Descemet membrane endothelial keratoplasty (DMEK) for Fuchs endothelial dystrophy: review of the first 50 consecutive cases

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Abstract

Purpose: To evaluate the clinical outcome and complications of Descemet membrane endothelial keratoplasty (DMEK), using Descemet-stripping endothelial keratoplasty (DSEK) as a back-up procedure, in the management of Fuchs endothelial dystrophy. **Design:** Non-randomised prospective clinical study.

Methods: The first fifty consecutive eyes that underwent DMEK, that is, transplantation of an isolated donor Descemet membrane carrying its endothelium, for Fuchs endothelial dystrophy were evaluated. In all eyes, the best-corrected visual acuity (BCVA) as well as the endothelial cell density (ECD) was measured before and at 6 months after surgery, as clinical outcome parameters. **Results:** Ten patients required a secondary DSEK for failed DMEK. In the remaining 40 DMEK eyes, 95% had a BCVA of $\geq 20/40$ (≥ 0.5) and 75% $\geq 20/25$ (≥ 0.8) at 6 months after surgery. ECD averaged 2618 (± 201) cells/mm² before, and 1876 (± 522) cells/mm² at 6 months after surgery ($n = 35$). When the outcomes of DMEK and secondary DSEK procedures were combined, 94% reached a BCVA of $\geq 20/40$ (≥ 0.5) and 66% $\geq 20/25$ (≥ 0.8) ($n = 47$), and ECD averaged 2623 (± 193) cells/mm² before, and 1815 (± 578) cells/mm² at 6 months after surgery ($n = 43$).

Conclusion: With DSEK as a back-up procedure, DMEK may provide relatively quick and complete visual rehabilitation in a majority of patients operated on for Fuchs

endothelial dystrophy. Endothelial cell survival may be similar to earlier types of (lamellar) keratoplasty. Early graft detachment was the main complication in this first series of DMEK surgeries for Fuchs endothelial dystrophy.

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Introduction

Since 1998, we introduced various techniques for endothelial keratoplasty, that is, the replacement of the corneal endothelium without corneal surface incisions or corneal sutures, as an alternative to penetrating keratoplasty (PK) in the management of corneal endothelial disorders.^{1–6} These techniques have been popularised in the United States as ‘deep lamellar endothelial keratoplasty’ (DLEK),^{7,8} and (femtosecond) Descemet stripping (automated) endothelial keratoplasty (DSEK/DSAEK/FS-DSEK).^{9–12} In 1998, we also described a technique for selective transplantation of Descemet membrane through a self-sealing 3.5 mm clear corneal incision,^{13,14} tentatively named Descemet membrane endothelial keratoplasty (DMEK).^{15–18}

As PK has been the gold standard for keratoplasty for almost a century,¹⁹ an

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alternative technique should bring major advantages in clinical outcome, reducing complications as well as technical feasibility, to get accepted and to change a long-standing consensus in ophthalmology. The early forms of endothelial keratoplasty, that is, DLEK and DSEK/DSEK, may have shown that the visual outcome could compete with PK, whereas the most frequent long-term complications were minimised.^{1–11} Endothelial keratoplasty shows little induced astigmatism because the recipient corneal surface is not compromised; suture-related problems are eliminated as endothelial keratoplasty requires no (corneal) sutures; and wound healing-related complications are rare, because instead of a circular corneal wound, the procedure can be performed through a self-sealing limbal or scleral tunnel incision.

In the current prospective study, we evaluated what clinical outcome and/or complications may be anticipated in patients with Fuchs endothelial dystrophy managed by DMEK, with DSEK as a back-up procedure in the event of DMEK graft failure.

Materials and methods

Fifty consecutive eyes of 46 patients suffering from Fuchs endothelial dystrophy underwent a DMEK procedure, as described earlier.^{14,15} Twenty-three patients were men and 27 women, ranging from 41 to 88 years of age (Table 1). All patients signed an IRB-approved informed consent.

From donor globes obtained less than 36 h postmortem, corneo-scleral buttons were excised and stored by organ culture in modified minimum essential medium at 31 °C.^{17,18} After 1 week of culture, endothelial cell morphology and viability were evaluated and the corneo-scleral buttons were mounted endothelial side up on a custom made holder with a suction cup. Descemet's membrane (DM) was stripped from the posterior stroma, so that a 9.0–10.0 mm diameter flap of posterior DM with its endothelial monolayer was obtained.²¹ Owing to the elastic properties of the membrane, a 'Descemet-roll' formed spontaneously, with the endothelium at the outer side. Each Descemet-roll was then stored in organ culture medium until the time of transplantation.

In recipient eyes, a 9.0 mm diameter epithelial mark was made to outline the area of DM excision. A 3.0 mm tunnel incision was made just within the limbus, entering the anterior chamber just at the mark. With an inversed Sinsky hook (D.O.R.C. International, Zuidland, The Netherlands), a circular portion of DM was scored and stripped from the posterior stroma, so that a 9.0 mm diameter 'descemetorhexis' was created, and the central portion of DM was removed from the eye.^{5,6}

The donor Descemet-roll was stained with a 0.06% trypan blue solution (VisionBlue™ D.O.R.C. International), and sucked into a custom made injector (Hippocratech, Rotterdam, The Netherlands), to transfer the tissue from the culture medium vial to the anterior chamber.^{15,17,18} Using the injector, the donor Descemet-roll was inserted into the anterior chamber and the graft was oriented endothelial side down (donor DM facing recipient posterior stroma) by careful, indirect manipulation of the tissue with air and fluid. While maintaining the anterior chamber with fluid and air, the graft was gently spread out over the iris. Then, an air bubble was injected underneath the donor DM to position the tissue onto the recipient posterior stroma.^{15,17,18} The anterior chamber was completely filled with air for 30–60 min followed by an air-liquid exchange to pressurise the eye. Each surgical procedure was recorded on DVD (Pioneer DVR-RT601H-S, Tokyo, Japan).

In the eye bank, donor endothelial cell density and viability were evaluated *in vitro* with an inverted light microscope (Axiovert 40, Zeiss, Göttingen, Germany), and digital photographs were made (PixelINK PL-A662, Zeiss, Göttingen, Germany).¹⁷ In patient eyes, the endothelium was photographed and evaluated *in vivo* using a Topcon SP3000p non-contact autofocus specular microscope (Topcon Corp, Tokyo, Japan). Images of the central corneal window were analysed and manually corrected and three measurements of endothelial cell density were averaged.

Results

For evaluating the outcome of our study on a first series of 50 consecutive eyes with Fuchs endothelial dystrophy managed by DMEK, two different approaches seem relevant. From a patient's perspective, the overall visual recovery is of interest, to answer the question: 'If DMEK is performed for Fuchs endothelial dystrophy, with DSEK as a back-up procedure in the event of graft failure, what percentage of eyes reaches 20/40 (0.5) or 20/25 (0.8)?' From a scientific perspective, it may be more appropriate to differentiate between the outcome of various endothelial keratoplasty procedures, that is, to evaluate only the successful DMEK cases, to answer the question: 'What visual potential holds DMEK?' Hence, both approaches are displayed below.

Patient's perspective: 6 months visual outcome of corneas transplanted with DMEK, using DSEK as a back-up procedure in the event of DMEK graft failure

Of the 50 eyes included in our study, 40 eyes had a successful primary DMEK (Figure 1). Ten eyes required a

Table 1 Patient data on Descemet membrane endothelial keratoplasty (DMEK) for Fuchs endothelial dystrophy

Patient	No. (No. contra-lateral)	Age (years)	M/F	OD/OS	Concomitant eye conditions	Snellen BCVA			ECD (cells/mm ²)		Remarks
						Preoperative	6 months postoperative		Pre-operative	6 months postoperative	
1 (17)	64	M		OS	Pseudophakic	20/60 (0.3)	20/20 (1.0)		2960	1750	None
3 (21)	72	M		OD	Pseudophakic; pre-existing subepithelial opacities	20/200 (0.1)	20/30 (0.6)		2660	1790	None
4	60	M		OS	Pseudophakic	20/60 (0.3)	20/20 (1.0)		2470	2270	None
5	76	F		OS	Pseudophakic	20/60 (0.3)	20/25 (0.8)		2520	2180	None
6 ^a	59	M		OD	Phakic	20/25 (0.8)	20/20 (1.0)		2480	1790	None
7	74	F		OS	Pseudophakic	20/60 (0.3)	20/28 (0.7)		2640	2730	None
9	41	M		OD	Phakic	20/50 (0.4)	20/20 (1.0)		(2640)	(N.A.)	None
11	71	F		OD	Pseudophakic	20/200 (0.1)	20/25 (0.8)		3150	2860	None
14	88	M		OD	Pseudophakic	20/50 (0.4)	20/100 (0.2)		(2600)	(N.A.)	Persistent partial graft detachment despite rebubble procedure 1 week after DMEK
17 (1)	64	M		OD	Pseudophakic	20/50 (0.4)	20/20 (1.0)		2780	1700	None
19	61	F		OS	Pseudophakic	20/200 (0.1)	20/25 (0.8)		2530	910	None
21 (3)	73	M		OS	Pseudophakic; pre-existing subepithelial opacities	20/80 (0.25)	20/30 (0.6)		2350	1190	None
22	55	F		OS	Pseudophakic	20/60 (0.3)	20/40 (0.5)		2750	1140	Partial detachment managed with re-bubble procedure 2 weeks after DMEK
23	78	F		OD	Pseudophakic	20/100 (0.2)	20/20 (1.0)		2780	2380	None
24	74	M		OD	Pseudophakic	CF	20/30 (0.6)		2430	1820	Persistent partial graft detachment despite rebubble procedure
25 (47)	49	M		OD	Pseudophakic	20/80 (0.25)	20/20 (1.0)		2630	1850	None
26 (38)	48	M		OS	Phakic	20/40 (0.5)	20/20 (1.0)		2500	2260	None
27	75	M		OD	Pseudophakic	20/50 (0.4)	20/40 (0.5)		2830	2280	None
28	45	M		OS	Phakic	20/80 (0.25)	20/20 (1.0)		2700	1430	Air bubble-induced dislocation iris diaphragm at 1 day postoperative
29	63	F		OD	Pseudophakic	20/100 (0.2)	20/20 (1.0)		2420	1720	None
30	62	F		OS	Pseudophakic	20/60 (0.3)	20/20 (1.0)		2930	2100	None
31	81	M		OD	Pseudophakic	20/60 (0.3)	20/25 (0.8)		2800	2350	None
32	75	F		OS	Pseudophakic	20/50 (0.4)	20/20 (1.0)		(2750)	(N.A.)	None
33	56	M		OD	Phakic	20/40 (0.5)	20/40 (0.5)		2630	1670	

Table 1 (Continued)

Patient		Snellen BCVA				ECD (cells/mm ²)		Remarks
No. (No. contra-lateral)	Age (years)	M/F	OD/OS	Concomitant eye conditions	Preoperative	6 months postoperative	Pre-operative	
34	70	F	OD	Pseudophakic	20/200 (0.1)	20/50 (0.4)	(2480)	Small wrinkle centrally in graft Complete graft detachment^b
35	77	F	OS	Pseudophakic	20/40 (0.5)	20/25 (0.8)	2630	Allograft rejection 4 months after DMEK
36	47	F	OS	Phakic	20/50 (0.4)	20/25 (0.8)	(2700)	Persistent complete graft detachment despite 2x re-bubble procedure^b
37	78	F	OD	Pseudophakic	20/60 (0.3)	20/25 (0.8)	2150	None
38 (26)	48	M	OD	Phakic	20/40 (0.5)	20/20 (1.0)	2450	Air bubble-induced dislocation iris diaphragma at 1 day postop and secondary cataract formation
39	59	F	OD	Pseudophakic	20/60 (0.3)	20/23 (0.9)	2350	None
40	77	F	OD	Pseudophakic	CF	20/20 (1.0)	2690	None
42	58	M	OD	Pseudophakic	20/40 (0.5)	20/20 (1.0)	2560	Lieste
43	68	M	OD	Pseudophakic	20/60 (0.3)	20/20 (1.0)	2490	None
44	80	M	OS	Pseudophakic	20/60 (0.3)	20/23 (0.9)	2650	Retinal detachment (with detached macula) 2 months after DMEK
45	65	F	OD	Pseudophakic	20/60 (0.3)	20/23 (0.9)	2650	None
46	74	F	OS	Pseudophakic	20/30 (0.6)	20/20 (1.0)	2520	None
47 (25)	49	M	OS	Pseudophakic	20/100 (0.2)	20/20 (1.0)	2500	None
48	69	F	OS	Pseudophakic	20/60 (0.3)	20/40 (0.5)	2640	20/25 (0.8) at 3 months; lower BCVA at 6 months attributed to PCO
49	61	M	OS	Pseudophakic	20/50 (0.4)	20/25 (0.8)	2470	None
50	68	F	OD	Pseudophakic	20/80 (0.25)	20/20 (1.0)	2950	None
Outcome: 95% BCVA $\geq$ 20/40 (0.5) and 75% BCVA $\geq$ 20/25 (0.8) (n = 40)								2618 ($\pm$ 201) (n = 35)
2	86	F	OD	Pseudophakic	20/60 (0.3)	20/40 (0.5)	2510	Complete DMEK graft detachment: DSEK 3 weeks after DMEK
8	45	F	OD	Phakic	20/40 (0.5)	20/40 (0.5)	2480	Failure of DMEK graft to clear: DSEK 3 weeks after DMEK
Outcome: 95% BCVA $\geq$ 20/40 (0.5) and 75% BCVA $\geq$ 20/25 (0.8) (n = 40)								1876 ($\pm$ 522) (n = 35)

Table 1 (Continued)

Patient	No. (No. contra-lateral)	Age (years)	M/F	OD/OS	Concomitant eye conditions	Snellen BCVA			ECD (cells/mm ²)		Remarks
						Preoperative	6 months postoperative		Pre-operative	6 months postoperative	
10		78	F	OD	Pseudophakic; macular hole	[20/200 (0.1)]	[20/150 (0.15)]		(2520)	(N.A.)	Complete DMEK graft detachment: DSEK 4 weeks after DMEK
12		70	M	OD	Pseudophakic; prior retinal detachment	[20/100 (0.2)]	[20/100 (0.2)]		2690	1580	Complete DMEK graft detachment: DSEK 4 weeks after DMEK
13		57	F	OD	Phakic	20/40 (0.5)	20/40 (0.5)		2890	1990	Failure of DMEK graft to clear: DSEK 3 weeks after DMEK
15		82	F	OS	Pseudophakic	20/80 (0.25)	20/50 (0.4)		2580	800	Complete DMEK graft detachment: DSEK 3 weeks after DMEK
16		70	F	OS	Pseudophakic	20/100 (0.2)	20/40 (0.5)		2640	1820	Partial DMEK graft detachment: DSEK 4 weeks after DMEK
18		70	M	OD	Pseudophakic	20/80 (0.25)	20/25 (0.8)		2860	2690	Complete DMEK graft detachment: DSEK 5 weeks after DMEK
20		57	F	OS	Pseudophakic	20/60 (0.3)	20/40 (0.5)		2480	870	Failure of DMEK graft to clear: DSEK 2 weeks after DMEK
41		68	F	OS	Pseudophakic	20/100 (0.2)	N.A.		(2450)	(N.A.)	Partial DMEK graft detachment: DSEK 4.5 months after DMEK
Outcome: 86% BCVA $\geq$ 20/40 (0.5) and 14% BCVA $\geq$ 20/25 (0.8) (n = 7)									2641 (± 163) (n = 8)	1551 (± 765) (n = 8)	
Overall outcome: 94% BCVA $\geq$ 20/40 (0.5) and 66% BCVA $\geq$ 20/25 (0.8) (n = 47)									2623 (± 193) (n = 43)	1815 (± 578) (n = 43)	

Abbreviations: BCVA = Best corrected visual acuity; DMEK = Descemet membrane endothelial keratoplasty; DSEK = Descemet stripping endothelial keratoplasty; ECD = Endothelial cell density; PCO = Posterior capsule opacification; N.A. = Not available.

^aCorneal decompensation initially diagnosed as bullous keratopathy *etc.*¹⁷ but the recent development of guttata in the contralateral cornea is indicative for bilateral Fuchs endothelial dystrophy.

^bCases 34 and 36 showed spontaneous corneal clearance despite complete graft detachment.²⁰

The bold indicates special cases.

Red = <20/40 (<0.5); Yellow = 20/40–20/28 (0.5–0.7); Blue = >20/25 (>0.8).

Figure 1 Slit-lamp photographs of an eye (case 50) before (a–c) and at 3 months (d–f) after Descemet membrane endothelial keratoplasty (DMEK) for Fuchs endothelial dystrophy. Note the near anatomical restoration of the transplanted cornea as well as its clarity after DMEK.

Figure 2 Slit-lamp photograph of an eye (case 47) 1 day after Descemet membrane endothelial keratoplasty (DMEK). Note the relative clarity of the transplanted cornea. At 1 day postoperative, the BCVA was 0.6 (20/30), despite the presence of the 50% air-fill of the anterior chamber.

secondary DSEK because of complete or partial DMEK graft detachment (cases 2, 10, 12, 15, 16, 18, and 41; Table 1) or failure of the transplanted cornea to clear (cases 8, 13, and 20; Table 1). Of the 50 eyes, 47 eyes (40 DMEK and 7 secondary DSEK) had good visual potential and were available for examination (Cases 10, 12, and 41 were excluded from analysis; Table 1). Of the latter eyes, 94% (44/47) achieved a best corrected visual acuity (BCVA) of 20/40 or better (≥ 0.5) and 66% (31/47) reached 20/25 or better (≥ 0.8) at 6 months after surgery

(Table 1). Three of these 47 eyes did not reach the 20/40 (0.5), which was attributed to partial graft detachment in case 14 and graft detachment in case 34, and case 15 had a low visual acuity despite uneventful secondary DSEK surgery and complete clearance of the transplanted cornea (Table 1).

Scientific perspective: Visual outcome of transplanted corneas with DMEK grafts in situ at 6 months

In 40 eyes the DMEK graft was *in situ* at 6 months. In these eyes, 95% had a BCVA of $\geq 20/40$ (≥ 0.5) and 75% reached $\geq 20/25$ (≥ 0.8) at 6 months after surgery. Interestingly, all of the eyes with a functional DMEK graft obtained a BCVA of 20/40 or better (≥ 0.5). In the 10 DMEK eyes that did not reach 20/25 or better (≥ 0.8) (cases 3, 7, 14, 21, 22, 24, 27, 33, 34, and 48; Table 1), the reduced BCVA could not be explained in three eyes (10%) (cases 7, 22, and 27). In the remaining seven patients, a visual recovery limited to 0.5 to 0.7 (20/40 to 20/28) was attributed to secondary subepithelial stromal scarring due to long-standing dystrophic changes in one patient with bilateral DMEK surgery (cases 3 and 21; Table 1); partial graft detachment just below the corneal centre (cases 14 and 24; Table 1); the presence of a small wrinkle in the central graft area (case 33; Table 1); partial corneal clearance despite complete graft detachment

(case 34; Table 1); and the development of posterior capsule opacification (Case 48; Table 1).

DMEK endothelial cell density

Of the 50 eyes included in our study, pre- and postoperative endothelial cell density (ECD) measurements were available in 43 eyes (35 DMEK and 8 secondary DSEK). The overall donor ECD averaged 2623 (± 193) cells/mm² before, and 1815 (± 578) cells/mm² at 6 months after surgery (Table 1). Of the 40 DMEK eyes, pre- and postoperative ECD measurements were available in 35 eyes, and donor ECD averaged 2618 (± 201) cells/mm² before, and 1876 (± 522) cells/mm² after surgery (Table 1). Of the 10 eyes with a secondary DSEK procedure, ECD measurements were available in eight eyes. Donor ECD averaged 2641 (± 163) cells/mm² before, and 1551 (± 765) cells/mm² after surgery (Table 1). No significant difference in preoperative as well as postoperative ECD was found among the groups ($P > 0.1$). The drop in ECD between preoperative and postoperative ECD was significant in all groups ($P < 0.05$).

Complications

Seven eyes developed a graft detachment, characterised by the presence of a free-floating Descemet-roll in the anterior chamber (cases 2, 10, 12, 15, 18, 34, and 36; Table 1) and five eyes a partial detachment (cases 14, 16, 22, 24, and 41; Table 1). Seven of these twelve (partial) detachments were managed by a secondary DSEK procedure (cases 2, 10, 12, 15, 16, 18, and 41; Table 1), and one case with a partial detachment (case 22; Table 1) had a successful re-bubbling procedure. In two cases with a partial detachment, the clinical outcome was satisfactory to the patient (cases 14 and 24; Table 1). Two cases (cases 34 and 36; Table 1) showed spontaneous corneal clearance despite graft detachment, with visual recoveries to 20/50 (0.4) and 20/25 (0.8).²⁰ In three eyes (cases 8, 13, and 20; Table 1) that did not show corneal clearance within the first weeks after surgery, a secondary DSEK procedure was performed.

Two cases (cases 28 and 38, Table 1) showed imminent angle-closure glaucoma due to entrapment of residual air behind the iris, with forward dislocation of the iris diaphragm at the first operative day. Although the air bubble could be repositioned towards the anterior chamber by pupillary dilatation, both cases developed a mild anterior subcapsular cataract similar to 'Glaukomflecken' for which a phaco-emulsification was performed at 6 months postoperatively in case 38. One eye (case 35; Table 1) showed an allograft rejection at 4 months after DMEK, and a retinal detachment occurred

in a (anatomically) high myopic eye at 2 months after surgery in case 43 (Table 1).

Discussion

Our study shows that in a first series of 50 consecutive Fuchs endothelial dystrophy patients that underwent a primary DMEK and if indicated a secondary DSEK procedure, the far majority of eyes obtained a Snellen visual acuity of 20/40 or better (≥ 0.5), the threshold for a driving license in various countries. When the three eyes with low visual potential or unavailability were excluded from analysis, over 90% of cases achieved a BCVA of 20/40 or better (≥ 0.5) and two-third reached 20/25 or better (≥ 0.8) at 6 months after surgery (Table 1). When secondary DSEK eyes were excluded from analysis, that is, when only eyes with a DMEK graft *in situ* were considered, $\frac{3}{4}$ of cases showed (nearly) complete visual recovery to 20/25 or better (≥ 0.8). In the latter eyes, the rate of visual rehabilitation was found to be unprecedented: one-third of eyes obtained 20/40 or better (≥ 0.5) within 1 week (Figure 2), and virtually all eyes reached their maximal visual potential at 1–3 months.¹⁸

The overall visual recovery for the whole group as well as that obtained specifically with DMEK, may compare favourably to PK and the early endothelial keratoplasty techniques, like DLEK and DSEK/DSAEK. To the best of our knowledge, there is not a single report in the scientific ophthalmic literature describing a visual outcome in PK even approaching that after DMEK. On average, historic cohort studies on PK for Fuchs endothelial dystrophy report a visual outcome of 20/40 or better at 1 year in only 40–50% of patients.²² These reports may be flattered by contact lens fitting, that commonly meets little compliance with elderly people in the long term. Studies on DSEK/DSAEK generally report a better visual outcome than with PK, with visual acuities up to 20/40 (0.5) in a majority of cases, with only small percentages reaching 20/25 or better (≥ 0.8).^{10,11,19,23} Both in PK and DSEK/DSAEK, a final visual acuity is usually achieved at 6–12 months, whereas most DMEK patients reach their maximal visual potential at 1–3 months.¹⁸

When comparing postoperative endothelial cell densities, a second major clinical outcome parameter in keratoplasty surgery, DMEK outcomes may be roughly similar to those after PK or DSEK/DSAEK. Our study shows an initial decline in donor cell density of approximately 30% at 6 months, mimicking the pre- to postoperative cell loss after other types of keratoplasty.^{12,24–26} Longer term endothelial cell counts may be required to better evaluate how the decline in cell density after DMEK compares to PK and DSEK/DSAEK. As DMEK graft diameters (9.0–10.0 mm) exceed those in

PK (7.0–8.0 mm) and DSEK/DSAEK (8.0–9.0 mm), more endothelium is transplanted, thus longer graft survival might theoretically be expected in DMEK.

In the best of hands, PK is often complicated by long-term complications like high and/or irregular astigmatism, suture-related problems and/or late wound disruption.¹⁶ Although endothelial keratoplasty techniques were designed to minimise these problems, a detailed analysis may be warranted regarding the incidence and severity of complications after DMEK, to evaluate how the latter technique compares to PK. As in DSEK/DSAEK, graft detachment initially stood out as the major drawback of performing DMEK.^{10,17} In the current study, (partial) graft detachment in 25% (12/50) of eyes, consistently within the first week after surgery, was also found to be the main complication after DMEK (Table 1). Nine of these detachments were clustered within the first 25 eyes (that is, a 36% detachment rate), whereas only three detachments occurred in the last 25 eyes (that is, a 12% detachment rate). Although possibly just due to a learning curve, detachments may also have been reduced by two changes in surgical and eye banking techniques. First, we extended the duration of a complete air-fill of the anterior chamber at termination of the surgery from 30 to 45–60 min. Second, we eliminated the use of plastic vials during the entire tissue processing, for electrostatic charges may somehow relate to changes in surface tension of the relative thin, isolated Descemet graft.

The clinical course of the detachments varied. Five complete detachments were managed with a secondary DSEK procedure (cases 2, 10, 12, 15, and 18), whereas two cases (cases 34 and 36) showed spontaneous corneal clearance despite graft detachment, with visual recovery up to 20/25 (0.8).²⁰ Of the five partial detachments, one case (case 22) had a successful re-bubbling procedure, two were managed by secondary DSEK procedures (cases 16 and 41), and the clinical outcome was satisfactory to the patient in two cases (cases 14 and 24). In three cases (cases 8, 13, and 20; Table 1), the transplanted cornea failed to clear within the first weeks after surgery, despite complete DMEK graft adherence. As all grafts showed acceptable ECDs when examined after explantation in the eye bank, in retrospect the secondary DSEK procedure may have been conducted prematurely. Some Descemet grafts may show no apparent clearance for 6–8 weeks. Case 17 proved a turning point in our clinical management to postpone a secondary surgery if persistent postoperative corneal decompensation is accompanied by complete graft adherence: being scheduled for re-operation, the transplanted cornea showed complete clearance with visual recovery to 1.0 at 2 months after the DMEK surgery.

Other complications following the DMEK surgery included an allograft rejection at 4 months after DMEK (case 35; Table 1), and a retinal detachment in a highly

myopic eye at 2 months after surgery (Case 43; Table 1). Both complications seemed isolated events and may therefore be considered coincidental. In two cases (cases 28 and 38; Table 1) an iatrogenic cataract developed due to entrapment of the 50% air-bubble (left *in situ* in the anterior chamber at the termination of the surgery) behind the iris, with forward dislocation of the iris diaphragm. Although peripheral iridotomies were routinely made with the Argon-YAG laser prior to DMEK surgery to prevent angle-closure glaucoma, an iridotomy is not effective in preventing glaucoma due to air-bubble dislocation with mechanical displacement of the iris diaphragm. In both cases, displacement of air behind the iris occurred during surgery, so that in cases with preoperative air dislocation, postoperative medication for pupillary dilatation may routinely be prescribed.

Compared to DSEK/DSAEK, a major advantage of DMEK may be that the donor Descemet can be stripped directly from a corneo-scleral rim, without the need for a microkeratome or femtosecond laser. As donor corneal tissue is commonly distributed as corneo-scleral rims by most eye banks throughout the world, the accessibility to endothelial keratoplasty may be far better with DMEK than with DSEK/DSAEK. Even in third world countries or in low volume keratoplasty centres with a limited budget for equipment, DMEK may prove a feasible technique although requiring minimal financial investment.

In conclusion, our study shows that DMEK is a feasible procedure with a relatively short learning curve, although DMEK may require specific training in surgical technique and tissue handling. With regard to visual outcome and endothelial cell density as clinical outcome parameters, the incidence and severity of complications, as well as technical and logistic feasibility, DMEK may soon be preferred over PK and DSEK/DSAEK, in the management of Fuchs endothelial dystrophy.

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References

- 1 Melles GRJ, Eggink FAGJ, Lander F, Pels E, Rietveld FJR, Beekhuis WH *et al*. A surgical technique for posterior lamellar keratoplasty. *Cornea* 1998; **17**: 618–626.

- 2 Melles GRJ, Lander F, Beekhuis WH, Remeijer L, Binder PS. Posterior lamellar keratoplasty for a case of pseudo-phakic bullous keratopathy. *Am J Ophthalmol* 1999; **127**: 340–341.
- 3 Melles GRJ, Lander F, van Dooren BTH, Pels E, Beekhuis WH. Preliminary clinical results of posterior lamellar keratoplasty through a sclerocorneal pocket incision. *Ophthalmology* 2000; **107**: 1850–1857.
- 4 Melles GRJ, Lander F, Nieuwendaal C. Sutureless, posterior lamellar keratoplasty. *Cornea* 2002; **21**: 325–327.
- 5 Melles GR, Wijdh RH, Nieuwendaal CP. A technique to excise the descemet membrane from a recipient cornea (descemetorhexis). *Cornea* 2004; **23**: 286–288.
- 6 Melles GRJ, Kamminga N. Techniques for posterior lamellar keratoplasty through a scleral incision. *Ophthalmologie* 2003; **100**: 689–695.
- 7 Terry MA, Ousley PJ. Deep lamellar endothelial keratoplasty in the first United States patients: early clinical results. *Cornea* 2001; **20**: 239–243.
- 8 Terry MA, Ousley PJ. Small-incision deep lamellar endothelial keratoplasty (DLEK): six-month results in the first prospective clinical study. *Cornea* 2005; **24**: 59–65.
- 9 Price Jr FW, Price MO. Descemet's stripping with endothelial keratoplasty in 200 eyes. Early challenges and techniques to enhance donor adherence. *J Cataract Refract Surg* 2006; **32**: 411–418.
- 10 Price MO, Price FW. Descemet's stripping endothelial keratoplasty. *Curr Opin Ophthalmol* 2007; **18**: 290–294.
- 11 Gorovoy MS. Descemet-stripping automated endothelial keratoplasty. *Cornea* 2006; **25**: 886–889.
- 12 Cheng YY, Hendrikse F, Pels E, Wijdh RJ, van Cleynebreugel H, Eggink CA *et al*. Preliminary results of femtosecond laser-assisted descemet stripping endothelial keratoplasty. *Arch Ophthalmol* 2008; **126**: 1351–1356.
- 13 Melles GRJ, Rietveld FJR, Pels E, Beekhuis WH, Binder PS. Transplantation of Descemet's membrane carrying viable endothelium through a small scleral incision. *Invest Ophthalmol Vis Sci* 1998; **39**(suppl): S76, abstract no 343.
- 14 Melles GRJ, Rietveld FJR. Transplantation of Descemet's membrane carrying viable endothelium through a small scleral incision. *Cornea* 2002; **21**: 415–418.
- 15 Melles GRJ, Ong TS, Ververs B, van der Wees J. Descemet membrane endothelial keratoplasty (DMEK). *Cornea* 2006; **25**: 987–990.
- 16 Melles GRJ. Posterior lamellar keratoplasty. DLEK to DSEK to DMEK. (editorial). *Cornea* 2006; **25**: 879–881.
- 17 Melles GRJ, Ong TS, Ververs B, van der Wees J. Preliminary clinical results of Descemet membrane endothelial keratoplasty (DMEK). *Am J Ophthalmol* 2008; **145**: 222–227.
- 18 Ham L, Balachandran C, Verschoor CA, van der Wees J, Melles GRJ. Visual rehabilitation rate after isolated Descemet membrane transplantation: Descemet membrane endothelial keratoplasty (DMEK). *Arch Ophthalmol* 2009; in press.
- 19 Bahar I, Kaiserman I, McAllum P, Slomovic A, Rootman D. Comparison of posterior lamellar keratoplasty techniques to penetrating keratoplasty. *Ophthalmology* 2008; **115**: 1525–1533.
- 20 Balachandran C, Ham L, Verschoor MA, Ong TS, van der Wees J, Melles GRJ. Spontaneous corneal clearance despite graft detachment in Descemet membrane endothelial keratoplasty (DMEK). *Am J Ophthalmol* 2009; in press.
- 21 Lie JT, Van der Wees J, Melles GRJ. Donor tissue preparation for Descemet membrane endothelial keratoplasty (DMEK). *J Cataract Refract Surg* 2008; **34**: 1578–1583.
- 22 Williams KA, Muehlberg SM, Lewis RE, Coster DJ. How successful is corneal transplantation? A report from the Australian Corneal Graft Register. *Eye* 1995; **9**: 219–227.
- 23 Chen ES, Terry MA, Shamie N, Hoar KL, Friend DJ. Descemet-stripping automated endothelial keratoplasty: six-month results in a prospective study of 100 eyes. *Cornea* 2008; **27**: 514–520.
- 24 van Dooren BTH, Mulder P, Nieuwendaal CP, Beekhuis WH, Melles GRJ. Endothelial cell density after posterior lamellar keratoplasty (Melles technique); 3 years follow-up. *Am J Ophthalmol* 2004; **138**: 211–217.
- 25 Busin M, Bhatt PR, Scorcia V. A modified technique for descemet membrane stripping automated endothelial keratoplasty to minimize endothelial cell loss. *Arch Ophthalmol* 2008; **126**: 1133–1137.
- 26 Chen ES, Terry MA, Shamie N, Phillips PM, Friend DJ, McLeod SD. Descemet-stripping automated endothelial keratoplasty: insertion using a novel 40/60 underfold technique for preservation of donor endothelium. *Cornea* 2008; **27**: 941–943.