Incidence and Outcomes of Intraoperative Descemet Membrane Perforations During Deep Anterior Lamellar Keratoplasty

OLIVIA S. HUANG, HLA M. HTOON, AMY M. CHAN, DONALD TAN, AND JODHBIR S. MEHTA

• PURPOSE: **To report the incidence and outcomes of intraoperative Descemet membrane (DM) perforations during deep anterior lamellar keratoplasty (DALK).**

• DESIGN: **Retrospective, consecutive, interventional case series.**

• METHODS: **A retrospective audit of all DALK cases performed from 2004 to 2015 in a tertiary center, with and without intraoperative DM perforations. We excluded cases with preexisting corneal perforations before surgery.**

• RESULTS: **There were a total of 540 eyes, of which 101 (18.7%) had intraoperative DM perforations. These included 79 eyes (78.2%) with microperforations and 15 eyes (14.9%) with macroperforation. The most common steps at which DM perforation occurred intraoperatively were during deep lamellar dissection (32 cases; 31.7%), air injection (27 cases; 26.7%), and suturing (21 cases; 20.8%). Management of the DM perforations included a combination of intracameral air tamponade (49 cases; 48.5%), stromal patching (10 cases; 9.9%), fibrin glue (8 cases; 7.9%), and suturing of the defect (1 case; 1.1%). There were 2 eyes (2/540; 0.37%) that were converted to penetrating keratoplasty (PK). There were no significant differences in the postoperative unaided or best-corrected visual acuity, or in the numbers of patients with postoperative graft failure, graft rejection, or subsequent surgery at postoperative years 1 and 3.**

• CONCLUSIONS: **DALK cases with DM perforations intraoperatively are often able to be managed without conversion to PK. Cases with DM perforations intraoperatively have equivalent visual acuity outcomes compared to those without DM perforations, and did not have any increased risk of graft failure, rejection, or subsequent surgery at postoperative years 1 and 3. (Am J Ophthalmol 2019;199:9–18. © 2018 Elsevier Inc. All rights reserved.)**

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DEEP ANTERIOR LAMELLAR KERATOPLASTY (DALK) is a partial-thickness corneal transplant procedure that involves removing the corneal stroma while preserving the host endothelium.[1] The stroma can be separated from the Descemet membrane (DM) and endothelium via manual stromal dissection[2] or via injection of air, saline, or viscoelastic material just anterior to the DM,[3] or assisted by femtosecond laser/diamond knife dissection.[1] Compared with penetrating keratoplasty (PK), DALK avoids complications of an open-sky surgery, such as expulsive hemorrhage, and also results in better wound strength, earlier visual rehabilitation, avoidance of the possibility of endothelial allograft rejection, improved graft survival,[4] and lower rates of secondary glaucoma and endothelial cell loss.[5] Disadvantages of DALK include a steep learning curve, as well as visual outcomes being affected by possible interface haze[1] and the depth of stromal recipient dissection.[6–9]

DM perforation is a complication unique to DALK that is not encountered in PK.[1] The incidence of DM perforation in the literature ranges from 1.3% to 54.3%,[4,10] and the risk is higher in cases with corneal scarring near the DM (eg, owing to hydrops or keratitis) and in advanced ectasias with cornea thickness < 250 μm.[11] Sequelae of DM perforations include postoperative DM detachments,[12] higher endothelial cell loss,[12] endothelial decompensation,[13] and interface scarring.[14] In addition, intracameral air injected intraoperatively for DM perforations may cause permanent mydriasis,[15,16] anterior subcapsular cataract,[16] pupil block,[17] and possibly higher rates of endothelial cell loss.[16] In macroperforation or multiple microperforations, conversion to PK may be needed. The incidence of DM perforations requiring conversion to PK (which ultimately may be considered as a DALK surgical failure) in the literature ranges from 0 to 18%[6,18] depending on case selection.

There are few studies[13,14,19] that have reported on the outcomes of intraoperative DM perforations during DALK, and those that have, have had small sample sizes. The largest study to date by Den and associates[13] compared 25 of 71 eyes with and without DM perforations, respectively, and found that perforated cases had reduced graft survival and endothelial cell density at 1 year. Another study by Senoo and associates[14] showed no significant differences in endothelial cell loss or best-corrected postoperative visual acuity (VA) up to 5 years, in 15 of 39 cases with

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and without DM perforations, respectively. However, this study did not report on the rates of graft survival. Other studies[4,18,19] that had larger numbers of intraoperative DM perforations were not designed as comparative studies. One of the largest series, a study by Ogawa and associates,[4] reported that the 10-year graft survival of cases undergoing DALK for optical indications was favorable (74.1%). In their study, there were varying rates of intraoperative DM perforations (overall 99/175) dependent on the underlying corneal pathology—herpetic keratitis (54.3%), keratoconus (52.7%), stromal scars (36.8%), corneal dystrophies (32.8%). However, they did not report on the differences in graft survival between perforated and nonperforated cases.

In this study, we aimed to report the incidence and longer-term outcomes of intraoperative perforations during DALK surgeries in our center over 12 years.

METHODS

WE INCLUDED ALL CONSECUTIVE EYES THAT HAD DALK performed from January 2004 to December 2015 in the Singapore National Eye Center. We excluded cases with preexisting corneal perforation in the same eye before surgery and cases with previous corneal grafts. Singhealth Institutional Review Board approval was obtained, and the research adhered to the tenets of the Declaration of Helsinki.

Preoperative data collection included best-corrected visual acuity (BCVA), defined as either best-corrected Snellen vision or pinhole vision; intraocular pressure (IOP); indication for surgery; and any coexisting ocular disease. Intraoperative data collected included the size of the donor button and recipient bed, additional operative procedures, the type of DM perforation (microperforation or macroperforation), the step of the surgery where the perforation occurred, and interventions taken to repair the perforation. We clinically defined microperforation as a small perforation that in general did not lead to consistent anterior chamber collapse (often a needle perforation), as compared to a macroperforation, in which a sizeable tear or gap in DM (usually 0.5 mm or more in length) resulted in persistent, complete collapse of the anterior chamber despite the use of air or balanced salt solution to reform the chamber.

The surgeries were performed using the modified Anwar technique or a manual layer-by-layer predescemetic technique.[20] The surgeries were performed by a large number of corneal surgeons in our center, including more than 30 corneal fellows in training but using the same techniques.

• **MODIFIED ANWAR TECHNIQUE FOR DEEP ANTERIOR LAMELLAR KERATOPLASTY:** In brief, the modified Anwar technique[21] involved partial trephination using a guarded Hanna trephine (Moria, France) followed by manual dissection of the stroma to a depth of approximately 50%, leaving 150–200 μm of residual stroma.[22,23] This dissection allowed the needle or DALK cannula to be placed closer to the DM more consistently, enabling a higher rate of separation of DM. A 27 gauge needle or DALK cannula (Rycroft Air Injection Cannula; ASICO, Illinois, USA) attached to an air-filled 5-mL syringe was inserted bevel down and advanced 2–3 mm into the paracentral cornea, parallel to the corneal surface. Air was injected to create a cleavage plane between the DM and posterior stroma. On successful attainment of a big bubble reaching the trephination margins, a slit was created in the posterior stroma to break the air bubble and gain access to the DM, and the remnant posterior stromal tissue was removed. If a bubble was not obtained, the procedure was converted to a manual layer-by-layer technique described below.

• **MANUAL TECHNIQUE OF DEEP ANTERIOR LAMELLAR KERATOPLASTY:** The manual technique involved performing anterior lamellar dissection freehand using either a crescent blade or the DALK Marginal Dissector (ASICO AE-2549), a blunt dissector that lessened the risk of perforation.[2] Deep lamellar dissection was in multiple layers to attempt to result in a smooth residual stromal bed of approximately 100 μm or less—direct baring of DM was not attempted in the majority of cases.[24]

In both the big-bubble and manual technique, the donor cornea was punched; stripped of DM, endothelium, and epithelium; and sutured onto the recipient bed with 10-0 nylon monofilament suture. A bandage contact lens was placed to aid re-epithelialization. In the majority of cases, the donor size was the same as recipient. In cases of extreme ectasia, donors were undersized by 0.25 mm to reduce postoperative high myopia.

• **INTRAOPERATIVE MANAGEMENT OF DESCEMET MEMBRANE PERFORATIONS:** The management of DM perforation intraoperatively included 1 or a combination of the following interventions: injection of air into the anterior chamber, conversion to manual dissection,[1] stromal patching,[1] fibrin glue to seal the defect,[25] or suturing of the defect[9] if the defect was large. These techniques have been described in detail in previous publications by our group.[1,9,25]

• **POSTOPERATIVE CARE:** All patients received topical antibiotics and corticosteroids postoperatively. The topical corticosteroid chosen was given initially at a 3-hourly interval, and was gradually tapered for approximately 6–8 months. Cases with DM detachments postoperatively were managed with intracameral air tamponade. Cases with nonresolving DM detachments despite intracameral air tamponade were managed with repeat DALK or PK surgery. Sutures were removed between 6 and 18 months depending on the VA and astigmatism. Data on Snellen VA and IOP was collected at 6 months, 12 months, 3 years, and 5 years. Other

TABLE 1. Preoperative and Intraoperative Characteristics of Deep Anterior Lamellar Keratoplasty Cases With and Without Descemet Membrane Perforation

	All Cases (N = 540)	Cases With DM Perforations (N = 101)	Cases Without DM Perforations (N = 439)	*P* Value
Sociodemographic				
Age, mean (SD)	38.3 (19.2)	40.5 (21.1)	37.7 (18.8)	.217
Sex, male, n (%)	295 (54.6)	47 (46.5)	248 (56.5)	.070
Race, n (%)				.154
Chinese	199 (36.9)	37 (36.6)	162 (36.9)	
Malay	82 (15.2)	21 (20.8)	6 (13.9)	
Indian	104 (19.3)	13 (12.9)	91 (20.7)	
Others	155 (28.7)	30 (29.7)	25 (28.5)	
Duration of follow-up, years, mean (SD)	2.5 (2.5) (n = 412)	3.95 (2.9) (n = 96)	2.1 (2.2) (n = 316)	<.001
Preoperative				
Indication, n (%)				.203
Optical	484 (89.6)	86 (85.1)	398 (90.7)	
Tectonic	26 (4.8)	6 (5.9)	20 (4.6)	
Therapeutic	30 (5.6)	9 (8.9)	21 (4.8)	
Best-corrected visual acuity (logMAR), mean (SD)	1.1 (0.6) (n = 533)	1.2 (0.6) (n = 99)	1.1 (0.6) (n = 434)	.285
IOP (mm Hg), mean (SD)		10.9 (6.4) (n = 95)	11.22 (6.0) (n = 432)	.193
Concomitant disease, n (%)	126 (23.3)	26 (25.7)	100 (22.8)	.525
Glaucoma, n (%)	27 (5.0)	5 (5.0)	22 (5.0)	.980
Uveitis, n (%)	4 (0.7)	2 (2.0)	2 (0.5)	.161
Cataract, n (%)	72 (13.3)	13 (12.9)	59 (13.4)	.880
Allergic/atopic conjunctivitis/vernal keratoconjunctivitis, n (%)	3 (0.5)	1 (1.0)	2 (0.05)	1.0
Ocular surface disease, n (%)	7 (1.2)	2 (2.0)	5 (1.1)	.620
Meibomian gland disease/ blepharoconjunctivitis, n (%)	2 (0.4)	0	2 (0.5)	1
Aphakia, n (%)	3 (0.5)	1 (1.0)	2 (0.5)	1
Active infection, n (%)	1 (0.2)	0	1 (0.2)	1
Intraoperative				
Size of donor button, median (min-max)	8 (3–12) (n = 526)	8 (6–11) (n = 99)	8 (3–12) (n = 427)	.368
Size of recipient bed, median (min-max)	8 (3–13) (n = 514)	8 (6–11) (n = 92)	8 (3–13) (n = 422)	.256
Secondary intraoperative procedures, n (%)	98 (78.9)	23 (22.8)	75 (17.1)	.182

DM = Descemet membrane; IOP = intraocular pressure.

χ^2 test and Fisher exact test for categorical variable; independent *t* test for parametric, and Mann-Whitney *U* test for nonparametric continuous variables.

postoperative data collected included BCVA, graft failure, glaucoma, recurrence of primary disease, wound dehiscence, cataract formation, postoperative anterior synechiae at graft junction, air injections into the anterior chamber, subsequent surgery (including repeat corneal grafting, glaucoma surgery, and cataract surgery), and immunosuppression regime at 1 year. The primary outcomes were graft survival and BCVA post DALK. We conducted a sub-analysis of a random sample of 50 eyes with and without DM perforations (including those with and without air bubbling postoperatively) to assess the unaided VA and BCVA in the early postoperative period at week 1, 4, 8, and 12. Cases that had intraoperative conversion to PK following DM perforations were excluded from our analyses postoperatively.

• **STATISTICAL ANALYSIS:** Data were analyzed using SPSS version 24 (SPSS Inc, Chicago, Illinois, USA). χ^2 and Fisher exact test were conducted for categorical comparisons. Continuous variable analyses were conducted with independent Student *t* test and Mann-Whitney *U* test, as appropriate. Kaplan-Meier survival analysis with log-rank *P* value analysis were used for comparing cases with and without DM

perforations, and according to surgical indications. The survival time was estimated from the start of operation and time of graft failure or survival. A P value of $<.05$ was considered statistically significant.

RESULTS

AMONG 540 DALK CASES, 101 CASES (18.7%) HAD INTRAOPERative DM perforations, of which 79 (14.6%) were clinically classified as microperforations and 15 (2.8%) were classified as macroperforations. Among cases with DM perforations, 54 cases (53.5%) occurred when performing the big bubble technique and 44 cases (43.5%) when performing manual layer-by-layer deep lamellar dissection (in which big bubble was not attempted in the first instance). Among 15 cases with macroperforations, there were 7 cases (46.7%) that were done using the Anwar big bubble technique and 8 cases (53.3%) that were done using the manual technique.

The mean age for all cases was 38.3 ± 19.2 years, and about half (54.6%) of patients were male. Most patients were of Asian descent (Chinese 36.9%, Malay 15.2%, and Indian 19.3%). The mean duration of follow-up was 2.5 ± 2.5 years for all cases, and eyes with DM perforations had a longer follow-up (3.95 ± 2.9 years) compared with eyes without DM perforations (2.1 ± 2.2 years, $P < .001$). The indications for DALK surgery were predominantly optical (89.6%). Among cases in which surgery was done for optical reasons, the 2 most common indications were keratoconus (47.7%) and scarring following infectious keratitis (12.8%). There was no difference in preoperative BCVA between eyes with and without DM perforations (1.2 ± 0.6 logMAR vs 1.1 ± 0.6 logMAR, $P = .285$). Intraoperatively, the median sizes of the donor and recipient corneal button were 8 mm for cases with and without DM perforations (Table 1).

The various steps at which DM perforation occurred intraoperatively included during deep lamellar dissection (37 cases; 36.6%), air injection (27 cases; 26.7%), suturing (21 cases; 20.8%), and trephination (2 cases; 2.2%). Management of the DM perforations included a combination of intracameral air tamponade (49 cases; 48.5%), stromal patching[1] (10 cases; 9.9%), fibrin glue[25] (8 cases; 7.9%), and suturing of the defect[9] (1 case; 1.1%). There were 2 cases of macroperforations (2/540, 0.37%) that were converted to PK. No microperforations were converted to PK.

There were no significant differences in the postoperative unaided VA or BCVA (Figure 1), or in the numbers of eyes with postoperative graft failure (Figure 2), graft rejection, glaucoma, or subsequent repeat corneal grafts at postoperative years 1 and 3 (Table 2) among eyes with and without DM perforations intraoperatively. In a subanalysis of DALK cases done for optical indications, there was similarly no significant difference in graft survival amongst cases with and without DM perforations intraoperatively (Figure 3). In the sub-analysis of the early postoperative visual outcomes of a random sample of 50 eyes, we found that at week 1 postoperatively, eyes without DM perforations had better BCVA compared to those with DM perforations (including both cases with and without air bubbling). At weeks 4, 8, and 12 postoperatively, there was no significant difference in BCVA in the perforated and nonperforated group (Table 3). There was also no significant difference in the graft survival of eyes with DM microperforations compared to DM macroperforations (Figure 4), and no significant difference in graft survival between perforated cases that were performed via the Anwar big bubble technique compared to those done using the manual technique ($P = .40$). At postoperative year 1, a higher proportion of cases with DM perforations were still on topical immunosuppression compared to eyes without DM perforations (61.4% vs 43.5%, respectively, $P = .001$), but this difference was not significant by postoperative year 3 (7% vs 3.7%, respectively, $P = .168$).

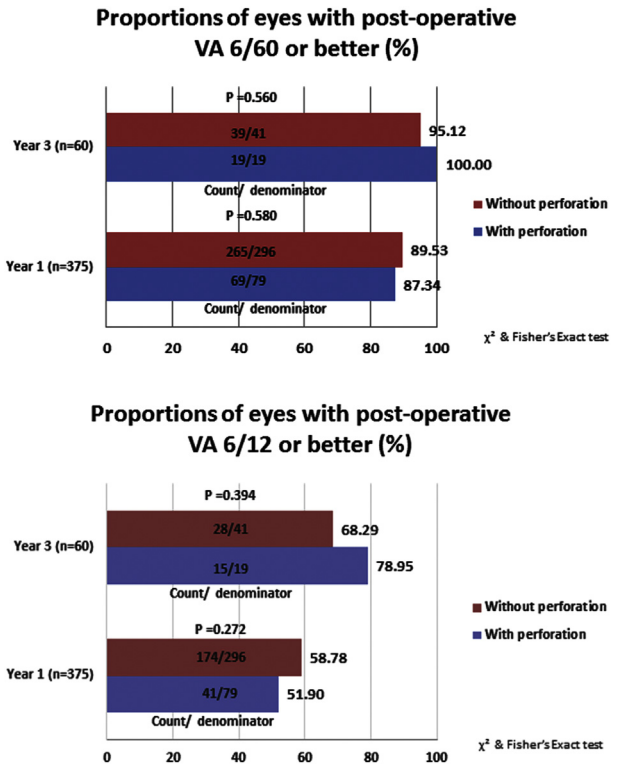

FIGURE 1. Visual acuity categories at postoperative years 1 and 3.

Among eyes with intraoperative DM perforations, 39 patients (38.6%) developed DM detachments postoperatively (Table 4), and in the majority of patients they were noted on the first postoperative day (28 patients; 71.8%). Of these 39 cases, 24 cases (87.1%) required intracameral air tamponade postoperatively, while the remainder of the DM detachments resolved spontaneously. Unresolved or recurrent DM

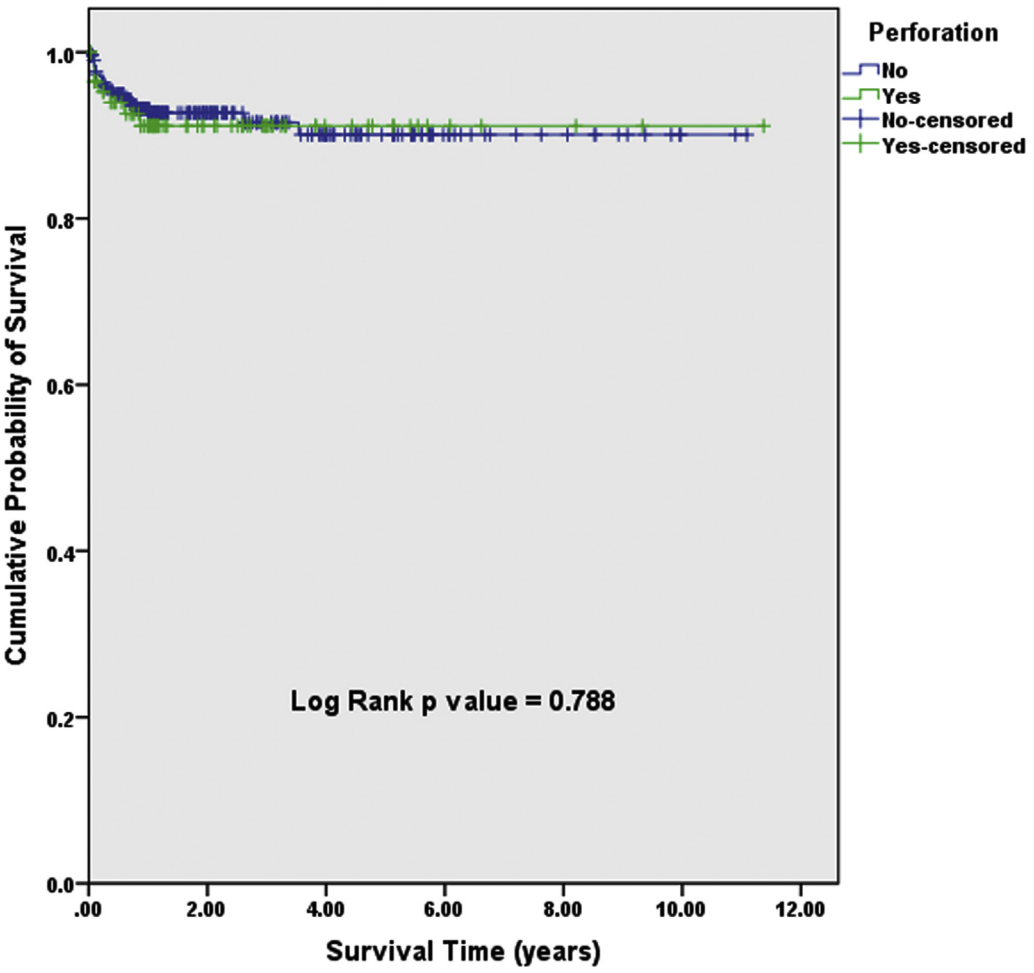

FIGURE 2. Kaplan-Meier survival curve of all eyes with and without intraoperative Descemet membrane perforation (all cases).

detachments requiring repeat intracameral air tamponade was seen in 8 (7.9%) cases, and 1 case had unresolved DM detachment with bullous keratopathy after repeated intracameral air tamponade and subsequently underwent a PK.

DISCUSSION

DM DETACHMENTS REMAIN ONE OF THE MOST COMMON complications in DALK surgery.[26] Our study is the largest series to compare the medium- to long-term graft survival and visual outcomes of eyes with and without intraoperative DM perforations. Intraoperative DM detachments occurred in 18.7% of cases in our study, with 2.8% of them being macroperforations. The majority of cases were safely managed intraoperatively with intracameral air tamponade and other adjunctive measures, and very few were converted to PK (0.37%). The key findings of our study were that visual outcomes and graft survival at postoperative years 1 and 3 were comparable in eyes with and without intraoperative DM perforations. These findings provide valuable information for prognostication for eyes with intraoperative DM perforations.

The incidence of intraoperative DM detachments in our study (18.7%) is comparable to the literature, which has reported a range from 1.3% to 54.3% of DM perforations,[4,10] and 0 to 9% of macroperforations.[27] DALK surgery was first performed in our center in 2004, and there was a trend toward a lower rate of intraoperative DM detachments after the first 4 years, ranging from 6.1% to 23.8% from 2008 onward, compared to 13.3% to 50% from 2004 to 2007, suggesting the presence of a learning curve effect. The development of customized DALK instruments, including blunt DALK cannulas, blunt-tipped DALK scissors, and the DALK Marginal Dissector, also allowed us to effectively separate remaining stromal attachments from the Descemet membrane at the periphery of the big bubble. The T-shaped design of the DALK Marginal Dissector allows a better fit between the donor-host interface, and it has highly polished edges, which prevents inadvertent perforation.[28]

The majority of the DM perforations in our series occurred during deep lamellar dissection (36.6%), air

TABLE 2. Postoperative Outcomes of Deep Anterior Lamellar Keratoplasty Cases With and Without Descemet Membrane Perforation

	Postoperative Year 1				Postoperative Year 3			
	All Cases (n = 540)	Cases With DM Perforations (n = 101)	Cases Without DM Perforations (n = 439)	*P* Value	All Cases (n = 540)	Cases With DM Perforations (n = 101)	Cases Without DM Perforations (n = 439)	*P* Value
UAVA logMAR mean (SD)	0.85 (0.6) (n = 318)	0.88 (0.6) (n = 65)	0.84 (0.6) (n = 253)	.598	0.85 (0.6) (n = 42)	0.6 (0.4) (n = 16)	0.61 (0.4) (n = 26)	.754
BCVA logMAR mean (SD)	0.47 (0.5) (n = 375)	0.55 (0.6) (n = 79)	0.45 (0.6) (n = 296)	.124	0.47 (0.5) (n = 60)	0.28 (0.2) (n = 19)	0.29 (0.4) (n = 41)	.468
Graft failure for optical cases, n (%)	13 (2.4)	4 (3.9)	9 (2.0)	.259	1 (0.2)	0	1 (0.2)	1.0
Graft failure for tectonic/therapeutic cases, n (%)	15 (2.8)	3 (3.0)	12 (2.7)	.896	15 (2.8)	3 (3.0)	12 (2.7)	.896
Infection, n (%)	4 (0.07)	2 (2.0)	2 (0.5)	.161	1 (0.7)	0	1 (0.2)	1.0
Rejection, n (%)	8 (1.5)	0	8 (1.8)	.362	0	0	0	NA
Glaucoma/raised IOP, n (%)	30 (5.6)	6 (5.9)	24 (5.5)	.851	4 (0.7)	0	4 (0.9)	.596
Subsequent surgery, n (%)	92 (17.0)	23 (22.8)	69 (15.7)	.365	7 (1.2)	1 (1.0)	6 (1.4)	1.0
Repeat corneal graft, n (%)	24 (4.4)	7 (6.9)	17 (3.9)	.179	1 (0.2)	0	1 (0.2)	1.0
Glaucoma surgery, n (%)	6 (1.1)	1 (1.0)	5 (1.1)	1.0	0	0	0	NA
Cataract surgery, n (%)	25 (4.6)	5 (5.0)	20 (4.6)	.865	6 (1.1)	2 (2.0)	4 (0.9)	.599
Immunosuppression regime, n (%)	255 (47.2)	62 (61.4)	193 (43.9)	.002*	23 (4.3)	7 (7.0)	16 (3.7)	.168
Immunosuppression topical, n (%)	253 (46.9)	62 (61.4)	191 (43.5)	.001*	23 (4.3)	7 (7.0)	16 (3.7)	.168
Immunosuppression systemic, n (%)	2 (0.04)	2 (2.0)	0	1.0	0	0	0	NA

BCVA = best-corrected visual acuity; DM = Descemet membrane; IOP = intraocular pressure; NA = not available; UAVA = unaided visual acuity.

Statistically significant *P* values are indicated by an asterisk (*).

χ^2 test and Fisher exact test for categorical variables; independent *t* test for parametric and Mann-Whitney *U* tests for nonparametric continuous variables.

injection (26.7%), and suturing (20.8%), suggesting that extra care should be taken during these steps. Consistent with the literature, intracameral air tamponade was one of the most commonly used methods of managing DM perforations intraoperatively (48.5%) in our series. In our series, we also used a small amount of dispersive viscoelastic to coat the endothelium prior to using air to re-form the anterior chamber, similar to the concept of the softshell technique for cataract surgery. Other measures included conversion to a manual dissection technique in cases where the big bubble technique was initially used (33.7%), intraoperative stromal patching (9.9%), adjunctive use of fibrin glue (2%), and suturing of perforation (2%). Only 2 eyes required conversion to PK intraoperatively owing to a large DM tear (0.37%).

Notably, despite the intraoperative measures taken to address the intraoperative DM perforation, nearly 1 in 3 eyes (38.6%) had DM detachment postoperatively in our study. It is known that postoperative DM detachments occur up to 3 times more often in eyes with intraoperative DM perforations compared to those without.[13] This suggests that closer postoperative follow-up may be warranted following intraoperative DM detachments, such that timely diagnosis and management of postoperative DM detachments can be instituted. The majority of cases were successfully managed with a single postoperative injection of air (87%).

More importantly, graft survival rates and best-corrected visual outcomes were not significantly different in those with or without intraoperative DM perforations at postoperative years 1 and 3. Only 1 other study in the literature has reported on graft survival following intraoperative DM perforations in DALK surgery. This study, by Den and associates,[13] on 25 of 96 eyes with DM perforations reported that the rate of endothelial decompensation was significantly higher in those with DM perforations compared to those without (12% vs 1.4%, $P = .047$) at 6 months. This difference might be owing to the fact that their series had higher numbers of cases with macroperforations (6/96, 6.3%), compared to our study (2.8%). A sub-analysis of their study showed that endothelial decompensation occurred more often in cases with macroperforations compared to microperforations (33.3% vs 5.3%, $P = .09$). In our study, there was no significant difference in graft survival between eyes with DM macroperforations compared to those with DM microperforations. This suggests that although DM macroperforations are not common, they may have a worse prognosis than microperforation. Hence it is imperative to minimize further endothelial trauma in the setting of DM microperforation so that it does not convert into a macroperforation. In a setting

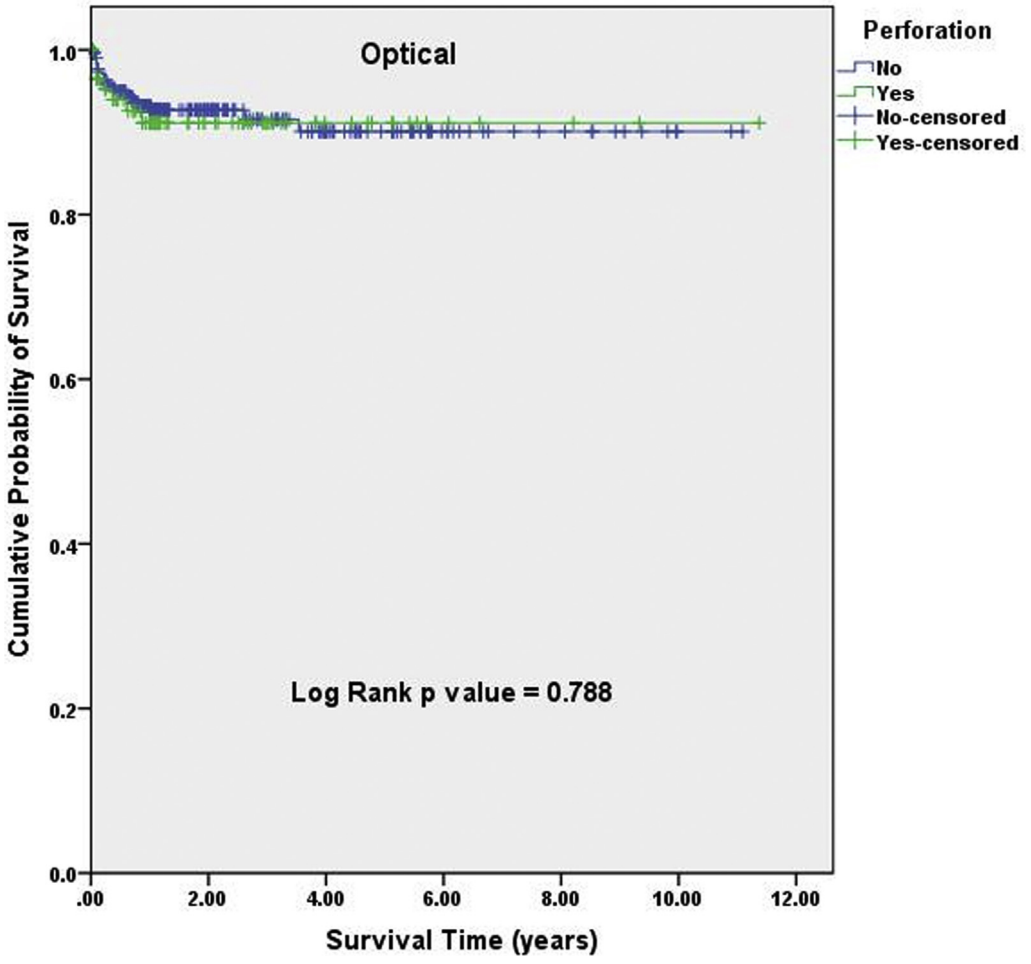

FIGURE 3. Kaplan-Meier survival curve of eyes with and without intraoperative Descemet membrane perforation who had deep anterior lamellar keratoplasty performed for optical indications.

TABLE 3. Postoperative Best-Corrected Visual Acuity in Cases With and Without Descemet Membrane Perforations

	BCVA LogMAR, Mean (SD)				*P* Value[b]		
Duration	DM Perforation With No Air Bubbling	DM Perforation With Air Bubbling	No DM Perforation	Overall *P* Value[a]	No DM Perforation vs DM Perforation With No Air Bubbling	No DM Perforation vs. DM Perforation With Air Bubbling	DM Perforation With No Air Bubbling vs DM Perforation With Air Bubbling
Week 1	0.99 (0.57) (n = 34)	1.26 (0.54) (n = 12)	0.71 (0.48) (n = 44)	.003	0.041	0.007	.608
Week 4	0.76 (0.58) (n = 29)	0.85 (0.45) (n = 12)	0.72 (0.57) (n = 39)	.417	NS	NS	NS
Week 8	0.73 (0.69) (n = 27)	1.11 (0.68) (n = 7)	0.72 (0.62) (n = 36)	.227	NS	NS	NS
Week 12	0.63 (0.51) (n = 26)	1.05 (0.76) (n = 8)	0.61 (0.58) (n = 34)	.182	NS	NS	NS

BCVA = best-corrected visual acuity; DM = Descemet membrane; NS = *P* value not significant.
[a]*P* value calculated using Kruskal Wallis test.
[b]*P* value calculated using adjusted Bonferroni correction.

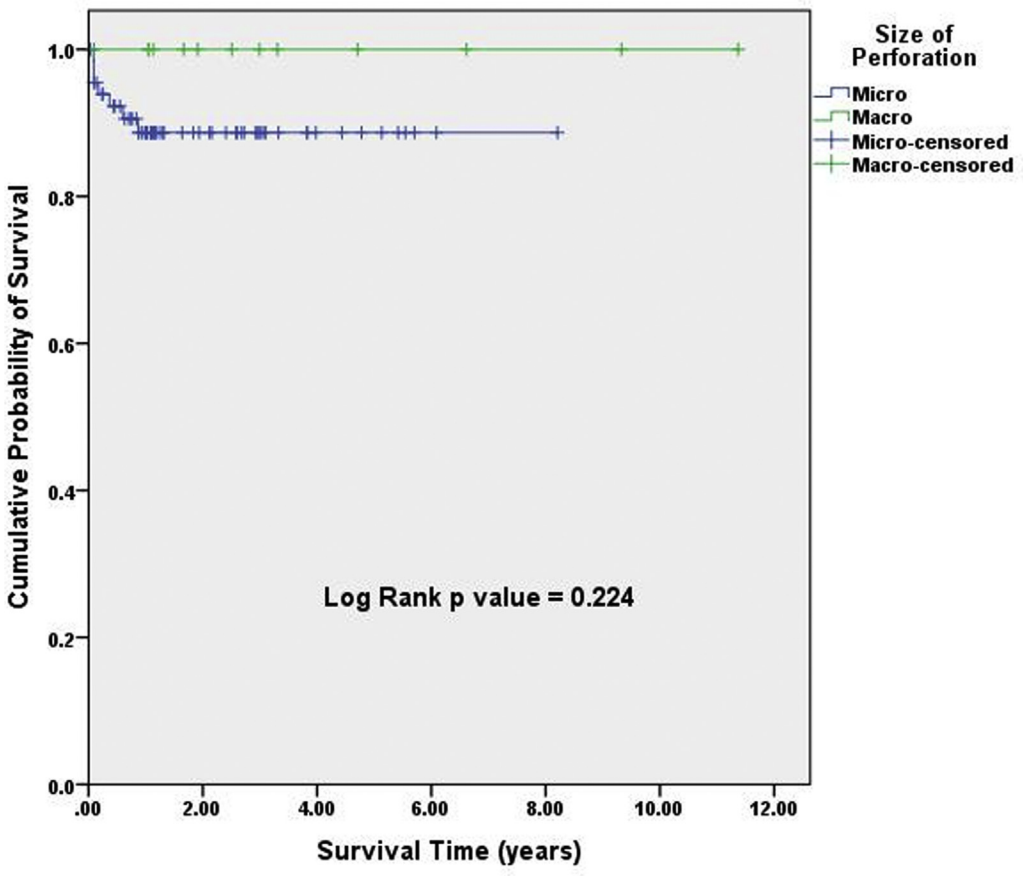

FIGURE 4. Kaplan-Meier survival curve of eyes with and without intraoperative Descemet membrane microperforation compared to macroperforation.

of a macroperforation it is important to minimize excessive endothelial trauma. Some strategies may include placing a small amount of ocular viscoelastic device (eg, Viscoat) to coat and protect the endothelium prior to placing air in the anterior chamber, and also preventing the extension of a microperforation to a macroperforation by keeping the anterior chamber very shallow.[29]

Few studies[13,14,20] have reported on the visual outcomes of cases with intraoperative DM perforations during DALK surgery. Similar to our findings, all these studies[13,14,20] showed no significant difference in BCVA in perforated and nonperforated eyes at 1–5 years after DALK surgery. However, 1 study[13] showed that BCVA in uncomplicated eyes was significantly better than perforated eyes in the short term (3 months postsurgery).[13] This was likely owing to the inclusion of cases with endothelial decompensation or postoperative DM detachments in the early postoperative period.[14] Other factors affecting VA in perforated cases included the duration of pseudo–anterior chamber, which can result in more interface scarring.[14] The findings from a sub-analysis of our study of short-term visual outcomes similarly showed that patients without DM perforations had better BCVA compared to those with DM perforations (including both cases with and without air bubbling) at week 1 postoperatively, but there was no significant difference in BCVA in the perforated and nonperforated group subsequently at weeks 4, 8, and 12 postoperatively.

It is known from previous literature that the longer-term postoperative visual outcomes of DALK and PK cases are comparable, with a previous meta-analysis of DALK vs PK cases showing no significant difference in the BCVA of eyes undergoing DALK compared to PK at the postoperative month 6, month 12, and month 24 time points. Few studies have looked at the shorter-term postoperative visual outcomes of PK compared to DALK, and 1 study[26] showed better BCVA in the PK group compared to the DALK at the third postoperative month. This suggests that in the short term, postoperative BCVA may be better in PK cases compared to DALK cases, including nonperforated and perforated DALK cases, but this advantage was not seen after 3 months postoperatively.

Our study also found that a higher proportion of cases with intraoperative DM perforations were still on topical immunosuppression compared to eyes without DM

TABLE 4. Characteristics of Deep Anterior Lamellar Keratoplasty Cases With Descemet Membrane Perforations

Characteristic	N % (N = 101)
Size of perforation[a]	
Microperforation	79 (78.2)
Macroperforation	15 (14.9)
Step of surgery in which DM perforation occurred[a]	
Deep lamellar dissection	37 (36.6)
Air injection	27 (26.7)
Suturing	21 (20.8)
Trephination	2 (2.0)
Management of DM perforation	
Air bubble injected	49 (48.5)
Conversion to manual dissection	34 (33.7)
Intraoperative stromal patching	10 (9.9)
Fibrin glue	8 (7.9)
Suturing	2 (2.0)
Conversion to PK	2 (2.0)

DM = Descemet membrane; PK = penetrating keratoplasty.
[a]Some not classified.

perforations at first postoperative year, but this difference was not significant by postoperative year 3. This might be because eyes with intraoperative DM perforations had more prolonged postoperative inflammation. There was no difference in eyes with cataract formation or high IOP at postoperative year 1 or 3, suggesting that there was no significant adverse outcome from the prolonged duration of steroids.

The limitations of our study include its retrospective nature and a significant proportion of cases being lost to follow-up after 3 years. In addition, we did not have data regarding rates of endothelial cell loss following DM perforations. However, we documented graft survival rates, which is clinically more important, as eyes with a low endothelial cell count may still maintain a clear graft for some time and may not require regrafting unless there is loss of graft clarity from endothelial failure. The strengths of our study include its inclusion of all consecutive cases undergoing DALK over a 12-year period, and relatively large numbers of eyes in both cohorts compared to the available literature.

In conclusion, the 12-year experience from our center shows that DM perforations were not uncommon in DALK surgery (18.7%), and the majority were microperforations (14.6%). Intraoperative DM perforations could be safely managed in our series, most commonly using intracameral air tamponade, with a low rate of conversion to PK intraoperatively (0.37%). Postoperatively, DM detachments were not uncommon (38.6%), and a higher number of cases with intraoperative DM perforation required topical steroids at postoperative year 1 compared to imperforated cases. There were no increased rates of graft failure, rejection, glaucoma, or repeat corneal grafts postoperatively. The postoperative BCVA of nonperforated cases was better than those with perforations in the first 1 week, but was equivalent at postoperative weeks 4, 8, and 12 through to years 1 and 3. These findings suggest that although intraoperative DM perforation remains a common complication in DALK surgery, with careful management using a variety of procedures these cases can have a reasonable prognosis postoperatively. The findings from our study may be instructive to corneal surgeons facing the decision whether to salvage intraoperative DM perforations during DALK surgery, or to convert to PK intraoperatively.

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