of BLT graft, with enlargement of fluid pocket, resembling fluid interface syndrome (approx. 2mo after surgery); D: Further equatorial shrinking and anterior to posterior tissue expansion alongside "adaptation" of BL graft to underlying stromal tissue, possibly a combination of tissue expansion and collagen neoformation. Resolution of fluid pockets after introduction of latanoprost 0.05% OD. OCT: Optical coherence tomography; DSEK: Descemet stripping endothelial keratoplasty; BL: Bowman layer; BLT: Bowman layer transplant; AC: Anterior chamber.

In summary, three cases showed some common features. Epithelialisation represents a significant challenge, which

can result in swelling of the BLT graft. In the early stages this seems to lead to shrinking of the equatorial diameter of the graft with increase on its central thickness, which can be a combination of both tissue swelling and tissue expansion. The BL graft tends to adjust to the underlying irregularities in a "lock and key" fashion, possibly reflecting tissue expansion and new collagen formation (Figures 2 and 3). The BL graft may partially thin when full epithelialization is achieved. Reinterventions are likely to be needed (AMT for epithelial defects (2 cases), DSEK rebubbling (one case) or acute angle closure glaucoma (one case). Still, the three cases showed tectonic restoration of the globe with expected quicker healing and potentially less postoperative complications than that of a PKP for the same cases.

DISCUSSION

Corneal perforations are still an eye emergency that needs prompt action in order to save the eye globe, and whenever possible, useful vision[1]. Traditional approaches may vary depending on the size and location of the perforation. They may also vary depending on whether the goal of surgery is just a tectonic repair, or whether there is also an intention to optimize final visual outcome. These include temporary measures, such as glue patches; and more permanent solutions such as AMTs, scleral or pericardium patches, conjunctival flaps, and corneal grafts (mainly PKP). Any of these solutions may provide tectonic restoration of the eyeball, being the latter the option of choice for larger perforations and/or cases with good visual potential.

We recently reported the outcomes of a case series of corneal perforations of different sizes and locations that were managed with a tectonic manual DSEK (for some cases, supported with a glue patch on the superficial side of the perforation)[2]. Further iterations to this treatment have also been described in the form of tectonic mini-Descemet stripping automated endothelial keratoplasty (DSAEK)[8]. Cases with peripheral perforations may have a better visual prognosis compared to central ones, as the surface irregularity and scarring that remains in the central/paracentral corneal perforations leave a severe impact on final visual outcome. For larger perforations, a glue patch may be required to help keep the t-DSEK graft in place. However, a glue patch is not always possible even when required, if the area of perforation and/or surrounding melting is large enough to compromise its attachment.

By combining the principles of t-DSEK for the management of corneal perforations, and providing with tectonic support *via* simultaneous t-BLT, we treated 3 cases of corneal perforation. For patients in whom a tectonic PKP would be deemed high risk, the t-DSEK would serve as a very valid option to tackle the perforation[2]; and an overlying BLT would serve for numerous purposes. First, it would provide further tectonic support[9] for the t-DSEK with biological tissue, rather than with a glue patch. Second, in cases of perforation due to trophic corneas, there is usually progressive thinning of the host cornea around the perforation, leaving a "sinkhole" appearance, with a larger defect in stromal tissue than the size of the perforation itself. Whereas usually, following t-DSEK alone, it would result in this gap being filled in by epithelial cells[10], in this case series the stromal tissue defect would be replaced by BL tissue (or BL and underlying new collagen formation), resembling more of a normal corneal anatomy (Figure 2). Third, this would be much closer to a PKP for selected cases in which PKP would still be the option of choice, however not possible to be performed due to other ocular or non-ocular reasons (high risk of expulsive haemorrhage, co-morbidities, logistics, *etc*). Fourth, it results in optimization of donor tissue utilisation. Fifth, it doesn't represent an increased risk of rejection compared to t-DSEK alone or tectonic PKP, since BL is acellular. Sixth, it doesn't (in theory) slow down the healing process, as this would be dictated by the healing time of DSEK, which is longer than that of a BLT. Seventh, BL is tectonically far more robust than the deeper layers used for DSEK. In fact, in our first case that resulted in acute angle closure, it was visible how the DSEK graft was being "squeezed" through the perforation, only held in place by the robust overlying t-BLT. Furthermore, the advantages of combining t-DSEK with t-BLT instead of doing a PKP or a combination of t-DSEK with tectonic DALK (t-DALK) or patch graft are the following:

1) It seems not to be possible to simultaneously combine t-DSEK and t-DALK in the same procedure, as the DSEK would't have a scaffold to attach to, but rather it would need to be in two separate stages, with two separate donor corneas. Between the first step (t-DSEK) and second step (t-DALK) a glue patch or similar would need to be applied, and it's been discussed how it was deemed that supporting the DSEK with a glue patch in these cases was thought to probably be ineffective.

2) A patch graft, whereas tectonically sound, wouldn't provide with an equally anatomical layer by layer substitute of corneal tissue. Whereas in our cases postoperative vision was not a primary drive for the decision, it is possible that other cases with greater visual potential may benefit from this option mora than froma glue patch.

3) This approach addresses the risk of expulsive haemorrhage posed by a PKP.

A criticism to this approach is that final VA was not better than that expected from our report with t-DSEK alone[2], nonetheless some of these cases presented with areas of perforation/necrosis large enough to suspect that a DSEK alone would have not been enough for tectonic restoration of the globe.

Moreover, in the first case with high pressure, the tectonic BL helped to keep a sealed AC. Also, in the second case, it kept a formed AC despite of a partial DSEK detachment (which included the area of the perforation) facilitating a rebubbling at the slit lamp.

In conclusion, we think this case series supports the idea that a simultaneous t-DSEK and t-BLT from the same donor cornea is a useful alternative to an emergency PKP for corneal perforations in selected cases where t-PKP is not considered the ideal initial approach. Additional studies would be required to support this hypothesis.

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