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Analysis of the learning curve of big bubble-deep anterior lamellar keratoplasty by a single corneal surgeon

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Purpose

The aim of the study was to identify the duration of surgery, the incidence of Descemet's membrane (DM) perforation during deep anterior lamellar keratoplasty (DALK), and the incidence of conversion to a penetrating keratoplasty (PKP) surgery when the procedure are performed by a single corneal surgeon during his learning curve.

Setting

This study was conducted in a specialized eye hospital from March 2013 to April 2014.

Design

This was a retrospective noncomparative case series study.

Patients and methods

We conducted a retrospective analysis of the first 52 cases of planned DALK that used the big-bubble (BB) technique, focusing on the 10 cases that were converted to PKP (19.23%). The cases were subdivided into four groups, categorized chronologically from A to D, comprising 13 patients each.

Results

DM perforation occurred during initial trephination in one case (10% of converted cases), during BB (over) injection with escape through (iatrogenic) DM break in one case (10% of converted cases), and during air injection with escape through a pre-existing big DM break in one case (10% of converted cases). During initial stab/deroofing of the BB using a superblade, perforation occurred in two cases (20% of converted cases). Perforation was most commonly encountered during supradescemetic cleavage plane dissection, which happened in five cases (50% of converted cases). However, microperforations that occurred during dissection into the bare DM in six cases (11.53% of total cases) were managed successfully without conversion to PKP. Of the successful DALK cases, five were converted to manual DALK with complete baring of DM.

Conclusion

Despite a learning period needed to successfully perform DALK with the BB technique, complications related to this technique and total surgery duration decrease significantly after the first 10 cases.

Keywords:

conversion, deep anterior lamellar keratoplasty, learning curve, penetrating keratoplasty

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Introduction

During early trials of lamellar keratoplasty, manual or microkeratome-assisted lamellar dissection led to disappointing results because of the poor optical quality of the interface [1].

In the late 1970s, Malbran and Gasset were performing deep anterior lamellar keratoplasty (DALK) to excise and replace the corneal tissue anterior to the deepest stromal lamellae [2]. However, the problem of interface haze shifted corneal grafting toward penetrating keratoplasty (PKP). DALK advantages include more rapid wound healing and a short topical corticosteroid regimen. In addition, preservation of the host endothelium makes endothelial rejection impossible [3].

In recent times, several techniques for the dissection of the plane of tissue alongside Descemet's membrane (DM) have been applied to optimize the quality of the interface. Sugita and Kondo used the manual hydrodissection layer-by-layer method. Melles adopted the mirror-image technique by using intracameral air and intrastromal ophthalmic viscosurgical device injection. However, the closed method of lamellar dissection in this technique potentially increases the chances of perforation [4,5]. Diamond knife-assisted DALK was assumed to be

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a safer technique. However, a thin layer of corneal stroma is left over DM [6].

The most popular are the Anwar big-bubble (BB) technique and the Melles technique [7]. Anwar and Teichmann developed the BB technique in 2002. This technique showed a higher success rate in achieving bare DM, with better visual results when compared with all other procedures [8]. In case initial creation of BB failed, puncturing the microbubbles followed by viscodissection may help to achieve separation of DM from the remaining stroma [9].

Three types of BB can be achieved on intrastromal air injection: (a) the first is type 1 BB, in which the air separates Dua's layer (DL) from the deep stroma, creating a large central 8–9-mm bubble with white edges. This is the preferred type of bubble in DALK, owing to the strength added by the adherent DL to the recipient DM. (b) The second is type 2 BB, wherein the DM is separated from the posterior surface of DL by a larger thinner air bubble with clear edges. DM is more susceptible to tears and bursting with this type. (c) Finally, there is mixed BB, in which the above two coexist; usually type 1 is complete and type 2 is partial but both can be complete [10].

During the DALK procedure, the attempt to bare DM can be complicated by its perforation, which according to its size and location can cause conversion to PKP, or double anterior chamber with aqueous collected in the recipient–donor interface [11].

Pre-Descemet's plane lamellar dissection, leaving a bare DM with the endothelium in place, reduces the incidence and severity of interface-related complications [12]. However, trying to achieve this plane always carries the risk of perforation of the DM during any of the surgical steps, starting with trephination and ending with suturing, often requiring the surgery to be converted to a PKP [13].

Many surgeons have had difficulty mastering the technique, which has resulted in increased operative time, higher rates of intraoperative DM perforation, and unexpected conversion to PKP. Accordingly, a steep learning curve is required to master the technique of DALK, which has been analyzed in this study in detail.

The purpose of the present study was to undertake a retrospective analysis of the first consecutive series of keratoconus patients undergoing DALK by air dissection (DALK-AD), which was performed by a single surgeon experienced with PKP, using the BB

technique. The objective was to evaluate the learning curve needed to successfully achieve the DALK using the BB technique.

Patients and methods

This is a retrospective analysis of the first 52 cases of planned DALK using the BB technique, focusing on 10 cases that were converted to PKP (19.23%). The cases were subdivided into four groups, categorized chronologically from A to D, comprising 13 patients each. An informed consent was obtained before operation. The study followed the tenets of declaration of Helsinki. The time frame for each group was as follows: group A, March 2013 to July 2013; group B, July 2013 to November 2013; group C, November 2013 to January 2014; and group D, January 2014 to April 2014.

All surgeries were video recorded, and retrospectively and collectively analyzed, including calculation of time spent at every step of the operation. All intraoperative events were analyzed to evaluate the rate of DM perforation and conversion into PKP with this procedure, and to establish a learning curve for the successful performance of DALK, using the BB technique. All of the procedures of DALK were performed in a specialized eye hospital in the Kingdom of Saudi Arabia (KSA) under general anesthesia by the same surgeon (S.A.E.), using the Anwar BB technique.

As per initial description by Anwar and Teichmann [8], partial thickness trephination up to 80% depth was performed with a single-use vacuum trephine (Moria Inc., Pennsylvania, PA, USA). Following trephination, dissection was completed with a crescent blade to remove a free cap of superficial corneal stroma. Type 1 bubble was targeted, using a 27-G needle, inserted bevel-down into the paracentral residual stroma in the direction of the center of the cornea, followed by 3.00 ml of air injection by exerting firm and continuous pressure on the piston of the syringe. Deroofing of the BB was achieved using a 15° disposable knife as seen in Fig. 1. The rest of the residual posterior stromal lamellae were divided into four quadrants in a cruciate manner, using blunt-tipped Vannas scissors, and separated from bare DM using a DALK iris spatula (Moria Inc.) as seen in Fig. 2, before being completely excised with transplantation scissors. In the event of a significant macroperforation of the DM, the procedure was converted to PKP.

The donor cornea was trephined from the endothelial side using vacuum donor punch (Moria Inc.), and the trypan blue-stained DM was meticulously stripped off with a pair of forceps. The donor button was then positioned on the

host descemetic plane, and sutured with 16 interrupted stitches of nylon 10/0. Early cases were subjected to cautious suturing movements by the surgeon, to avoid DM perforation, using a 10/0 nylon needle, which added to the total duration for completion of the procedure in successful cases.

Postoperative treatment included topical combination of tobramycin 0.3% antibiotic and dexamethasone 0.1% steroid (Tobradex; Alcon Laboratories Inc., Fort Worth, Texas, USA) five times a day, with a gradual decrease over 7 months.

Statistical analysis

All data were analyzed using the statistical software package SPSS, version 15 (SPSS Inc., Chicago, Illinois, USA). Categorical data were presented as frequencies (%) and analyzed using the χ^2 -test. Continuous data were presented as mean±SD, and different learning stages were analyzed using one-way analysis of variance. A *P* value less than 0.05 was considered statistically significant.

Results

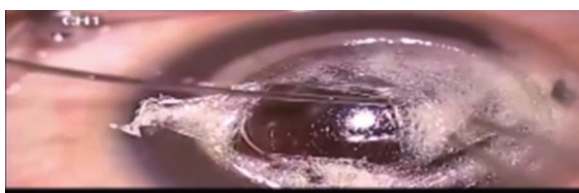
Intraoperative complications were analyzed over the 52 consecutive keratoplasties performed. Of the enrolled

Figure 1



Deroofing of the big bubble using a 15° disposable knife.

Figure 2



Dissection into bare Descemet's membrane (DM) using a deep anterior lamellar keratoplasty (DALK) iris spatula.

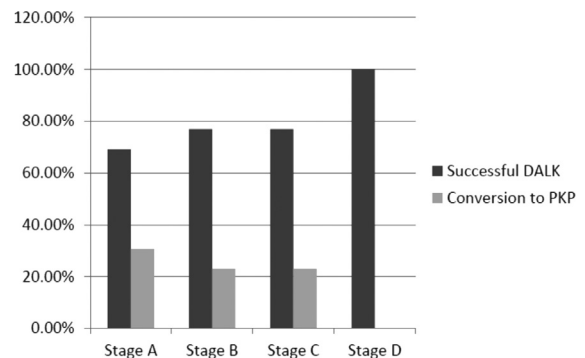
cases, 47 eyes had advanced keratoconus, two eyes had granular corneal dystrophy, and three cases presented with postherpetic scarring. The conversion to PKP secondary to DM macroperforation occurred in four (30.8%) of the first 13 grafts in group A, in three cases (21.3%) in group B and group C, and in no cases (0%) in group D (Fig. 3).

Conversion rate decreased in indirect proportion to increase in the surgeon's experience.

DM perforation occurred during initial trephination in one case (10% of converted cases), during BB forceful (over) injection with escape through an iatrogenic DM break (bubble burst) in one case (10% of converted cases), and during BB injection with escape through a pre-existing big DM break in one case (10% of converted cases). During initial stab/deroofting of the BB using a superblade, perforation occurred in two cases (20% of converted cases). Perforation was most commonly encountered during supradescemetic space dissection performed using a pair of 0.12 mm Colibri forceps, a DALK dissector, and a blunt-tipped Vannas, which occurred in five cases (50% of converted cases).

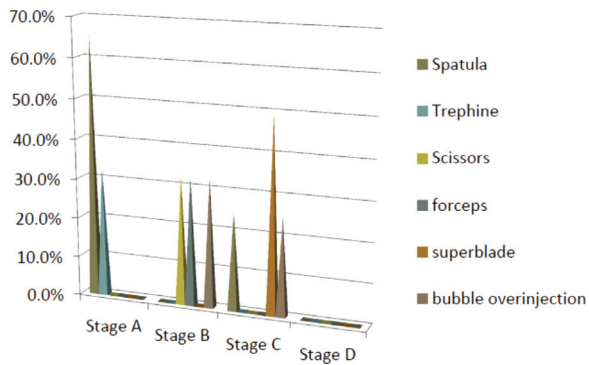
However, during dissection into the bare DM, six cases from groups A and B (11.53% of total cases) experienced microperforations that could be managed successfully without conversion to PKP. Microperforations resulted from DM injury caused by an iris spatula/DALK dissector in three cases, and by the 0.12 mm corneal forceps in another three cases, all of which were managed by intracameral air injection and application of a stromal plug until the end of the dissection procedure. The contribution of every instrument or step involved in DM perforation in each group is shown in Fig. 4.

Figure 3



Conversion rate to penetrating keratoplasty (PKP) in the four chronologically based groups.

Figure 4



Contribution of every instrument or step incriminated in Descemet's membrane (DM) perforation in each group.

Intraoperative perforations occurred in 16 out of 52 cases (30.8%), of which 10 cases (62.5%) were macrop perforations, requiring conversion to PKP, and six cases (37.5%) were microp perforations in which the lamellar dissection was preserved and DALK resumed successfully.

On comparing groups B, C, and D with group A, a statistically significant difference was found in the total duration of surgery, duration of stromal dissection, and donor tissue preparation time ($P < 0.05$). Regarding the duration of surgery, the mean time spent in group A was 59.23 ± 15.54 min, compared with 41.61 ± 10.72 , 37.30 ± 9.25 , and 36.76 ± 5.79 min for groups B, C, and D, respectively. Dissection into the bare DM was the most time-consuming step, which required a mean duration of 29.91 ± 8.14 min in group A, which can be attributed to the extra caution exercised by the assigned surgeon to guard against DM perforation. The aforementioned step required 17.91 ± 8.79 , 16.40 ± 4.03 , and 11.92 ± 2.43 min for groups B, C, and D, respectively. Donor tissue preparation required a mean duration of 9.53 ± 1.61 , 7.92 ± 0.95 , 6.61 ± 1.60 , and 6.38 ± 1.19 in groups A, B, C, and D, respectively.

Discussion

The main limitation of DALK when using the BB technique is its surgical skill-demanding complexity, as well as the steep learning curve required, which was evaluated in this study, with all surgeries performed by the same surgeon over 1 year.

The incidence of DM perforation during DALK depends on the surgical technique, the programmed depth, surgeon learning curve [14], and preoperative corneal thinning [15]. The risk of perforation is higher in cases with advanced keratoconus and extreme

corneal thinning ($< 250 \mu\text{m}$) [15]. One of the challenges in performing this surgery is the presence of a corneal scar due to resolved hydrops [16].

In the present study, the main problem encountered during DALK was the relatively superficial trephination by the beginner surgeon, trying to avoid full-thickness penetration into the AC. This resulted in a thick stromal bed with a high incidence of failed bubble. In addition, in cases with a successful BB, thick posterior stroma results in difficult deroofting of the achieved bubble with stab incision of the air pocket. This encountered difficulty is currently overcome using precise depth trephination using a femtosecond laser, which makes an anterior side cut $50 \mu\text{m}$ above the thinnest corneal site as measured by Scheimpflug imaging [17]. Femtosecond LASER-assisted DALK (FSL-DALK) with the BB technique and baring of DM provided matching visual acuity in comparison with PKP, whereas FSL-DALK without baring DM, which left behind a layer of the recipient bed, produced poorer visual outcomes [18].

David and colleagues studied the DALK learning curve outcomes in 44 cases. DM perforation during the surgical step of dissection into bare Descemet's layer occurred in 27.3% of 44 cases, compared with the present study, which reported five cases (9.61%) of perforation during this step. Of the 52 cases in this study, the total number of cases converted to PKP was 10 (19.23%), compared with David *et al.* [13] who reported surgery conversion to a PKP in all 12 cases (27.3%) with perforation. In the present study, secondary to failure of BB achievement, 16.66% (seven of 42 successful DALKs) required further manual dissection to achieve complete DM baring, which is close to the results of David *et al.* [13] (seven of 31 successful DALKs).

In a study by Antonio [19] on 35 eyes subjected to DALK, intraoperative perforation occurred in eight eyes (23%): in five eyes during manual deep dissection, in one eye during trephination, in one eye as the air needle was introduced into the stroma, and in one eye as the BB was injected.

Other studies in the literature report mixed yet comparable results, ranging from 9% in the study by Anwar and Teichmann [8], 11% in the study by Sarnicola *et al.* [20], 13% in the study by Al-Torbak *et al.* [21], 15.4% in the study by Fogla and Padmanabhan [14], and 39.2% in the study by Sugita and Kondo [4]. After perforation, the rate of immediate conversion to PKP in the most recent reports ranges from 0 to 100% [15].

Conclusion

To our knowledge, this is the first study to analyze the progress in operative timing in every surgical step throughout the DALK learning curve, in each chronological stage. Despite a learning period needed to successfully perform DALK with the BB technique, complications related to this technique and total surgery duration decrease significantly after the first 10 cases, due to increased surgeon experience.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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