

Clinical Outcomes of Descemet Membrane Endothelial Keratoplasty in Eyes With a Glaucoma Drainage Device



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- **PURPOSE:** To evaluate the feasibility and clinical outcomes of Descemet membrane endothelial keratoplasty (DMEK) in eyes with a glaucoma drainage device (GDD).
- **DESIGN:** Retrospective, interventional case series.
- **METHODS:** Clinical outcomes of 23 DMEK procedures for bullous keratopathy (52%), failed previous transplant (39%), or Fuchs endothelial corneal dystrophy (9%) in 20 eyes (19 patients) with a GDD were retrospectively analyzed at 2 tertiary referral centers. Main outcome measures were best-corrected visual acuity (BCVA), endothelial cell density (ECD), postoperative complications, and graft survival.
- **RESULTS:** Mean length of postoperative follow-up after DMEK was 19 (± 17) months. Kaplan-Meier survival analysis showed an 89% cumulative graft success rate at 1 year postoperatively. At 1 year postoperatively ($n = 15$ eyes), BCVA improved by ≥ 2 Snellen lines in 11 eyes (73%) and remained stable in 4 eyes (27%). Donor ECD decreased by 37% ($n = 14$), 60% ($n = 11$), and 71% ($n = 11$) at 1, 6, and 12 months postoperatively, respectively. Postoperative complications up to 2 years postoperatively comprised pupillary block in 1 eye (successfully reversed by partial air removal), visually significant graft detachment requiring rebubbling in 5 eyes (22%), allograft rejection successfully reversed with topical steroids in 2 eyes (9%), secondary graft failure in 2 eyes (9%), and cataract in 1 of 3 phakic eyes (33%). Re-keratoplasty was required in 2 eyes (9%).
- **CONCLUSIONS:** With specific surgical modifications, DMEK provided acceptable clinical outcomes when taking the complexity of these eyes into account. However, presence of a GDD may reduce graft survival times and may pose a risk for more frequent

regrafting. (*Am J Ophthalmol* 2019;199:150–158. © 2018 Elsevier Inc. All rights reserved.)

SHIFTING PARADIGMS IN THE FIELD OF CORNEAL transplantation have led to an evolution in the management of corneal endothelial dysfunction in eyes with coexisting glaucoma and a glaucoma drainage device (GDD). With the introduction of Descemet stripping automated endothelial keratoplasty (DSAEK) and Descemet membrane endothelial keratoplasty (DMEK), penetrating keratoplasty (PK) has been replaced as the standard of care not only for endothelial disorders in general, but also for glaucomatous eyes with a GDD.^{1–4}

Glaucomatous eyes may pose a challenge for corneal surgeons, as extensive corneal edema often obscures visibility of the ocular structures, extensive peripheral anterior synechiae may require concurrent synechiolysis, and the presence of a GDD may necessitate adapted surgical protocols. Studies on the clinical outcomes of PK and DSAEK in eyes with endothelial dysfunction and a GDD are widely available and reveal increased allograft rejection rates and decreased graft survival rates compared to eyes without a GDD,^{3–8} whereas reports on DMEK are sparse, as it is a relatively new technique.^{9–12}

With an increasing number of corneal surgeons adopting DMEK globally and employing it more and more in challenging cases, optimization of surgical technique and understanding of the clinical outcomes gain importance.¹³ Thus, this study was intended to evaluate the feasibility and the clinical outcomes of DMEK in eyes with a GDD.

METHODS

- **PATIENT DATA:** In this retrospective, interventional case series, 23 DMEK procedures were included that were performed in 20 eyes of 19 patients (mean [\pm standard deviation] age of 63.8 [± 12.7] years; range 37–83 years) at 2 tertiary referral centers (Melles Cornea Clinic Rotterdam [Center 1] and Parker Cornea [Center 2]) (Table 1; Supplemental Table; Supplemental Material available at [AJO.com](https://www.ajon.com)). All included eyes had a postoperative follow-up of at least 6 months. All patients signed an informed

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TABLE 1. Patient and Donor Baseline Characteristics

Characteristic	Result
Patient	
Number of procedures/eyes/patients	23/20/19
Recipient age, years (mean ± SD)	63.8 ± 12.7
Sex	
Female, n (%)	10 (53)
Male, n (%)	9 (47)
Race	
White, n (%)	15 (79)
African-American, n (%)	3 (16)
Other, n (%)	1 (5)
Lens status	
Phakic, n (%)	3 (13)
Pseudophakic, n (%)	20 (87)
Indication for surgery	
Bullous keratopathy, n (%)	12 (52)
Failed previous transplant, n (%)	9 (39)
Fuchs endothelial corneal dystrophy, n (%)	2 (9)
Type of glaucoma	
Primary open-angle glaucoma, n (%)	10
Secondary glaucoma, n (%)	5
Angle closure glaucoma, n (%)	3
Congenital glaucoma	2
Trabeculectomy, n (%)	13 (65)
Tube(s)	
1, n (%)	17 (85)
2, n (%)	3 (15)
Donor	
Donor age, years (mean ± SD)	68.6 ± 7.4
Donor sex	
Female, n (%)	11 (48)
Male, n (%)	12 (52)
Donor death cause	
Cardiovascular/stroke, n (%)	9 (39)
Respiratory, n (%)	4 (17)
Cancer, n (%)	8 (35)
Other, n (%)	2 (9)
Graft storage medium	
CorneaMax, n (%)	14 (61)
Optisol-GS, n (%)	9 (39)

consent prior to surgery for research participation and the study adhered to the tenets of the Declaration of Helsinki.

• **DONOR TISSUE PREPARATION:** Corneoscleral buttons were excised from donor globes less than 36 hours postmortem, and stored in organ culture medium (CorneaMax; Eurobio, Courtaboeuf, France) at 31° C (Center 1) or in Optisol-GS corneal storage medium (Bausch & Lomb Inc, Rochester, New York, USA; Center 2). For Center 1, donor tissue preparation was performed at Amnitrans EyeBank Rotterdam as previously described,^{14,15} while for Center 2 donor tissue preparation was performed according to local protocol at the Alabama Eye Bank.

Peripheral Descemet membrane was circumferentially stripped, preserving a small area still attached to the underlying posterior stroma in the center.

• **SURGICAL TECHNIQUE:** Surgeries were performed as previously described, with some technique modifications.^{16,17} A 3.0-mm clear corneal incision was created at the 12 o'clock position, avoiding the area of the GDD and the intracameral tube(s), and preserving the superior conjunctiva for future glaucoma surgery. Using a reversed Sinsky hook (DORC International, Zuidland, The Netherlands) and/or custom-made scraper (Melles scraper; DORC International), scoring over 360 degrees and descemetorhexis were performed under air. In eyes with failed previous endothelial transplants (DSAEK or DMEK), grafts were stripped from the recipient posterior stroma in a similar fashion using identical instruments.

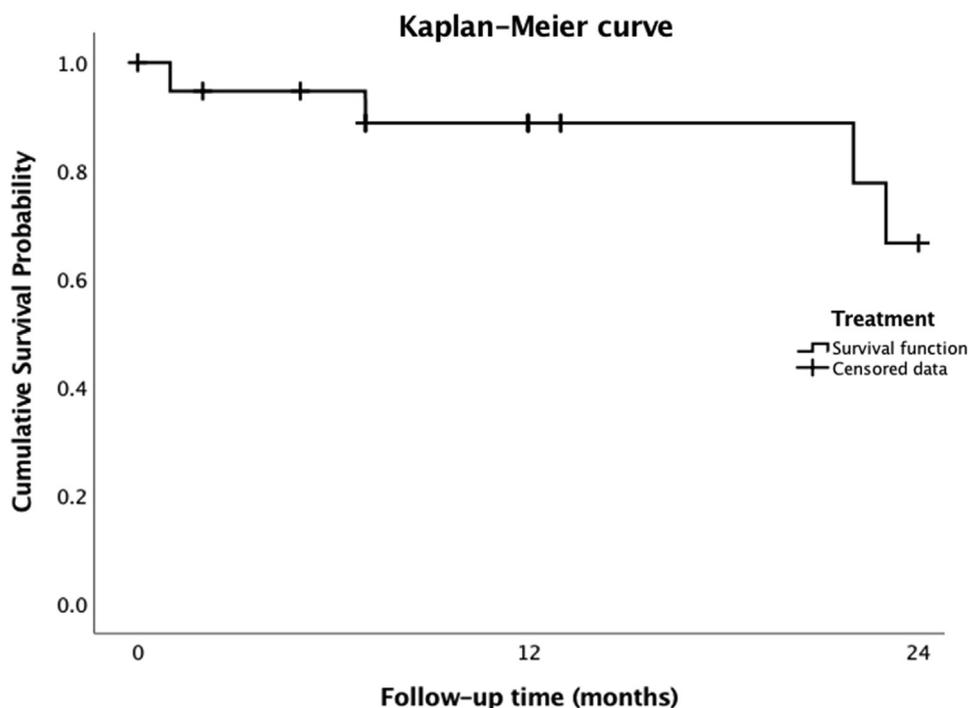
After insertion, the graft was carefully unfolded and lifted against the recipient posterior stroma with an air bubble underneath, avoiding any contact between the graft and the tube(s). Subsequently, the anterior chamber was pressurized with air. Repetitive air injections were required for sufficient pressurization of the eye. The anterior chamber was then completely filled with air for on average >60 minutes and in most of the eyes the air bubble was not reduced.

If required, glaucoma tubes were trimmed during the DMEK procedure (n = 6, 26%); none of the tubes was repositioned.

• **POSTOPERATIVE MANAGEMENT:** For Center 1, the standard DMEK postoperative medication regimen included chloramphenicol 0.5% (6 times daily during the first week tapered to twice daily during the second week), ketorolac tromethamine 0.4% 4 times daily, and dexamethasone 0.1% 4 times daily, switched to fluorometholone 0.1% 4 times daily at 1 month, and reduced to 3 times daily at 3 months, 2 times daily at 6 months, and once daily at 9 months postoperatively.

For Center 2, postoperative medical therapy included Tobradex (tobramycin 0.3%/dexamethasone 0.1%; Novartis Pharmaceuticals Corporation, Hanover, New Jersey, USA) 4 times daily for 1 month, switched to prednisolone acetate 1% 4 times daily at 1 month postoperatively, tapered to 3 times daily at 3 months postoperatively, 2 times daily at 6 months postoperatively, and once daily at 9 months postoperatively. In case of elevated intraocular pressure (IOP), prednisolone acetate was replaced by fluorometholone. For pseudophakic eyes, bromfenac ophthalmic solution 0.07% was administered once daily during the first postoperative month.

• **DATA COLLECTION AND OUTCOME ANALYSIS:** In both centers, recipient eyes were examined at 1 day; 1 week; 1, 3, 6, 9, and 12 months; and every 6 months thereafter. Eyes were evaluated with anterior segment optical coherence tomography (AS-OCT) (Center 1: Heidelberg Slit Lamp-OCT; Heidelberg Engineering GmbH, Heidelberg,



Time (months)		0	1	2	5	7	12	13	22	23	24
Cumulative success probability at FU	Estimate	.	.	0.95	0.95	0.95	0.89	0.89	0.89	0.78	0.67
	SE	.	.	0.05	0.05	0.05	0.08	0.08	0.08	0.12	0.15
Cumulative events		0	0	1	1	1	2	2	2	3	3
Remaining cases		20	19	18	17	16	13	10	8	7	7

FIGURE 1. Kaplan-Meier curve demonstrating the cumulative success rate of Descemet membrane endothelial keratoplasty in eyes with a glaucoma drainage device. For eyes included twice in the study ($n = 3$), only the first surgery was included for the survival analysis ($n = 20$). The cumulative success probability was shown to be 0.89 and 0.67 at 1 and 2 years postoperatively, respectively. FU = follow-up, SE = standard error.

Germany; and Center 2: Zeiss Visante OCT; Carl Zeiss Meditec, Jena, Germany) and rotating Scheimpflug corneal tomography (Pentacam HR; Oculus Optikgeräte GmbH, Wetzlar, Germany). Endothelial cell density (ECD) was evaluated in vivo using noncontact specular microscopy (Center 1: Topcon SP3000p; Topcon Medical Europe BV, Capelle a/d IJssel, The Netherlands; Center 2: Tomey EM-3000; CBD/Tomey, Phoenix, Arizona, USA).

Secondary graft failure (SGF) was defined as corneal decompensation following an initially functional graft after DMEK. Best-corrected visual acuity (BCVA) was assessed using a Snellen letter chart. BCVA was defined as stable for changes ≤ 1 Snellen lines, and as improving or deteriorating for changes ≥ 2 Snellen lines. BCVA outcomes were converted to logarithm of the minimum angle of resolution units (logMAR) for analysis. IOP was measured with applanation tonometry and increased IOP following DMEK was defined as an IOP ≥ 24 mm Hg or an increase in IOP of ≥ 10 mm Hg from baseline.

Kaplan-Meier survival analysis was performed using SPSS 25.0 (SPSS Inc, Chicago, Illinois, USA) to estimate the cumulative success probability of graft survival. Only primary eyes were included for the survival analysis (excluding 3 repeat-DMEK procedures). Descriptive data analysis was performed using SPSS 25.0 and Excel Software for Windows (Microsoft, Redmond, Washington, USA).

RESULTS

• **CLINICAL OUTCOMES:** All surgeries were uneventful. Mean follow-up after DMEK was 19 (± 17) months. Kaplan-Meier survival analysis showed 89% and 67% cumulative graft success rates at 1 and 2 years, respectively (Figure 1).

Median BCVA improved from 1.30 (interquartile range [2.00-0.82]) preoperatively to 0.60 (interquartile range

TABLE 2. Overview of Preoperative and Postoperative Endothelial Cell Density, Best-Corrected Visual Acuity, Central Corneal Thickness, and Intraocular Pressure

	Cases (N)	Clinical Outcome
LogMAR BCVA, median (IQR)		
Preoperative	23	1.30 (2.00-0.82)
1 m FU	21	0.70 (1.65-0.52)
6 m FU	17	0.60 (1.30-0.40)
12 m FU	15	0.60 (1.30-0.40)
Change in BCVA from preoperative to 12 m FU, n (%)	15	
Improved		11 (73)
Unchanged		4 (27)
Worsened		0
ECD in cells/mm ² , mean (SD) [ECD decrease in %, mean (SD)]		
Preoperative	23	2810 (± 330)
1 m FU	14	1820 (± 510) [37 (± 17)]
6 m FU	11	1150 (± 430) [60 (± 15)]
12 m FU	11	850 (± 430) [71 (± 13)]
CCT in μm, mean (SD)		
Preoperative	18	902 (± 329)
1 m FU	13	583 (± 151)
6 m FU	13	537 (± 92)
12 m FU	13	633 (± 165)
IOP in mm Hg, mean (SD)		
Preoperative	23	11.9 (± 2.7)
1 m FU	20	12.9 (± 5.6)
6 m FU	16	12.1 (± 4.4)
12 m FU	15	12.9 (± 4.2)

BCVA = best-corrected visual acuity; CCT = central corneal thickness; ECD = endothelial cell density; FU = follow-up; IOP = intraocular pressure; IQR = interquartile range; SD = standard deviation.

[1.30-0.40]) logMAR at 1 year after surgery, representing an improvement in Snellen equivalent from 20/400 (0.05) preoperatively to 20/80 (0.25) at 1 year after DMEK. At 1 year postoperatively (n = 15), BCVA had improved by ≥2 Snellen lines in 11 eyes (73%) and remained stable in 4 eyes (27%) (Table 2).

Donor ECD decreased from 2810 (± 330) cells/mm² before surgery (n = 23) to 850 (± 430) cells/mm² (-71%; n = 11) at 1 year postoperatively (Table 2).

Mean pachymetry decreased from 902 (± 329) μm (n = 18) preoperatively to 633 (± 165) μm (n = 13) 1 year postoperatively. Mean IOP averaged 11.9 (± 2.7) mm Hg preoperatively and remained stable throughout the study period.

• **POSTOPERATIVE COMPLICATIONS:** Pupillary block occurred in 1 of 23 (4%) cases (Case 12) and resulted in

TABLE 3. Postoperative Complications Among 23 Descemet Membrane Endothelial Keratoplasty Procedures

Complication	N (%)
Pupillary block	1 (4.3)
IOP decompensation	2 (8.7)
Graft detachment at 6 m FU (n = 17)	
Minor (<1/3)	10 (58.8)
Major (≥1/3)	2 (11.8)
Rebubbling	5 (21.7)
Allograft rejection	2 (8.7)
Secondary graft failure	2 (8.7)
Re-keratoplasty	2 (8.7)
Cataract	1 (33.3) ^a

FU = follow-up; IOP = intraocular pressure.

Postoperative follow-up time (mean ± SD) was 19 ± 17 months.

^aOne out of 3 phakic eyes developed cataract and underwent phacoemulsification at 15 months after Descemet membrane endothelial keratoplasty.

an IOP elevation, which could be reversed by partial air removal from the anterior chamber (Table 3). Interestingly, the same eye developed inflammation and spontaneous graft detachment (≥1/3 of the graft surface area) after the patient switched from dexamethasone to fluorometholone drops at 1 month postoperatively. After the eye was treated with an intensified regimen of topical steroids, it received secondary Descemet stripping endothelial keratoplasty (DSEK). IOP elevation was observed in 2 of 23 (9%) cases (Cases 10 and 16) and occurred at 1 month and 6 months postoperatively, respectively. In both cases the patients were suspected to be steroid responders, and after the steroid load was reduced and topical beta-blockers were applied, the IOP normalized.

Visually significant graft detachment requiring rebubbling was observed in 5 of 23 (22%) cases (Cases 3, 7, 13, 14a, and 20). In Case 3, all the air in the anterior chamber had escaped through the glaucoma shunt tube by the end of the operation. Because the postoperative AS-OCT showed a paracentral, ≥1/3 inferior detachment, the eye underwent immediate rebubbling and the anterior chamber was left with a complete air fill. At 1 day postoperatively, AS-OCT examination showed a fully attached graft. Cases 7, 13, and 14a (<1/3 of the graft surface area) and Case 20 (≥1/3 of the graft surface area) underwent rebubbling for graft detachment at 1 week postoperatively. In Case 20, the graft detachment persisted and the eye underwent successful DSAEK at 2 months postoperatively.

Allograft rejection was suspected in Case 7 at 7 months postoperatively and was treated with an intensified regimen of topical steroids. Case 2 developed an allograft rejection at 9 months postoperatively and was successfully treated with topical steroids (Figure 2). Secondary graft failure

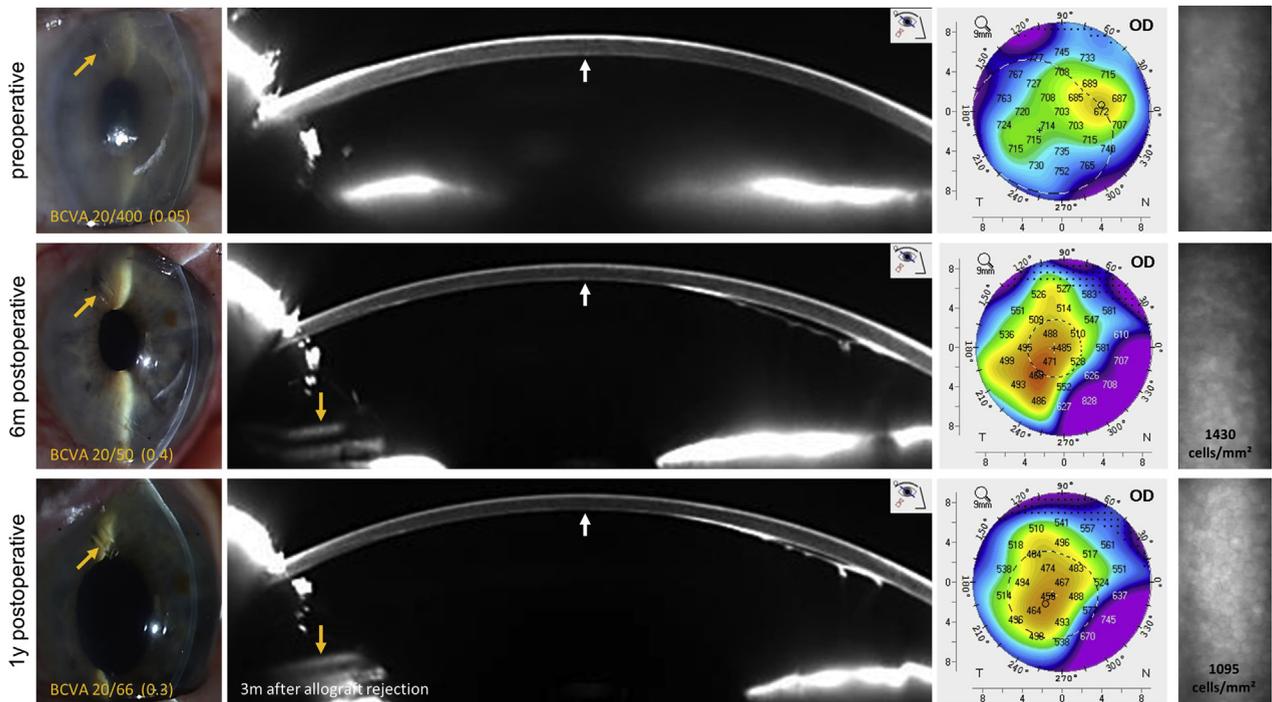


FIGURE 2. Slit-lamp images, Scheimpflug overviews, and pachymetry and specular microscopy images before and after Descemet membrane endothelial keratoplasty (DMEK). Images are shown for an eye (Case 2) preoperatively (Top row), at 6 months (Second row), and at 1 year after DMEK (Third row). Note the glaucoma drainage device superotemporally (orange arrows) and the deturgescence of the cornea (white arrows). The eye developed an allograft rejection at 9 months postoperatively, which was successfully reversed with an intensified regimen of topical steroids.

was observed in 2 of 23 (9%) cases (Cases 14a and 15a), which underwent successful re-DMEK at, respectively, 26 and 30 months postoperatively.

One of 3 phakic eyes developed cataract in the postoperative course and received phacoemulsification and posterior chamber lens implantation at 15 months postoperatively.

DISCUSSION

IN THE CURRENT STUDY, THE CLINICAL OUTCOMES OF DMEK in eyes with a GDD were evaluated. While several research groups have reported outcomes of PK and DS(A)EK in eyes with a GDD, reports on DMEK are few, with small sample sizes and short-term follow-up (Table 4).^{3-12,18-26} In addition, for the available keratoplasty studies heterogeneity in study design—for example “mixed study groups” (shunt tube vs trabeculectomy vs trabeculectomy and shunt tube)—poses a challenge when interpreting results.

Our study showed lower graft survival rates for DMEK in eyes with a GDD compared to our standard DMEK cohort.²⁷ At 1 year postoperatively, survival probability was still at 89% for our study group, which decreased to

67% at 2 years postoperatively. This fast drop in survival probability was also reported after PK and DSAEK in eyes with a GDD (Table 4) and might be an inherent problem for this group of eyes, taking their complexity into account. For these cases, counseling patients regarding the graft survival prognosis and the higher risk of needing to undergo re-endothelial keratoplasty may be even more important, so that patients can anticipate this.

The presence of a GDD also seems to negatively affect donor ECD, as ECD decrease was higher at 12 months postoperatively (71%) than previously reported for our standard DMEK cohort.²⁷ The incidence of secondary graft failure was also higher than after standard DMEK, but occurred less frequently than compared to DSAEK (26%-50%) and PK (30%-70%) in eyes with a GDD.^{3-5,8,18,19,21,22,24-26}

The underlying cause of the greater ECD decrease and higher graft failure rates in the presence of a GDD has been described to be “multifactorial”. Firstly, changes in aqueous humor circulation patterns owing to a glaucoma shunt tube tube may adversely affect the endothelial cell viability.^{23,24,28,29} Secondly, the GDD itself may induce a breach in the blood-aqueous barrier by intermittent tube-uveal touch and/or chronic trauma by intermittent tube-corneal touch caused by heavily rubbing or forcefully blinking, resulting in an increase of influx of oxidative,

TABLE 4. Overview of Previously Published Studies on Penetrating Keratoplasty or Endothelial Keratoplasty in Eyes With a Glaucoma Drainage Device

Type of Surgery	Year	Author	No. of Cases	Mean FU Time (Months)	Graft Detachment, % (N)	Allograft Rejection, N (%)	Graft Survival, % (Duration)
PK	2001	Kwon et al ¹⁸	GDD n = 55	34	n.a.	Immunologic 7 (13%); Nonimmunologic 17 (31%)	70 (24 m) 55 (37 m) 40 (89 m)
	2004	Alvarenga et al ¹⁹	GDD n = 40	18	n.a.	n.a.	30
	2010	Witmer et al ²⁰	GDD n = 51	38	n.a.	1 (after cessation of topical steroids)	61
	2010	Hollander et al ⁵	GDD n = 77	n.a.	n.a.	Overall 13 (17%)	89 (12 m) 67 (24 m) 64 (36 m) 41 (48 m)
PK/DSEK	2012	Knape et al ¹⁶	GDD n = 28	60	n.a.	13 (46%)	43
	2017	Iverson et al ⁸	PK GDD n = 21 DSEK GDD n = 12	23 14	n.a. 25 (3)	2 (10%) 0	62 58
DS(A)EK	2011	Wiaux et al ²	Surgically treated n = 56 (52 eyes); GDD n = 33 (29 eyes)	12	12.5 (7/56)	3/52 (6%)	87.5 [7/56]
			Trab n = 29				
	2012	DeCroos et al ²¹	Trab n = 20; GDD n = 27;	24	5 26	2 (3%)	95 74
			multiple GDD n = 12; GDD + Trab n = 12		30 8.3		80 66.7
			Trab n = 18 Trab + GDD n = 11	44	16.7 18.2	n.a.	83.3 72.7
	2012	Nguyen et al ²²	GDD n = 35		17.1		74.3
			GDD n = 11	20	36.4	36.4	18.2
	2012	Anshu et al ³	Trab n = 26; Trab + GDD n = 10; GDD n = 10	Up to 60	n.a.	Overall 6 (13%)	Overall 59
			GDD n = 18	24	50	n.a.	50
	2014	Aldave et al ⁴	Total 76 Trab n = 37; GDD n = 61;	21	13.5 (5/37) 18.0 (11/61)	5/35 (14.3%) 6/52 (11.5%)	84 74
2015	Ni et al ²⁵	Trab + GDD n = 15		0	2/14 (14.3%)	93	
		GDD n = 24	12	2	n.a.	87	
			24 36			80 70	

Continued on next page

TABLE 4. Overview of Previously Published Studies on Penetrating Keratoplasty or Endothelial Keratoplasty in Eyes With a Glaucoma Drainage Device (Continued)

Type of Surgery	Year	Author	No. of Cases	Mean FU Time (Months)	Graft Detachment, % (N)	Allograft Rejection, N (%)	Graft Survival, % (Duration)
	2016	Kang et al ²⁶	129 cases/102 eyes Trab n = 62 GDD n = 26; Trab + GDD n = 14 GDD n = 14	29	33.9 (21) 42.3 (11) 35.7 (5) Overall 0	Overall 9 (8.8%)	65 54 57 71 36 30
DMEK	2011	Bersudsky et al ⁹	GDD n = 1	12	0	0	100
	2013	Heindl et al ¹⁰	GDD n = 2	12	50	0	100
	2015	Liarakos et al ¹¹	GDD n = 1	6	0	0	100
	2017	Aravena et al ¹²	Total 60; GDD = 23	10	Overall 23.2	Immunogenic 4 (3 after cessation of topical steroids and 1 in the control group)	100

DMEK = Descemet membrane endothelial keratoplasty; DS(A)EK = Descemet stripping (automated) endothelial keratoplasty; EK = endothelial keratoplasty; FU = follow-up; GDD = glaucoma drainage device; n.a. = not available; PK = penetrating keratoplasty; Trab = trabeculectomy.

apoptotic, and inflammatory proteins, potentially causing corneal endothelial damage.^{28,30,31} Kim and associates similarly showed progressive decrease of the ECD in the first year after Ahmed valve implantation without keratoplasty in eyes with a GDD and even showed that cell loss was highest in the area of the tube.³²

Graft detachment was the main postoperative complication, with 22% of eyes requiring a rebubbling procedure. While this is comparable to rates reported in other series after DSAEK (17%-50%) and DMEK (24%),^{4,12,21-24} it is significantly higher than for our standard DMEK cohort.²⁷ This may reflect that eyes with a GDD are more prone to surgical complications, which is possibly related to the added difficulty of pressurizing these eyes with air at the conclusion of the operation.

The allograft rejection rate observed in this study is similar to the rates reported for DSAEK (7%-14%)^{3,4,7} but lower than the 10%-40% reported for PK.^{5,6,8,18} A possible explanation for the lower rejection rate may be the lower antigen load with reduction of the graft tissue. While our allograft rejection rate for DMEK in eyes with a GDD may seem higher than the 1%-2% that we have reported for standard DMEK before,³³ the current study concerns a relatively small sample size and results should be interpreted with caution.

Most of the observed postoperative complications are thus inherent to the presence of a GDD but might partly be mitigated by special surgical considerations. These may include the following: (1) creating the main incision in such a way that a preexisting filtering bleb of a trabeculectomy or a GDD is preserved (more corneal rather than limbal) and the superior conjunctiva is spared for possible future glaucoma surgery; (2) trimming or displacing the shunt tube laterally in order to avoid donor endothelial cell damage; (3) unfolding the Descemet graft over the tube rather than over the iris; (4) maintaining a complete air fill of the anterior chamber for 90-120 minutes (instead of 45-60 minutes) with repetitive air injections in between, if required; (5) leaving a 100% air bubble at termination of the surgery, since the risk of pupillary block glaucoma may be relatively small owing to the presence of a preexisting peripheral iridotomy and the tube shunt.

The limitations posed by the retrospective study design and the relatively small sample size of this study may be surpassed by additional prospective studies of larger sample size and longer follow-up terms, possibly with control groups (no glaucoma, medically treated glaucoma/glaucoma without previous glaucoma surgery, and trabeculectomy/shunt tube only).

In conclusion, with specific surgical modifications, DMEK provided acceptable clinical outcomes when taking the complexity of eyes with a GDD into account.

The presence of a GDD, however, may reduce graft survival times and may pose a risk for more frequent regrafting.

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