Mid-stromal lamellar keratoplasty (MSLK) offers a new approach to the management of advanced keratoconus that can bypass some of the problems other techniques present.
Bowman + Bulk = Better Results

Mid-stromal lamellar keratoplasty (MSLK) is a new surgical technique for the management of advanced keratoconus

By Mohammad Khan, Jonathan Martin, Priscilla Mathewson and Sunil Shah

There are several ways to treat keratoconus today, but none are perfect – each approach comes with drawbacks or limitations. Take corneal collagen cross-linking, which has revolutionized the field because of its ability to strengthen the cornea and slow progression (1) – and even flatten it slightly (2). But it’s never going to restore the corneal architecture, so your patients’ often highly debilitating visual symptoms remain.

You do have a number of strategies available to improve your patients’ visual acuity (VA), starting with spectacle correction and moving onto rigid gas permeable contact lenses (RGPCL), intra-corneal ring (ICR) segments and phakic toric intraocular lenses (IOLs) (2). But again, there are drawbacks: people can become RGPCL-intolerant, ICR segments flatten the mid-periphery and have a variable effect (especially if the ectasia is primarily central), and phakic IOLs only correct regular astigmatism.

In more advanced disease (or in cases of RGPCL intolerance), you then have to consider penetrating keratoplasty (PK) or deep anterior lamellar keratoplasty (DALK) – but this approach sacrifices the majority of the host cornea. Other older keratoplasty techniques have fallen out of favor – but keratoplasty for the treatment of corneal ectatic disorders, such as keratoconus, is an area of intense research. For example, Gerrit Melles’ team has recently described Bowman’s layer transplantation (3), which involves the isolation and detachment of Bowman’s layer from the anterior stroma of a donor cornea and transplantation into a manually created mid-stromal section.
pocket. Why? Histopathological studies have indicated that Bowman’s layer fragmentation contributes to the progression and visual debilitation of keratoconus (4), so its replacement is a logical therapeutic approach.

However, the fragmentation of Bowman’s layer is a late and secondary phenomenon in keratoconus, and there’s little or no established correlation between its fragmentation and reductions in VA (5). Replacement tissue will restore some of the original shape of the cornea, but it does not address the primary problem of apical stromal thinning – one of the biggest contributors to the corneal protrusion and irregular astigmatism present in keratoconus. Histopathological studies have shown that this stromal thinning is caused by a significant increase in the diameter of the collagen fibrils in the stroma and their interfibrillary distance (6), alongside a reduction in their number (7).

In theory, a procedure involving an intrastromal lamellar graft would, therefore, be expected to not only increase the central corneal bulk and thickness but also flatten the corneal architecture to a greater extent than Bowman’s layer transplantation – thereby reducing the need for more conventional grafts such as DALK or PK.

We report the first case of a novel surgical approach in the form of a mid-stromal lamellar graft assisted by collagen cross-linking for the management of advanced keratoconus. Whilst small incision lenticule extraction with cross-linking has been used for the treatment of keratoconus (8) this is the first report, to our knowledge, of an intrastromal lenticule being implanted to restore the stromal architecture in a keratoconic cornea.

<table>
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<th>Pre-op</th>
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<td>09</td>
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Table 1. Key corneal parameter assessments, pre- and post-operatively (up to four weeks’ follow-up). UCVA; uncorrected visual acuity. BCVA; best corrected visual acuity. CCT; central corneal thickness. IOP; intra-ocular pressure. GAT; Goldmann applanation tonometry.

Methods

Our patient was a 28 year old with advanced keratoconus and RGPCL intolerance. Following informed consent, a number of preoperative measurements were obtained including pachymetry, topography, anterior segment OCT (AS-OCT), and intraocular pressure measurements with Goldmann applanation tonometry and iCare tonometry.

The lamellar graft/lenticule was prepared with a Gebauer SLc Expert microkeratome system. This keratome, plus the use of a pre-shaped base, allowed precise cuts of defined thickness and a pre-defined shape to be made. This permitted the definition of two separate parameters: for this patient, a thickness of 100 µm with a 7 mm diameter, and a planar rather than concave or convex shape was chosen.

An anterior chamber paracentesis was created at 9 o’clock and air was injected following aqueous aspiration. A 7 mm superior limbal incision was fashioned to a depth of 250 µm and a mid-stromal pocket was then created manually using the dissection technique previously described for DALK (9), encompassing a
The lamellar graft was guided into the stromal pocket with an anterior chamber IOL surgical glide and positioned with a Rycroft anterior chamber cannula. Cross-linking was performed by immersing the intrastromal pocket (and graft) in riboflavin for 10 minutes followed by ultraviolet light exposure (9 mW) over a 9 minute period.

Post-operative anterior segment photographs, AS-OCT images, and topography are highlighted in Figures 1–3.

Results

Post-operatively, there was a significant reduction in topographic cylinder over four weeks and an increase in central corneal thickness of about 100 µm. The AS-OCT images show a well-positioned, mid-stromal lamellar graft (Figure 1). There is evidence of interface fluid, which would be expected to resolve with time and thereby improve contact and regularity between the graft and host surfaces, and this should aid further visual recovery. Table 1 details the patient's pre- and post-operative results up to four weeks of follow-up.

Discussion

Our technique theoretically confers a number of advantages over Bowman's layer transplantation. First, the 100 µm planar lamellar button resting intrastromally would be expected to provide more strength, bulk and flattening of the corneal architecture than Bowman's layer alone (which is approximately 17 µm thick (10)). In Bowman’s layer transplantation, the preparation of the graft involves manual dissection of Bowman’s layer with a 30-gauge needle and a custom-made stripping device as well as McPherson’s forceps. Given the delicate nature of Bowman's layer, it is not surprising that tearing of the graft is a significant problem during preparation – this affects almost 30 percent of all grafts harvested (11). Due to its elasticity, Bowman’s layer also tends to roll up and needs to be unfolded manually within the stromal pocket, putting the graft at further risk of damage (11). The lenticule used in our technique is much thicker (100 µm) and is prepared using an automated microkeratome. It also includes Bowman’s layer within the lenticule, so it may have the benefits of
Bowman’s layer transplantation, plus added bulk. In theory, this should make it less likely to be damaged during harvest.

Our mid-stromal lamellar keratoplasty (MSLK) procedure has the advantage of being less technically challenging than Bowman’s layer transplantation and therefore is likely to have a more favorable learning curve – for example, it uses a microkeratome system to dissect the donor tissue, and only the host corneal pocket is created manually. There’s another potential advantage to using a microkeratome when performing the graft dissection – in DSEK, VA recovery is reported to be faster than when manual graft dissection is performed (12), likely secondary to a more irregular interface between the host and graft that’s created in manual dissection (13). The procedure may be improved further by femtosecond laser creation of the pocket.

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The relative absence of sutures (when compared with other techniques such as DALK and PK) means that MSLK is relatively less time-consuming: this first case took 45 minutes to complete.

There are a number of potential limitations of this technique, like intraoperative perforation of Descemet’s membrane, as has been reported with Bowman’s layer transplantation (3). It is likely that patients with a very thin cornea could be ineligible for MSLK as the risk of perforation may be high. However, the procedure could still be attempted and converted to a different form of keratoplasty if a perforation occurred, as in DALK. In addition, the procedure could be completed even in the presence of a perforation. A DALK or PK is likely to be advantageous in cases of significant corneal scarring involving the visual axis.

Conclusion

There are many methods by which keratoconus can be treated – but all have drawbacks associated with their use. Recent years have seen some innovative keratoplasty approaches that aim to minimize these drawbacks, and MSLK, it is hoped, offers an exciting way forward for the management of keratoconus, with fewer drawbacks and compromises than the Bowman’s layer transplantation approach – and might offer a viable alternative to DALK or PK.

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References