



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

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Abstract

Objectives: The aim of this study was to evaluate the visual outcomes and complications of deep anterior lamellar keratoplasty (DALK) performed using the big-bubble technique in patients with keratoconus.

Methods: In this case series, 57 eyes of 57 patients with moderate to advanced keratoconus underwent DALK. All of the participants were contact lens-intolerant or had an unacceptable contact lens fitting as a result of advanced keratoconus. DALK was performed using the big-bubble technique. Full thickness donor corneas devoid of Descemet's membrane were sutured to the recipient bed. Preoperative and postoperative best spectacle-corrected visual acuity (BSCVA), corneal topography, and intra-postoperative complications were evaluated.

Results: The mean age of 40 male (70%) and 17 female (30%) patients who had an average follow-up of 48.84±18.12 months (range: 12–60 months) in this study was 28±11.3 years (range: 7–63 years) at the time of the DALK procedure. The mean BSCVA increased from 1.41±0.44 logMAR to 0.87±0.37 logMAR at the final follow-up ($p<0.001$). The mean preoperative value of flat (K1) and steep (K2) curvature power was 53.5±8.8 diopters (D) and 60.6 ± 8.5 D, respectively, while the postoperative mean K1 and K2 value was 42.8±1.2 D and 46.06±1.3 D. Microperforation was seen in 6 patients (10.5%) during the suturation as an intraoperative complication. Postoperatively, 8 patients (14%) underwent suture revision and 1 patient (0.2%) underwent amniotic membrane transplantation.

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

Keywords: Big-bubble, deep anterior lamellar, keratoconus, keratoplasty.

Introduction

There are 3 basic approaches to keratoconus treatment. There are methods that provide rehabilitation of the patient's vision (glasses, hard contact lenses, intracorneal segment insertion), stop the progression of the disease (cross-linking), and remove the source of the disease (keratoplasty). Surgery is required when the disease has become advanced and the patient's vision can no longer be rehabilitated with glasses or contact lenses (1).

The surgical treatment technique of keratoplasty for keratoconus can be applied using 2 methods: penetrating keratoplasty (PK) or deep anterior lamellar keratoplasty (DALK).

Though PK adversely affects the structure and integrity of the eye, it has commonly been used as the definitive treatment for many corneal pathologies, such as keratoconus and corneal degeneration or dystrophy (2).

DALK is a method that doesn't affect the endothelium or Descemet's membrane (DM), so it can be used in cases of corneal disease located above the DM (3). Although DALK is a time-consuming procedure and a method that requires experience, it has advantages, including the elimination of endothelial graft rejection, reduction of graft failure, faster visual rehabilitation, and longer graft survival due to lower rates of endothelial cell loss (4). Rather than manual dis-

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section, the injection of air or viscoelastic material into the deep corneal stroma in DALK provides for easier separation of the DM from the stroma and leaves a smoother and more uniform interface, thus reducing the likelihood of complications, such as interface opacity (5). The purpose of this study was to report and assess the results of DALK using the big-bubble technique in patients with keratoconus.

Methods

The medical records of patients who had undergone DALK with the big-bubble technique for moderate to advanced keratoconus between February 2012 and February 2017 were retrospectively reviewed. The study was conducted according to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all of the patients before the DALK procedure was performed. Keratoconus was diagnosed clinically based on slit lamp findings (stromal thinning, Fleischer ring, Vogt's striae) and keratometry, and was confirmed by corneal topography. The study inclusion criteria were moderate to advanced keratoconus with poor best spectacle-corrected visual acuity (BSCVA), rigid gas-permeable contact lens intolerance, or inappropriate contact lens fit. Exclusion criteria included ocular diseases that may affect measurements or visual acuity gains, such as vernal keratoconjunctivitis (VKC), or the presence of hydrops, cataracts, retinal disorders, or glaucoma. Preoperatively, all of the patients had a full ophthalmological examination to determine uncorrected visual acuity (UCVA), BSCVA, manifest and cycloplegic refractions, slit lamp evaluation, Goldman applanation tonometry, and funduscopy. Using the Sirius topography system (Costruzioni Strumenti Oftalmici, Florence, Italy), the following topographic parameters were recorded and evaluated preoperatively and postoperatively: the flattest keratometric reading (K1) and the steepest keratometric reading (K2). All of the patients were operated on using the big-bubble technique. The diameter of trephination was chosen according to the size of the cone and vertical corneal diameter. After trephination to approximately 80% of the corneal thickness with a Hessburg-Barron suction trephine (Katena Products Inc., Denville, NJ, USA), a 27-gauge needle attached to a 5-cc syringe and bent at 100° (bevel facing downward) was inserted into the stroma up to the center of the cornea. Air was gently injected into the midstroma until a big bubble was formed extending to the border of trephination. If no big bubble was formed the first time, the injection was repeated until a big bubble was formed. After bubble formation, debulking of the anterior two-thirds of the corneal stroma was performed with a crescent blade (Alcon Laboratories, Fort Worth, TX, USA). Thereafter, peripheral paracentesis was performed to reduce intraocular pressure, and the bubble was punctured with a 15° slit-knife

(Alcon Laboratories, Fort Worth, TX, USA) to allow for air to escape and collapse of the bubble. Viscoelastic material (Coatel, Bausch & Lomb, Inc., Bridgewater, NJ, USA) was injected to keep the DM away from the manipulations. Vannas scissors were used to divide the rest of the corneal stroma into 4 quadrants and each quadrant was completely excised using left and right transplanted scissors, taking care not to leave any posterior lip. The viscoelastic material was then completely washed out before proceeding to graft suturing. If DM perforation occurred and was large enough to preclude lamellar keratoplasty, the procedure was converted to PK. Data related to these eyes were excluded from the study. The donor cornea was punched from the endothelial side using the Barron punch (Katena Products Inc., Denville, NJ, USA). The donor material was oversized by 0.5 mm. The 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 (SharpPoint, Angiotech Pharmaceuticals, Inc. Vancouver, Canada) at the 3, 6, 9, and 12 o'clock positions. Three different suturing techniques were employed based on the surgeon's preference. 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). The suture bites encompassed approximately 90% of the thickness of the recipient and donor tissues in all of the suturing techniques. Intraoperative keratoscopy was performed to adjust suture tension. At the conclusion of surgery, dexamethasone 4 mg was injected subconjunctivally. Patients received topical moxifloxacin 0.5% drops every 6 hours for 30 days and topical prednisolone 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 International Co., Ltd., Shanghai, China) or amniotic membrane transplantation were used to treat non-healing epithelial defects. Postoperatively, patients were examined on the first day after surgery and every alternating day postoperatively to assess the status of corneal epithelial healing. Follow-up examinations were scheduled 1, 3, 6, 12, 24, 36, 48, and 60 months postoperatively, with an appointment at least once every 3 months until complete suture removal, and 6 months thereafter. BSCVA, corneal topography, biomicroscopic slit lamp examination, Goldman applanation tonometry, and funduscopy were performed at each visit. An automated phoropter (CV-5000; Topcon Corp., Tokyo, Japan) and a back-illuminated 19" LED LCD monitor chart (CC-100 XP; Topcon Corp., Tokyo, Japan) were used for visual acuity examinations. Visual acuity was converted to

logMAR for statistical analysis. BSCVA, K1, and K2 readings, as well as intra- or postoperative complications or secondary interventions (such as resuturing) were recorded and evaluated. When more than 1 procedure was required (such as resuturing), the final results were considered for analysis.

The mean and SD were used for descriptive statistics of variables with normal distribution. The Kolmogorov-Smirnov test was used to test the normality of the datasets. A dependent sample t-test was used in the statistical analysis of the comparisons of preoperative and postoperative repeated measures. The level of statistical significance was set at $p < 0.05$. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 20.0. (IBM Corp, Armonk, NY, USA).

Results

Fifty-seven eyes of 57 (40 male) patients with moderate to advanced keratoconus underwent surgery. The mean age of the patients was 28 ± 11.3 years (range: 7–63 years) at the time of the DALK procedure, and were followed for a mean of 48.84 ± 18.12 months (range: 12–60 months) (Table 1).

Table 1. Patient characteristics and preoperative data of deep anterior lamellar keratoplasty surgery patients

Age (mean±SD), years	28±11.3 (range 7–63)
Follow-up (mean±SD), months	48.84±18.12 (range 12–60)
Male/female	40/17
Right/left eye	30/27

The recipient trephination size was 7.25 to 8.0 mm.

The sutures were removed between the 6th and 12th postoperative month. The final outcome analysis was performed after complete suture removal.

The mean BSCVA increased from 1.41 ± 0.44 logMAR to 0.87 ± 0.37 logMAR at the final follow-up ($p < 0.001$) (Fig.1). The mean preoperative K1 and K2 value was 53.5 ± 8.8 diopters (D) and 60.6 ± 8.5 D, respectively, while the postoperative K1 and K2 value was 42.8 ± 1.2 D and 46.06 ± 1.3 D (Fig. 2).

Intraoperatively, microperforations in the DM occurred in 6 eyes (10.5%). Postoperatively, 8 eyes (14%) required resuturing, and 1 patient (0.2%) underwent amniotic membrane transplantation (Table 2).

Discussion

Keratoconus is the most common indication for PK in some countries (6). Several advantages and disadvantages have been published for DALK in comparison with PK (2, 7). Some studies (8, 9) have published comparable visual outcomes following DALK and PK, while others (2, 10) have reported superior visual outcomes after PK. This difference can be attributed to irregularity at the host-donor interface in DALK. DM perforation and conversion to PK have been reported at a rate of 4% to 39.2% and 0% to 14%, respectively (11). The difficult learning curve for the surgical technique may also contribute to differences in success rates of big-bubble formation seen in various studies. We decided to include only successful big-bubble formation cases in this study.

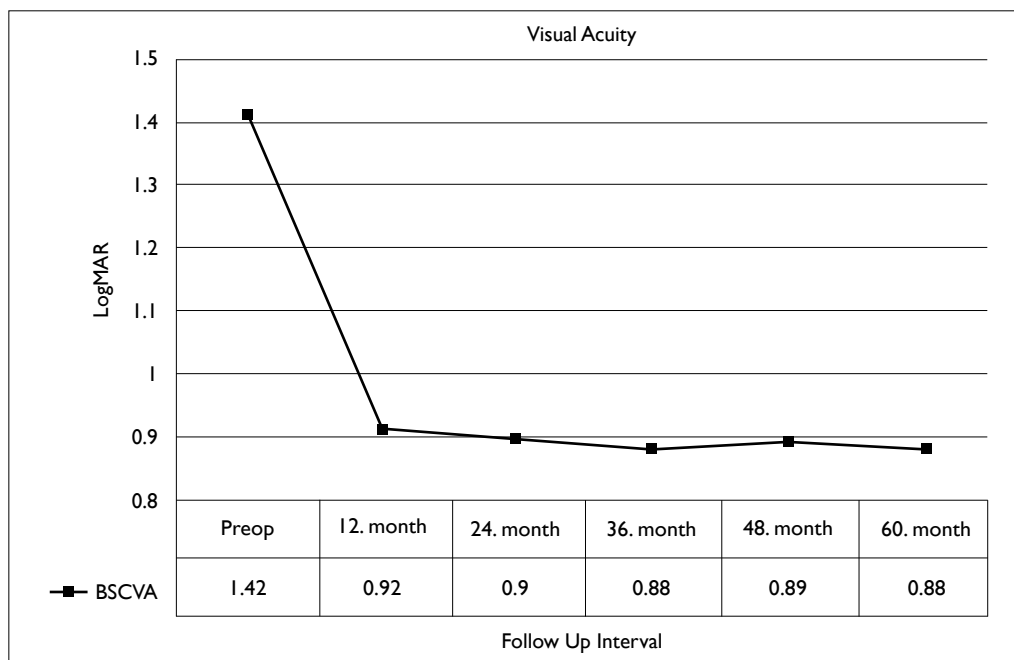


Figure 1. Visual acuity over the entire follow-up period.

BSCVA: Best spectacle-corrected visual acuity.

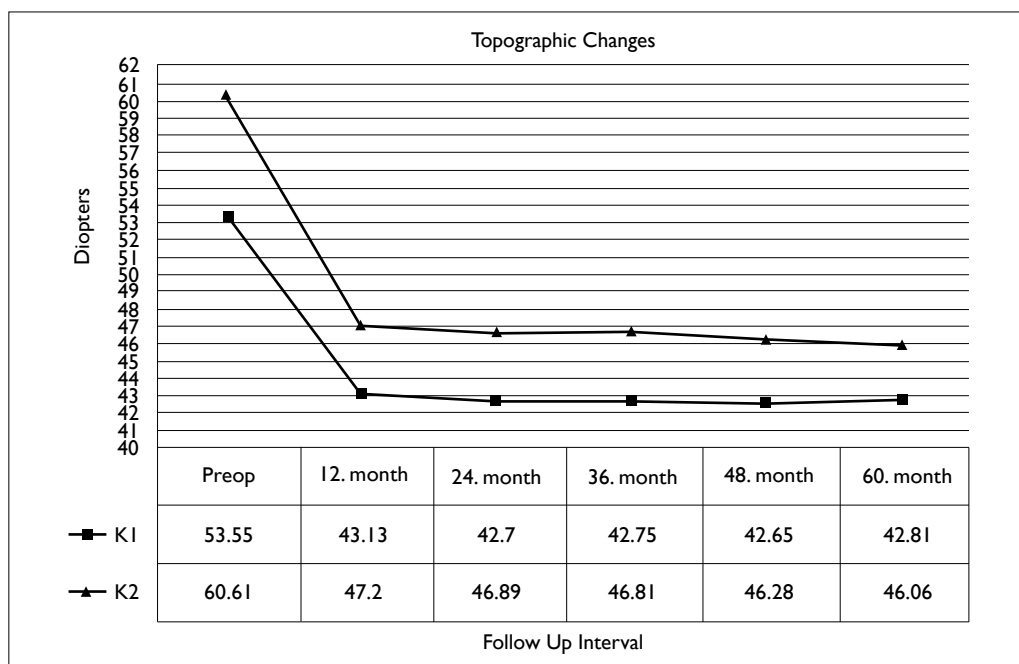


Figure 2. Topographic changes.

Table 2. Complications of deep anterior lamellar keratoplasty

Complication	n	%
Microperforation	6	10.5
Loose suture	14	24.5
Resuturation	8	14
Persistent epithelial defect	1	1.7
Amniotic membrane transplantation	1	1.7

Although DALK rules out the risk of endothelial rejection, other types of graft rejection (subepithelial and stromal) may still spring up. The clinical features of subepithelial and stromal graft rejections after DALK are very similar to those following PK (12). In this study, there was no rejection; which may be explained by excluding eyes with a history of VKC, and having too few patients to see rejections.

In our study, the mean BSCVA increased from 1.41 ± 0.44 logMAR to 0.87 ± 0.37 logMAR at the final follow-up ($p < 0.001$). Romano et al. (13) observed a corrected distance visual acuity (CDVA) of 20/25 (0.09 ± 0.1 logMAR) at the last control examination after DALK surgery in 158 eyes/150 consecutive patients with keratoconus with a postoperative follow-up time equal to or greater than 4 years when the CDVA was 20/50 (0.7 ± 0.2 logMAR) at the beginning. The length of the follow-up was longer in that study than in ours (76.9 ± 23.2 months [range: 48-120 months]) and the study included a larger number of patients.

Javadi et al. (14) found a mean preoperative BSCVA of 1.23 ± 0.4 logMAR (range: 0.0–2.0 logMAR), equivalent to

20/400, which improved to 0.26 ± 0.2 logMAR (range 0.0–1.4 logMAR), equivalent to 20/40, at the final follow-up ($p < 0.001$). In our study, the preoperative visual acuity and the BSCVA at the last follow up were lower, but there was a statistically significant increase in visual acuity change.

In this study, the mean preoperative K1 keratometry was 53.55 ± 8.85 D in the flattest meridian, whereas it was 42.81 ± 1.29 D at the last follow-up. The mean preoperative K2 keratometry measurement at the steepest meridian was 60.61 ± 8.51 D and 46.06 ± 1.31 D at the last control examination. The changes in K1 and K2 values were statistically significant. ($p < 0.05$) In 77 eyes, Javadi et al. (14) reported a mean preoperative keratometry measurement of 55.51 ± 5.33 D (range: 44.25–71.5 D) and a postoperative value of 47.04 ± 2.27 D (range: 42.25–55.5 D) ($p < 0.001$).

Behesht-Nejad et al. (15) performed DALK using the big-bubble technique in 17 eyes with a mean preoperative keratometry of 60.1 ± 7.3 D and observed a result of 44.86 ± 2.4 D 9 months after the procedure ($p < 0.0001$). Although our follow-up period was longer and our research included 57 eyes, the outcomes were similar, particularly the K2 readings.

The complications experienced are provided in Table 2. A total of 6 eyes (10.5%) had a microperforation in the DM, which occurred during air injection or removal of residual corneal stroma, though it was still possible to continue the DALK procedure because the defect was small. Several studies have reported DM perforation during DALK, ranging from 4% to 39.2%. Microperforation rates are highest with manual dissection (26.3%) and lowest with the Anwar big-bubble technique (5.48%). This variation likely reflects differences in surgeon experience, indications for keratoplasty,

and surgical technique (11).

In the Javadi et al. (14) study, perforation in the DM occurred in 5 eyes during air injection or removal of residual corneal stroma, and 3 required conversion to PK. Zhang et al. (16) performed DALK in 75 eyes and observed microporforation of the DM in 7 eyes (9.3%) and a large tear in the DM in 1 eye (1.3%).

In our study, loose sutures were noted in 14 patients (24.5%) over the follow-up period; however, only 8 cases required resuturing. This rate was similar to that seen in the Behesht-Nejad (15) study. A persistent epithelial defect was noted in 1 patient (1.7%) and was successfully managed with amniotic membrane transplantation. Reepithelialization was completed at 2 weeks, with some subepithelial haze present. There was no instance of subepithelial or stromal graft rejection, interface wrinkling, vascularization or opacification, fixed dilated pupil, suture abscess, or suture tract vascularization as a complication.

Abdel Hakeem et al. (17) compared the big-bubble technique with manual dissection in DALK and found that in the big-bubble group, the mean BCVA was significantly better ($p=0.006$), whereas the mean residual stroma was significantly lower ($p=0.0001$) and the interface haze was significantly less ($p=0.018$) than that found in the predescemetic DALK group.

In another study, Keane et al. (18) compared DALK with PK and found that no evidence to support a difference in outcome in the treatment of keratoconus with regard to BCVA at 3 months post-graft or at any of the other time points analyzed (GRADE rating: very low). They also found no evidence of a difference in outcomes with respect to graft survival, final UCVA, or keratometric outcome. They found some evidence that rejection was more likely to occur following PK than DALK (GRADE rating: moderate).

The principal limitations of our study are the retrospective design and the fact that it does not include a comparison with other keratoplasty techniques.

In conclusion, DALK is an appropriate alternative to PK in patients with keratoconus. It eliminates the risk of endothelial graft rejection, preserves globe integrity, and provides acceptable visual function. More extensive studies with a longer follow-up period are required to better understand all of the advantages and disadvantages of DALK.

Disclosures

Financial Disclosure: This retrospective study was not supported by any company. None of the authors has financial or proprietary interests in any material or method mentioned. These data have not been previously published.

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Conflict of Interest: None declared.

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