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ORIGINAL PAPER

"Double bubble" deep anterior lamellar keratoplasty for management of corneal stromal pathologies

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Abstract 'Big Bubble' deep anterior lamellar keratoplasty (DALK) is becoming an accepted corneal transplantation technique for keratoconus and other anterior stromal corneal pathologies that spare the Descemet's membrane (DM) and endothelium. However, it is not always possible to conclusively recognise formation and identification of the 'Big Bubble'. We describe the surgical technique of DALK called 'Double Bubble' technique that allows the surgeon to definitely and immediately identify the formation of an adequate big bubble. DALK was performed using the 'Double Bubble' technique in twelve eyes of twelve patients with corneal stromal pathologies (keratoconus, 9 eyes; macular corneal dystrophy, 2 eyes; postinfectious keratitis corneal stromal scar, 1 eye) at the Royal Victorian Eye and Ear Hospital, Melbourne. Big bubble was successfully formed in 10 eyes. Maximum-depth deep lamellar keratoplasty was performed in two eyes. There were no instances of intraoperative perforation of the DM. All grafts were clear at last follow-up. Best-corrected visual acuity of $\geq$20/40 was achieved in all the cases at last follow-up (6–12 months). 'Double Bubble' DALK helps in identification of the big bubble and has the potential to increase the success of standard 'Big Bubble' DALK in patients with corneal stromal pathologies sparing the DM and endothelium.

Keywords Double Bubble deep anterior lamellar keratoplasty · Big Bubble deep anterior lamellar keratoplasty · Deep anterior lamellar keratoplasty · Deep lamellar keratoplasty · Lamellar keratoplasty · Keratoplasty

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Introduction

'Big Bubble' deep anterior lamellar keratoplasty (DALK) is becoming an accepted corneal transplantation technique for keratoconus and other stromal corneal pathologies that spare the Descemet's membrane (DM) and endothelium [1–7]. However, the technique has a learning curve, related to formation

and identification of the 'Big Bubble', and this encourages modifications to the original technique. We describe the technique of 'Double Bubble' DALK that allows the surgeon to definitely and immediately identify the formation of an adequate big bubble.

Methods

Surgical technique

DALK was performed in twelve eyes of twelve patients with corneal stromal pathologies and normal DM and endothelium, using the 'Double Bubble' technique [8]. Cases with healed corneal hydrops and DM scars were excluded. A written and informed consent was obtained from all the patients prior to surgery. The study was approved by the Institutional Review Board of the Royal Victorian Eye and Ear hospital, Melbourne and adhered to the tenets of Declaration of Helsinki.

A Hessburg Barron suction trephine (JedMed Instrument Co, St. Louis, MO, USA) was used to perform partial-thickness trephination of the host cornea to an approximate depth of 60–70% of the corneal thickness. A self-sealing paracentesis wound was created with a 15° surgical blade (Alcon Surgical, Fort Worth, TX, USA), just posterior to the limbus at 11 o'clock, and some aqueous humor was expressed. Subsequently, a small amount of air (first bubble) of 3–4 mm in diameter and 0.08–0.1 cm^3 in volume was injected into the anterior chamber (AC) through the same paracentesis wound using a Rycroft cannula (Figs. 1a, 2a).

A 27-gauge disposable needle attached to a 2 cm^3 syringe containing sterile air was then used to perform the injection of air into the corneal stroma (second bubble). This needle was bent at an angle of about 70° close to its base in a direction away from the bevel. The needle tip, with the bevel facing down, was then advanced tangentially into the paracentral corneal stromal tissue at a depth of 60–70% through the previously created partial trephination wound (Fig. 2b). Under direct visual control, the needle was advanced horizontally into the corneal stroma and air was then injected gradually into the stroma to form the big bubble. Air was injected until peripheral movement of the bubble of air injected earlier into the AC was noted (Figs. 1b, 2c). This dynamic sign allowed us to immediately cease the injection of air into the cornea, as it was indicative of complete formation of the big bubble (second bubble) in the supra-Descemet's space.

The next step was to de-bulk the anterior two-thirds of the corneal stroma leaving a thin layer of posterior corneal stroma underneath (Fig. 1c). A 15° blade (Alcon Surgical) stained with gentian violet was used to create a shelved opening into the potential space between the DM and posterior stroma (Fig. 1d). Entry into this space was easily identified by the dynamic movement of the first bubble from the periphery of the AC back to the center of the AC (Fig. 1e). At this point, the incision was immediately discontinued and 2% hydroxypropyl methylcellulose was injected through the opening into the potential space to clearly delineate it (Fig. 1f). A pair of blunt-tipped curved Vannas scissors was used to divide the thin layer of posterior corneal stromal tissue into four quadrants (Fig. 1g), and each quadrant was subsequently excised, baring the DM completely (Fig. 1h). During the surgery, the air bubble initially injected into the AC was allowed to remain in the AC.

A 0.25-mm oversized donor lenticule was punched from the endothelial side and its DM was removed after staining with 0.06% trypan blue dye. The hydroxypropyl methylcellulose overlying the bare DM of the host cornea was washed away with balanced salt solution, and the donor lenticule was secured with 16 10–0 monofilament nylon interrupted sutures (Fig. 1i). The small air bubble injected initially into the AC was allowed to remain and the limbal wound was hydrated to seal it completely (see video file in supplementary material).

Results

The 'Double Bubble' DALK was attempted in twelve eyes of twelve patients. Indications for surgery were keratoconus (9 eyes), macular corneal dystrophy (2 eyes) and postinfectious keratitis corneal stromal scar (1 eye). Big bubble was successfully formed in 10 eyes. The dynamic shift of the first bubble in the AC helped us to recognize the adequate formation of the big bubble (second bubble). We did not observe this sign after the injection of the second bubble in two

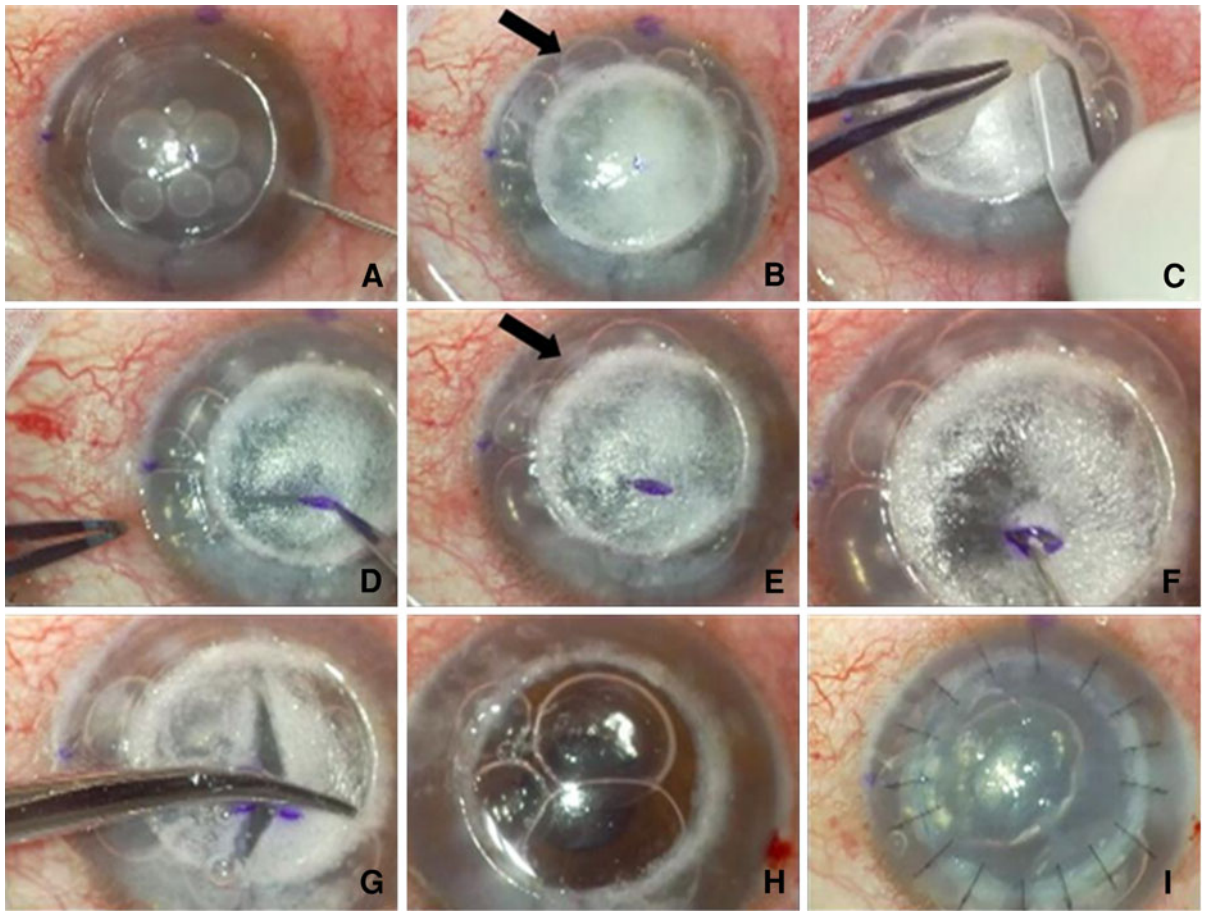

Fig. 1 Surgical steps of 'Double Bubble' deep anterior lamellar keratoplasty. Small amount of air (first bubble) was injected into the anterior chamber through the paracentesis (**a**); peripheral movement of the first bubble of air within the anterior chamber was noted after injection of big (second) air bubble (*arrow*) (**b**); debulking of corneal stroma (**c**); a 15° blade stained with gentian violet was used to enter into the potential space between the Descemet's membrane and posterior stroma (**d**); dynamic movement of the first bubble to the center of the anterior chamber after collapse of the big bubble was noted (*arrow*) (**e**); 2% hydroxypropyl methylcellulose was injected through the opening (**f**); quadratic excision of the posterior corneal stroma was performed (**g**); baring of the Descemet's membrane (**h**); donor lenticule was sutured on to the host (**i**)

cases with keratoconus. Subsequent corneal stromal debulking was performed in these cases followed by a repeat injection of air into the corneal stroma through a clear part of the cornea. The big bubble was not achieved and ultimately a maximum-depth deep lamellar keratoplasty was performed in these cases. There were no instances of intraoperative DM perforation. None of the cases were converted to penetrating keratoplasty. Postoperatively, all grafts were clear until the last follow-up (6–12 months). A final best-corrected visual acuity of ≥20/40 was achieved in all cases at the last follow-up (6–12 months) (Fig. 3a–f). Both cases with maximum-depth deep lamellar keratoplasty had a best-corrected visual acuity of 20/40 at the last follow-up.

Discussion

Since its conception, 'Big Bubble' DALK has been increasingly performed by corneal surgeons for the treatment of stromal corneal pathologies sparing the corneal endothelium. The technique is performed most commonly to treat cases of keratoconus [2]. Due to the obvious advantages of the technique, its range of indications continues to expand [1–7].

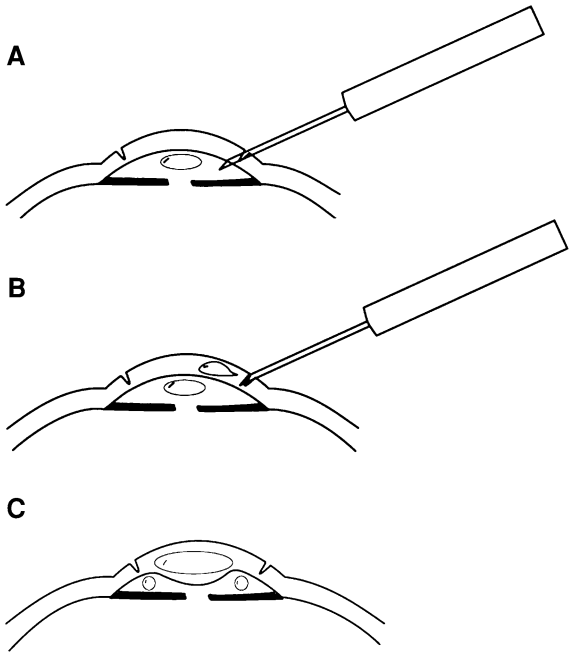

Fig. 2 Schematic diagram depicting the injection of first bubble into the anterior chamber through the paracentesis wound using a Rycroft cannula (**a**); injection of air into the corneal stroma using a 27-gauge needle tip inserted at a depth of 60–70% (**b**); movement of the first bubble of air towards the periphery of the anterior chamber, and inward bulging of the Descemet's membrane after the air injection into the corneal stroma (**c**)

Melles [9] and Anwar [10] have described the two major techniques of DALK. Of these, Anwar's technique of air injection to bare the DM is more popular due to the advantage of reduced surgical duration and complete baring of DM [11]. However, the 'Big Bubble' technique of DALK is associated with some intraoperative difficulties, particularly related to those associated with the formation and identification of big bubble formation in the potential space between the corneal stroma and DM. In our experience, the two major problems with 'Big Bubble' DALK have been the confirmation of formation and the instantaneous recognition of an adequate big bubble.

Teichmann and Anwar [10] described several signs to help the surgeon ascertain the presence of a big bubble. Firstly, blanching of the corneal stroma spreads in a wave-like circular fashion with the injection of a big bubble. Secondly, a completed bubble frequently exhibits a feathery white band at its circular periphery. Thirdly, the anterior surface of the cornea bulges after the bubble takes up space in the central cornea. Although these signs may help to confirm the presence of the big bubble, sometimes the identification is doubtful due to corneal emphysema and difficult visualization of the AC through an opaque central corneal disc.

In order to make this technique more successful and reproducible, corneal surgeons have proposed some modifications to the standard surgical technique. In these modifications, a small air bubble is injected into the AC after the injection of air into the cornea to form the big bubble [12–14]. The formation of the big bubble is identified by the confinement of the small bubble to the periphery of the AC and its lack of movement across the AC. Foroutan et al. [14] described the 'shifting bubble sign'. This is a description of a small bubble of air, injected into the AC after the injection of air into the cornea, moving to the center of the AC upon anterior decompression of the big bubble. Our technique differs from these modifications of Anwar's 'Big Bubble' technique. In our technique of 'Double Bubble' DALK, a small amount of air is injected into the AC before the injection of air into the corneal stroma. As soon as a big bubble is formed, there is a sudden peripheral movement of this 'first bubble' from the center of the AC due to the inward bulging of the DM (Fig. 2c). Being a dynamic sign, this sudden movement of the air bubble is easily appreciated by the surgeon. If the first bubble does not move towards the periphery of the AC after the injection of air into the cornea, this indicates that the DM is not bulging into the AC and that the big bubble has not formed. In such situations, a re-injection of air may be performed from a clear part of the cornea, with or without first debulking the anterior corneal stroma.

The 'Small Bubble' techniques previously described [12–14] have been developed to test the adequacy of the big bubble, only after the air has already been injected into the cornea. In our technique, the big bubble formation is recognized as soon as it occurs, allowing a 'real-time' evaluation. Moreover, the immediate recognition of the formation of the big bubble is advantageous as it prevents injecting too much air into the cornea. We have had cases in which failure to recognize the formation of the big bubble, and consequent continuous air injection, have led to perforation of the DM. Another possible advantage of our technique is that decompression of the AC prior to the air injection in the stroma allows space for the DM to bulge inward on formation of the big bubble.

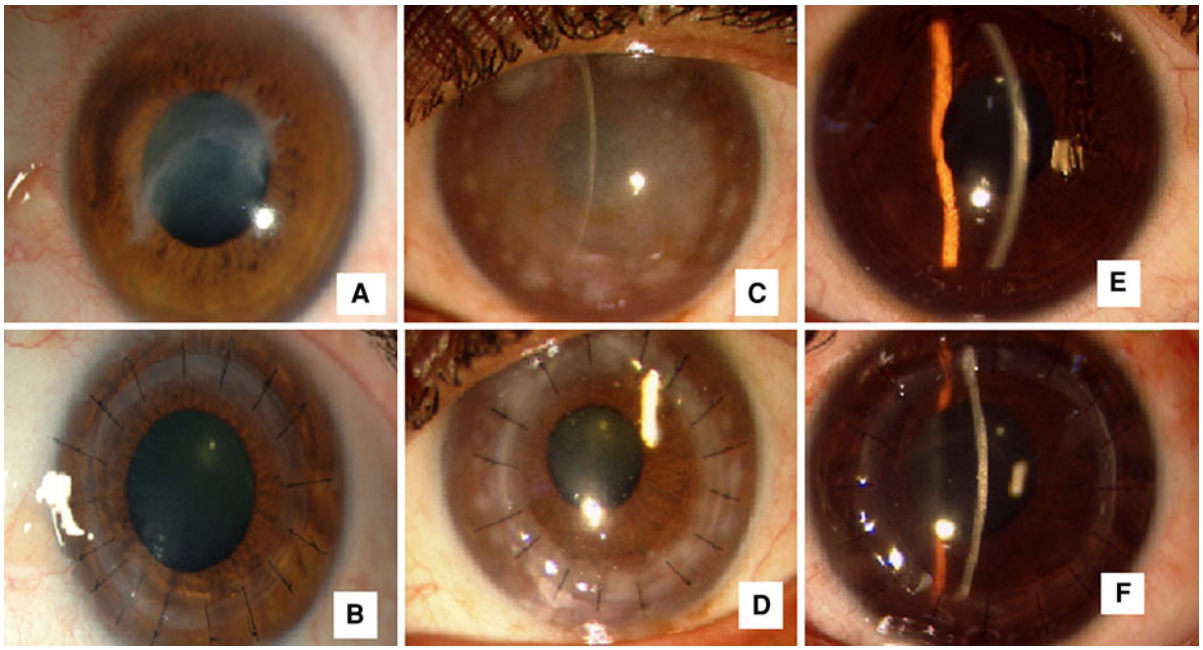

Fig. 3 Slit-lamp photographs showing the results of 'Double Bubble' deep anterior lamellar keratoplasty in cases with postinfectious keratitis corneal stromal scar preoperatively (**a**) and postoperatively after 3 months (**b**); macular corneal dystrophy preoperatively (**c**) and postoperatively after 4 months (**d**); keratoconus preoperatively (**e**) and postoperatively after 4 months (**f**)

We could not achieve a big bubble in two out of 12 cases. The first bubble did not move to the periphery of the AC after the injection of second bubble. Repeat air injection was performed after corneal debulking while observing the movement of the first bubble inside the AC. Since we could not achieve a big bubble in these cases, a maximum-depth deep lamellar keratoplasty was successfully performed without any difficulty.

We accept that there is a theoretical risk of hypotony and possible difficulty in lamellar corneal dissection with performing a paracentesis before injecting air into the corneal stroma, as described in the 'double bubble' technique. However, we did not encounter any such problem in our cases.

Conflict of interest The authors have no conflicts of interest to disclose.

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