Deep Anterior Lamellar Keratoplasty Using the Big-Bubble Technique in Keratoconus

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Purpose: To evaluate the visual outcomes and complications of deep anterior lamellar keratoplasty (DALK) using the big-bubble technique in patients with keratoconus.

Methods: In this case series, 104 eyes of 99 patients with moderate to advanced keratoconus underwent DALK. All subjects were contact lens intolerant or had unacceptable spectacle-corrected visual acuity. DALK was performed using the big-bubble technique. Full thickness donor corneas devoid of Descemet’s membrane (DM) were sutured to the recipient bed. Best spectacle-corrected visual acuity (BSCVA), refractive status, and intra- and postoperative complications were evaluated.

Results: Patients were male in 62.5%. Mean age of patients was 26.2±7.79 (range 15-46) years at the time of DALK and were followed for 23.07±8.1 (range 9-42) months. Mean BSCVA increased from 1.23±0.4 logMAR to 0.26±0.2 logMAR at final follow-up (P<0.001). Postoperative mean spherical equivalent refractive error and refractive and keratometric astigmatism were -3.41±3.1 D, 3.07±2.4 D, and 3.64±2.2 D, respectively. Bared DM was achieved in 86 (82.7%) eyes. Main complications encountered included filamentary keratitis (19.2%), non-endothelial graft rejection (14.4%), and suture abscess (10.6%).

Conclusions: DALK using the big-bubble technique appears to be a safe and effective procedure in patients with keratoconus.

Key words: Keratoconus; Keratoplasty, Deep Anterior Lamellar

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INTRODUCTION

Deep anterior lamellar keratoplasty (DALK) is an alternative procedure to penetrating keratoplasty (PKP) for corneal pathologies not affecting the endothelium and Descemet’s membrane (DM). Advantages of DALK over PKP include elimination of endothelial graft rejection, reduction of graft failure, better preservation of globe integrity in case of blunt trauma, faster visual rehabilitation and longer graft survival due to lower rates of endothelial cell loss. However, DALK is a time-consuming and technically demanding procedure. Additionally, light scattering at the host-donor interface is a potential cause of suboptimal vision following DALK. Compared with manual dissection, the injection of air or viscoelastic into the deep corneal stroma in DALK makes separation of DM from the stroma much easier and leaves a smoother and more uniform host-donor interface thereby reducing complications encountered with conventional lamellar keratoplasty such as interface opacity.
Herein, we report the results of DALK using the big-bubble technique in a large series of patients with keratoconus.

METHODS

In this retrospective case series, data related to patients who had undergone DALK for moderate to advanced keratoconus in a private practice setting from January 2003 to December 2007 were analyzed. Keratoconus was diagnosed clinically based on slitlamp findings (stromal thinning, Fleischer ring, Vogt’s striae) and keratometry, and was confirmed by corneal topography. Inclusion criteria were moderate to advanced keratoconus with poor spectacle-corrected visual acuity, rigid gas-permeable contact lens intolerance, or inappropriate contact lens fit. Exclusion criteria included the co-existence of other pathologies such as Fuchs’ endothelial dystrophy or active vernal keratoconjunctivitis (VKC) and the presence or history of acute hydrops as well as the presence of cataracts, retinal disorders, and glaucoma.

Preoperative evaluations included uncorrected visual acuity (UCVA), manifest refraction (when possible), best spectacle-corrected visual acuity (BSCVA), slitlamp biomicroscopy, tonometry, dilated funduscopy, corneal topography (TMS-1 Topographic Modeling System, version 1.61; Computed Anatomy Inc., USA), optical corneal pachymetry (Orbscan II, Bausch & Lomb, USA) and vitreous length measurement using A-scan sonography (A/B scan; Sonomed Inc., USA).

All patients were operated on by one anterior segment surgeon (MAJ) under general anesthesia using the big-bubble technique as described by Anwar and Teichmann. The diameter of trephination was chosen according to the size of the cone and vertical corneal diameter. After trephination to approximately 80% of corneal thickness with a Hessburg-Barron suction trephine (Katena, Denville, USA), a 27-gauge needle, attached to a 5-cc syringe, bent at 100 degrees (bevel facing downward) was inserted into the stroma up to the center of the cornea. Air was injected gently into the mid-stroma until a big-bubble was formed extending to the border of trephination. If the big-bubble was not formed after the first attempt, the injection was repeated until the big-bubble was formed or failed.

After big-bubble formation, debulking of the anterior two-thirds of the corneal stroma was performed with a crescent blade (Alcon Laboratories, Forth Worth, Texas, USA). Thereafter, a peripheral paracentesis was done to reduce intraocular pressure, the bubble was punctured with a 15° slit-knife (Alcon Laboratories, Forth Worth, Texas, USA) to allow escape of the air and collapse of the bubble. Viscoelastic material (Coatel, Bausch & Lomb, Waterford, Ireland) was injected to keep Descemet’s membrane away from manipulations. Vannas scissors were used to divide the rest of the corneal stroma into four quadrants and each quadrant was completely excised using left and right transplantation scissors taking care not to leave any posterior lip. The viscoelastic material was then completely washed out before proceeding to graft suturing. In cases where a big-bubble could not be accomplished after several attempts, manual stromal dissection down to DM was performed using a crescent knife (pre-Descemet group). If DM perforation occurred and was large enough to preclude lamellar keratoplasty, the procedure was converted to PKP. Data related to these eyes were analyzed separately.

The donor cornea was punched from the endothelial side using the Barron punch (Katena, Denville, New Jersey, USA). The donor was oversized by 0.25 mm for vitreous length ≥16 mm and by 0.5 mm for vitreous length <16 mm. Donor DM and endothelium were gently stripped off with a dry cellulose sponge or forceps. The donor cornea was initially fixed with 4 cardinal 10-0 nylon sutures (Sharpoint, Angiotech, USA) at 3, 6, 9, and 12 clock hour positions. Three different suturing techniques were employed based on surgeon’s preference and co-existing conditions such as peripheral corneal vascularization and history of VKC. These consisted of 16 interrupted sutures, a single running suture with 16 to 18 bites, or a combined technique (8 interrupted sutures accompanied by a single 16-bite running suture). With all suturing techniques, the suture bites encompassed approximately 90%
thickness of the recipient and donor tissues. Intraoperative keratoscopy was performed to adjust suture tension. At the conclusion of surgery, cefazolin 100 mg and betamethasone 4 mg were injected subconjunctivally.

Patients received topical sulfacetamide 10% drops every 6 hours for 30 days and topical betamethasone 0.1% every 6 hours tapered over 2 to 3 months. If indicated, sodium chloride 5% drops were prescribed to reduce graft edema and filamentary keratitis and topical lubricants were administered to hasten epithelial healing. In intractable cases, other interventions such as bandage contact lens fitting (OmniFlex, Hydron, UK) and temporary blepharorrhaphy were done to treat non-healing epithelial defects. Follow-up examinations were scheduled 1, 3, 7 and 30 days and 3, 6, and 12 months postoperatively and at least every 3 months until complete suture removal, and 6 months thereafter.

UVCA, BSCVA, manifest refraction, and keratometric astigmatism as well as intra- and postoperative complications or secondary interventions (such as resuturing) were evaluated. When more than one procedure was required (such as resuturing), the final results were considered for analysis. Paired t-test was used to compare pre- and postoperative keratometric and BSCVA values and Chi-square test was used for comparison of qualitative parameters. Significance level was set at 0.05.

RESULTS

One-hundred and seven eyes of 99 (62 male) patients with keratoconus were operated. A big-bubble was formed in 86 (80.4%) eyes, while 18 (16.8%) eyes underwent pre-Descemet’s dissection. In 3 (2.8%) eyes the procedure was converted into PKP intraoperatively, therefore data of 104 eyes were included for analysis (Table 1). Mean age at the time of surgery was 26.2±7.8 (range 15-46) years and mean follow-up period was 23.1±8.1 (range 9-42) months. Corneal scarring with variable extension into the corneal stroma was observed on slitlamp examination in 31 (29.8%) eyes. Recipient trephination size was 7.5 to 8.0 mm. Mean time from surgery to initiation and completion of suture removal was 6.8±5.3 (range 0.5-24) and 14.7±5.5 (range 5-27) months, respectively.

Mean preoperative UCVA was 1.38±0.3 (range 0.6-2.0) logMAR (equivalent to 20/500) which increased to 0.67±0.4 (range 0.1-1.5) logMAR (equivalent to 20/100) at final examination (P<0.001). Mean preoperative BSCVA was 1.23±0.4 (range 0.0-2.0) logMAR (equivalent to 20/400) which was improved to 0.26±0.2 (range 0.0-1.4) logMAR (equivalent to 20/40) at final follow-up (P<0.001). UCVA ≥ 20/200 and BCVA ≥ 20/40 were respectively seen in 17% and 1% of eyes preoperatively, but in 86.5% and 77.6% of eyes after the operation (P<0.001).

In 77 eyes for which corneal curvature was measurable, mean preoperative keratometry was 55.51±5.33 (range 44.25-71.5) D. This figure was reduced to 47.04±2.27 (range 42.25-55.5) D postoperatively (P<0.001). Postoperatively, mean spherical equivalent refractive error, and refractive and keratometric astigmatism were -3.41±3.1, 3.07±2.4, and 3.64±2.2 D, respectively.

Sixteen (15.4%) eyes had history of VKC which was inactive before surgery. There was no significant difference between patients with and without history of VKC in terms of final BSCVA and refraction (Table 2).

A bare DM was successfully achieved in 86 (80.4%) eyes but in 18 (17.3%) eyes, it was necessary to perform layer-by-layer manual stromal dissection because of lack of big-bubble...
formation after several attempts. Comparing these two groups (bared DM group vs pre-Descemnet group), we did not find any significant difference in terms of UVCA, BSCVA, and refractive error (Table 3). No eye in the latter group developed interface haziness.

Perforations in the DM occurred in 5 eyes during air injection or removal of residual corneal stroma of which, 3 required conversion to PKP. In 2 cases, it was still possible to continue DALK as the defect was not large. Of these, double anterior chamber formation developed in one eye immediately after the operation which resolved after air injection into the anterior chamber. Atonic pupil developed in the same 2 eyes after overfilling the anterior chamber by air injected to seal DM perforation.

Subepithelial (n=11) and stromal (n=4) graft rejection reactions occurred in 14.4% of the eyes. The majority of these episodes occurred in the first year after surgery (60%) and in patients with history of VKC (66.7%). Blurred vision was the cause of presentation to the surgeon in 4 eyes; in the remaining 11 eyes, rejections were discovered on routine examinations. All rejection episodes were successfully treated with frequent topical betamethasone 0.1%, which was gradually tapered over 3 to 6 weeks according to the clinical response. Two eyes required resuturing because of traumatic wound dehiscence but achieved BSCVA of 20/30 and 20/40 after resuturing. Complications encountered in this series are summarized in Table 4.

### Table 2 Visual outcomes in patients with and without history of VKC

|                      | With VKC (n=16) | Without VKC (n=88) | P value |
|----------------------|----------------|--------------------|---------|
| Age (yr)             | 26±0.7         | 26±7.7             | 0.7     |
| Final BSCVA (logMAR) | 0.25±0.19      | 0.29±0.24          | 0.47    |
| Final spherical equivalent refractive error (D) | -3.34±3.0 | -3.75±3.7 | 0.7    |
| Final mean keratometry (D) | 46.91±2.3 | 47.76±2.2 | 0.28    |
| Final keratometric astigmatism (D) | 3.70±2.1 | 3.48±2.5 | 0.75    |

VKC, vernal keratoconjunctivitis; BSCVA, best spectacle-corrected visual acuity; SE, spherical equivalent; D, diopter.

### Table 3 Visual outcomes and refractive error in bared DM and pre-Desmet groups

|                      | Bared DM group (n=83) | Pre-Desmet group (n=18) | P value |
|----------------------|-----------------------|-------------------------|---------|
| Final UCVA (logMAR)  | 0.67±0.4              | 0.62±0.3                | 0.67    |
| Final BCVA (logMAR)  | 0.25±0.2              | 0.32±0.1                | 0.20    |
| Final keratometric astigmatism (D) | 3.74±2.2 | 3.18±1.7 | 0.44 |
| Final spherical equivalent (D) | -3.63±2.2 | -2.25±2.5 | 0.15 |

DM, Descemet’s membrane; UCVA, uncorrected visual acuity; BCVA, best-corrected visual acuity.

### Table 4 Complications of deep anterior lamellar keratoplasty

| Complication                  | No | %  |
|------------------------------|----|----|
| Filamentary keratitis        | 20 | 19.2|
| Subepithelial or stromal graft rejection | 15 | 14.4|
| Suture abscess               | 11 | 10.6|
| Descemet’s membrane folding  | 7  | 6.7 |
| Severe superficial punctate keratitis | 7  | 6.7 |
| Suture tract vascularization | 4  | 3.8 |
| Persistent epithelial defect | 3  | 2.9 |
| Interface neovascularization | 3  | 2.9 |
| Atonic pupil                 | 2  | 1.9 |

### DISCUSSION

Keratoconus is the most common indication for PKP in some countries, accounting for 34.5% of cases in our nation. In comparison to PKP, several advantages and disadvantages have been reported for DALK. Some studies have reported comparable visual outcomes following DALK and PKP while, several others report superior visual outcomes after PKP. This difference can be attributed to the irregularity at the host-donor interface in DALK. Postoperative BSCVA of 20/40 or better was achieved in 77.6% of our patients which is fairly comparable to the 80% to 92.3% range reported in other studies.

We were able to form the big-bubble successfully in 86 (80.4%) eyes which is consistent with the success rate of 80% to 90% reported by Anwar and Teichmann, but better than that reported by Fogla et al and Fontana et al (69.2% and 64%, respectively). We encountered DM perforation and need for intra-
operative conversion to PKP in 4.7% and 2.8% of cases, respectively. DM perforation and conversion to PKP have been reported from 4% to 39.2% and from 0% to 14%, respectively. This variation may reflect different indications for keratoplasty or different surgical techniques in various studies. The steep learning curve of the surgical technique can explain the difference in the success rates of big-bubble formation in different studies; the majority of failed air injections among our patients occurred at the beginning of the study.

Interface scarring and irregularities are causes of poorer visual results in lamellar keratoplasty as compared to PKP. The interface between the host and donor should be smooth and the corneal stroma should be removed down to DM to achieve better optical quality. Comparing eyes with keratoconus undergoing DALK using Melles technique with those undergoing PKP, Ardjomand et al. found that visual acuity in the DALK group was similar to that in the PKP group only when the recipient corneal bed thickness was less than 20 µm. However, we did not find any significant difference between the bared DM and pre-Descemet groups in terms of visual outcomes and refractive status which can be attributed to the small number of cases in the pre-Descemet group (16 vs 88). Furthermore, the thickness of the residual recipient bed in the pre-Descemet group was not measured in our study, making it difficult to compare our results with those of Ardjomand et al.

Filamentary keratitis was the most common complication encountered in 19.2% of eyes in this study. As DALK makes it possible to use donor tissue with lower quality not considered appropriate for PKP, certain complications such as persistent epithelial defects and filamentary keratitis are more likely to develop. The deleterious effect of poor graft quality on epithelial healing has already been demonstrated. Van Meter et al. evaluated the effect of death-to-preservation time on donor corneal epithelium and found that increased death-to-preservation interval and hence poor donor tissue quality increases the incidence of corneal epithelial defects. Also, studies by Chou and associates and Kim and colleagues demonstrated that longer storage and longer death-to-preservation times are associated with epithelial defects after keratoplasty. Therefore, it may be advisable to use good donor quality for DALK and to avoid damage the corneal epithelium during the preparation of the donor.

Although DALK eliminates the risk of endothelial rejection, other types of graft rejection (subepithelial and stromal) may still develop. The clinical features of subepithelial and stromal graft rejections after DALK are very similar to those following PKP. In contrast to previous studies reporting rates of immunologic rejection of 3% to 8% after DALK, we observed a higher rate (14.4%) in our series. Frequent topical steroids led to reversal of rejection in all cases and all subjects regained the level of visual acuity prior to rejection. This higher rate of graft rejection in our series can be explained by the presence of risk factors for which the surgeon was inclined to choose DALK; this is supported by the fact that the majority of rejection episodes occurred in eyes with history of VKC. Although it has been suggested that rejection episodes following lamellar keratoplasty are easy to control, subepithelial and stromal graft rejections must be treated appropriately to prevent less severe but important complications such as stitch abscess and graft vascularization which can lead to a poor visual outcome. Another complication in our series was suture abscess which can also be attributed to underlying conditions such as VKC.

An interesting point is the good final visual function in 2 eyes which sustained blunt trauma after surgery leading to wound dehiscence. We believe that these eyes would have suffered severe damage if PKP had been performed instead of DALK because globe integrity does not reach normal values even up to 31 years after PKP. This observation highlights another advantage of DALK over PKP which is preservation of the globe integrity and more structural resistance against trauma.

Three (2.8%) eyes in our series underwent PKP and our results indicate that performing lamellar dissection does not pose any challenge to the surgical technique or postoperative course of these eyes all of which had mean postoperative BCVA better than 20/30.
In conclusion, DALK is an appropriate alternative to PKP in patients with keratoconus especially those with history of VKC, it eliminates the risk of endothelial graft rejection, preserves globe integrity and provides acceptable visual function.

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