Preoperative Evaluation in Descemet Membrane Endothelial Keratoplasty for Secondary Penetrating Keratoplasty Graft Failure

Khaled Safadi (khaled.safadi@gmail.com)
Hadassah Medical Center https://orcid.org/0000-0002-6425-8479

Ron Kaufman
Hadassah Medical Center

Eleanor Nche
Hadassah Medical Center

Denise Wajnsztajn
Hadassah Medical Center

Itay Lavy
Hadassah Medical Center

Research article

Keywords: Anterior-Segment Optical Coherence Tomography, Cornea, Descemet Membrane Endothelial Keratoplasty, Graft failure, Penetrating Keratoplasty, Preoperative evaluation

Posted Date: June 12th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-34409/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

**Background:** Over the past decade, Penetrating Keratoplasty (PKP) graft failure has been increasingly managed by Descemet Membrane Endothelial Keratoplasty (DMEK). Our aim is to emphasize the importance of preoperative evaluation by Anterior-Segment Optical Coherence Tomography (AS-OCT) and present the clinical outcomes and surgical modifications of DMEK performed for Secondary PKP graft failure.

**Methods:** A retrospective medical records review of patients that underwent DMEK for failed PKP at Hadassah Medical Center in 2018-2019. Collected data included demographic characteristics, PKP graft size measured by AS-OCT, corneal donor endothelial cell density (ECD), intra-operative surgical method adjustments, post-operative complications, visual acuity in Snellen (VA), central pachymetry and post-operative ECD.

**Results:** Included were 16 patients (9 males) and 16 eyes. The study period was 18 months. Mean age at performing DMEK was 63 years. Before DMEK, mean VA and central pachymetry were 0.04 and 685µm, respectively. At last follow up, they significantly improved to 0.3 (p-value=0.001) and 542µm (p-value=0.008) respectively. Mean ECD for donor grafts was 2662 cells per mm$^2$. Post-operative ECD was available only for 7 cases with a mean of 1391 cells per mm$^2$ (p-value=0.0002). At last follow up, 93.75% of the grafts were attached. Graft failure rate was 6.25% due to late decompensation, graft detachment rate and rebubbling rate were 18.75% respectively.

**Conclusion:** A suitable case-based pre-operative evaluation by AS-OCT may play a vital role in DMEK for failed PKP. No less important is to take into consideration multiple surgical adjustments. Both may further decrease complications rates along with accelerating visual recovery.

**Background**

Endothelial keratoplasty (EK) has recently became a viable surgical treatment in patients with secondary graft failure after penetrating keratoplasty (PK)[1]. About a decade ago, secondary PK graft failure was mostly treated by repeating full-thickness PK. However, repeating PKP (re-PKP) has multiple complications including a higher risk for allograft rejection, high risk of infections from loose sutures and their removal, scarring and thinning of the host cornea from sutures, increased risk of ocular surface disease and slow visual recovery[2, 3].

Over the last decade, failed PK graft has been increasingly managed by EK underneath the PK graft in the form of Descemet stripping (automated) endothelial keratoplasty (DSEK/DSAEK) or Descemet membrane endothelial keratoplasty (DMEK)[4–7]. Compared to re-PKP, it is believed that EK has a lower risk of allograft rejection and better clinical outcomes[2, 8, 9]. Besides, EK grafts do not require “open-sky” surgery, thereby reducing the risk of intraoperative and postoperative complications[10–14].
In comparison with DSEK/DSAEK, DMEK provides more selective replacement of the corneal endothelium resulting in smaller incisions, lower risk of allograft rejection and better visual and clinical outcomes[15]. Furthermore, the thinner and more flexible DMEK graft may be better suitable for positioning underneath a failed PK graft. It may achieve better apposition than the stiffer DSEK graft, favorable adjustment to the irregular posterior surface or across the posterior PK wound and covers a bigger surface area[16, 17]. However, the outcomes of DMEK for failed PK graft may not equal those of primary DMEK. Einan-Lifshitz et al.[18] found higher primary failure rates in DMEK compared with those reported for DSAEK after PKP attributed to persistent postoperative graft detachment. They also found high long-term failure rate, 43% of eyes in the DMEK group and 50% of eyes in the DSAEK group. This may be explained by immune-sensitized eyes due to previous transplant, higher rebubbling rates, intraoperative over-manipulation of the DMEK graft due to compromised anterior chamber structures and a different type of wound-healing response[19].

Our study aims to emphasize the importance of preoperative evaluation by Anterior-Segment Optical Coherence Tomography (AS-OCT) and present the clinical outcomes of 16 DMEK surgeries performed for secondary PK graft failure. In addition, the study focuses on adjustments and modifications to our surgical technique.

**Methods**

A retrospective review of data collected on 16 consecutive eyes of 16 patients who underwent DMEK surgery under a failed PK graft between 2018–2019 at Hadassah Medical Centre in Jerusalem, Israel. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Hebrew University of Jerusalem, Israel.

All surgeries were performed by a single surgeon (I.L) or directly supervised by him. Collected data included demographic characteristics, number of previous corneal transplants, donor corneal endothelial cell density (ECD), intraoperative and postoperative complications including DMEK graft detachment, number of rebubbling procedures, rejection episodes, graft failure, visual acuity in Snellen (VA), central pachymetry and post-operative ECD.

**Pre-Operative Graft Size Assessment and Donor Tissue Preparation**

Each patient underwent Anterior-Segment Optical Coherence Tomography (AS-OCT – Casia 2 Cornea/Anterior Segment OCT and Accessories, TOMEY GmbH) pre-operatively in order to assess the optimal DMEK graft size according to the original PK graft size and morphological features such as bulging posterior graft-host interphase scarring and anterior synechiae, the latter were assessed to consider removing them during the surgery (Figs. 1 and 2).
From donor globes, corneoscleral buttons were excised less than 24 hours postmortem and stored in organ culture medium at 5 °C. Endothelial cell density was checked using Konan CellChek D Donor Cornea Analytics CD-15 specular microscope. The basic standardized donor tissue preparation technique has been already described\[19\]. DMEK graft sizes ranged between 7.5–8.5 mm diameter. The required DMEK graft size was assessed by AS-OCT (Figs. 1 and 2) according to pre-operatively PK graft size.

**Surgical Technique and Multiple Adjustments**

The basic standardized DMEK surgical technique has been already described\[20\]. However, variability in the posterior corneal surface of the recipient due to the presence of the PK graft, as well as the potential restrictions of the PK graft–host junction, required some adjustments and particular manipulations.

Pre-operative sub-tenon Triamcinolone 40 mg was injected at the beginning of the surgery after sub-tenon local anaesthesia. The 2.4-mm wide corneal incision was performed in the host peripheral corneal rim without penetrating the PK graft. Descemetorhexis was started from the center of the PK graft and was completed in a curvilinear pattern along the PK wound in a manner resembling capsulorhexis. It was performed under air or fluid maintainer using a reversed Sinskey hook. If scars in the graft-host interphase or anterior synechia existed, they were frequently removed with reversed Sinskey hook, intraocular serrated tweezers, intraocular retinal scissors or with a vitrectomy probe accordingly (Fig. 3, A-C).

The donor Descemet-roll was then injected to the anterior chamber preferably, in a double scroll fashion. After confirming the correct orientation of the graft by intraoperative AS-OCT (Rescan 700 by Zeiss), when available, or the “Montsouris” sign where the graft is rolled over the tip of the cannula and assures correct orientation of endothelial side down and donor descemet membrane facing the recipient posterior stroma, the graft was unfolded by careful indirect manipulations with air and fluid\[20\]. In most of the more complicated cases, to prevent over-manipulations of the graft, a small air bubble was injected underneath the donor DM to position the tissue onto the recipient posterior stroma and then centering the graft by the “wave maneuver”; gentle tap and horizontal slide on the top of the cornea with the 27G cannula tip in a way like the “L” letter (Fig. 3, D and E). Some of the grafts were under-sized, in purpose not to be positioned underneath the PK graft–host junction. In cases with a glaucoma drainage device, the presence of the tube in the anterior chamber required specific additional maneuvers\[4\].

At the end, the anterior chamber was filled 80–100% with 20% SF6 gas and the eye was left pressurized (Fig. 3F). After 2–3 hours, the patient was checked on slit lamp to evaluate the intraocular pressure. If needed, a release of fluid/air/gas from the anterior chamber by pressing on the lower paracentesis with a 27-gauge needle was performed.

**Postoperative Management**

Postoperative visual acuity was measured using the Snellen visual acuity chart in decimals, post-operative AS-OCT was done to evaluate graft attachment and to measure central pachymetry (Fig. 2). In case of DMEK graft detachment of more than a third of the graft surface area or central detachment
affecting the visual axis, a rebubbling procedure was indicated. The main outcome measures were visual
acuity, central pachymetry, rebubbling rate and complications after surgery. Endothelial cell density was
checked, when the patient could afford performing the test, using CellChek XL Konan Medical specular
microscope. Cystoid macular edema (CME) was assessed one month after surgery using Spectralis
Spectral-Domain OCT machine (SD-OCT, Heidelberg Engineering, Heidelberg, Germany).

Statistical Analysis

Data were recorded in Microsoft Excel and analyzed using Microsoft Excel and GraphPad Prism 7. For
statistical significance testing of interval scale parameters, the One-way-ANOVA test was used to
compare results preoperatively, one month after surgery and at last follow-up regarding visual acuity and
central pachymetry. T-test was used to compare between ECD of the donor and ECD post-operatively. The
threshold for statistical significance was defined as P-value < 0.05.

Results

Demographic Features

Included were 16 patients (9 males, 56.25%) and 16 eyes. Mean age at performing DMEK was 63 years
(range 37–95). Before performing DMEK for failed PKP, 10 eyes (62.5%) underwent one PKP, 5 eyes
(31.25%) underwent two PKP’s and 1 eye (6.25%) underwent three PKP’s (Table 1). The study period was
18 months, and hence, the follow up period ranged between 4 to 18 months.
Table 1  
– Demographic features

| Patients, Eyes | 16, 16 |
|----------------|--------|
| Gender – Male, Female | 9, 7 |
| Mean age (range) at DMEK Surgery | 63 years (37–95) |

**Number of Previous PKP’s**

| One PKP | 10 (62.5%) |
| Two PKP’s | 5 (31.25%) |
| Three PKP’s | 1 (6.25%) |

**Initial Indications for PKP**

| Keratoconus | 11 (68.75%) |
| Bullous Keratopathy | 2 (12.5%) |
| Glaucoma | 1 (6.25%) |
| Trauma | 1 (6.25%) |
| Fungal keratitis | 1 (6.25%) |

**Lens Status**

| Phakic | 1 (6.25%) |
| Pseudophakic | 15 (93.75%) |

**Previous Glaucoma Surgery**

| Yes | 3 (18.75%) |
| No | 13 (81.25%) |

The most common indication for initial PKP was keratoconus in 11 patients (68.75%). Additional indications included bullous keratopathy in 2 patients (12.5%), corneal edema due to glaucoma, trauma and fungal keratitis in one patient each (6.25%). One eye was phakic (6.25%) and the rest were pseudophakic (93.75%). Two eyes (12.5%) had previous glaucoma surgery (Table 1). The PK grafts size ranged between 7.75–8.25 mm in diameter. DMEK grafts were sized according to the principles previously described after preoperative evaluation by AS-OCT for each eye and ranged between 7.5–8.5 mm in diameter (Figs. 1 and 2).

**Clinical Outcomes**

All surgeries ended with the DMEK graft attached to the posterior part of the PK graft with SF6 bubble supporting the graft. AS-OCT was performed on the same day or a day after the surgery and showed
complete attachment of all DMEK grafts.

Mean visual acuity before performing DMEK was 0.04, one month after DMEK it increased to 0.16 (P-value = 0.08) and at last follow-up it increased to 0.3 and was statistically significant (P-value = 0.001). Regarding mean central pachymetry, measured by AS-OCT, before performing DMEK it was 685 µm, one month after DMEK it decreased to 574 µm and was statistically significant (P-value = 0.04) and at last follow-up it decreased to 542 µm and was statistically significant (P-value = 0.008) (Table 2).

|                                      | Before surgery | 1-month after surgery | Last follow-up (4–18 months) |
|--------------------------------------|---------------|-----------------------|-----------------------------|
| **Mean Visual Acuity** (Snellen decimals) | 0.04          | 0.16 (P-value = 0.08) | 0.3 (P-value = 0.001)      |
| **Mean Central Pachymetry** (µm)     | 685           | 574 (P-value = 0.04)  | 542 (P-value = 0.008)      |
| **Mean Endothelial Cells Density** (cells/mm\(^2\)) | 2662\(^a\) | N/A                   | 1391\(^b\) (P-value = 0.002) |

\(^a\)-The mean ECD before surgery in the DMEK donor grafts.

\(^b\)-The mean ECD after DMEK surgery in recipients who performed specular microscopy test.

At last follow-up, 15 out of 16 eyes (93.75%) had a fully attached graft with a clear cornea (Table 3). Graft failure was observed only in one eye 10 months after surgery (failure rate was 6.25%). It was diagnosed with late decompensation and treated successfully with a second DMEK. Three eyes had a partially detached graft during their follow up period and underwent a rebubbling procedure (significant detachment of more than 1/3 of the graft and rebubbling rates were 18.75% respectively). All rebubbling procedures were successful with fully attached grafts afterward at their last follow-up; at least 4 months after the procedure. In addition, no rejection episodes were observed along the study follow up period, except in one eye that at last two follow up visits, early rejection signs were suspected. Therefore, immediate anti-inflammatory corticosteroids treatment was administered which successfully hindered the immune reaction and kept the cornea clear.
Table 3
- Postoperative complications

| Attached grafts with clear cornea at last follow-up | 15 (93.75%) |
|-----------------------------------------------------|-------------|
| Detached grafts after surgery (before rebubbling procedure) | 3 (18.75%) |
| Rebubbling procedures | 3 (18.75%) |
| Graft failure (late decompensation) | 1 (6.25%) |
| Graft rejection | 1 was suspected (6.25%) |

Regarding corneal endothelial cell density (ECD) (Table 2), donor grafts had a mean ECD of 2662 cells/mm². After surgery, on last follow up, only 7 cases had their ECD available with a mean of 1391 cells per mm². In comparison between the two results, there was a statistically significant difference (P-value = 0.0002).

In order to evaluate post-operative CME, posterior segment SD-OCT for the macula was performed one month after surgery. CME was observed only in one eye out of 16 (6.25%, case 12).

Discussion

Preoperative evaluation is fundamentally important in any medical procedure[21]. We believe that using AS-OCT has a vital role in adjusting the surgical steps for each case individually in DMEK for PK graft failure.

Common conclusions have emerged from multiple previous studies regarding the results of DMEK after PKP compared to primary DMEK[16, 18, 19, 22, 23], including higher rebubbling rates, higher endothelial cell density loss, higher late graft failure rates and more demanding surgical technique. Furthermore, glaucoma filtering surgeries, which are probably more prevalent in post-PKP eyes, are considered a significant risk factor for late graft failure, probably as a result of altering the microenvironment in the aqueous humor which accelerates endothelial cell loss[24]. Therefore, based on these eminent conclusions and our experience, additional comprehensive pre-operative AS-OCT evaluation was invested to carefully plan DMEK surgery for each case individually, as well as applying multiple adjustments to our surgical technique, in order to decrease failure rates.

Pre-operative assessment by AS-OCT aimed to evaluate both the PKP graft size and the presence of undesired posterior morphological features, including irregular bulging scars in the graft-host interphase or anterior synechiae (Figs. 1 and 2). Lavy et al.[19] showed that higher detachment rates occurred in oversized grafts. Posterior bulging of graft-host interphase scarring prevents proper graft attachment while anterior synechiae mainly impede intraoperative unfolding DMEK graft and its proper positioning. Therefore, in cases with posterior bulging and no intraoperative plan to dissect the extra tissue, it is important to plan for undersized DMEK graft to reduce the chances of positioning it underneath the PK-host interphase and enhance DMEK graft attachment post-operatively (Fig. 2, C and D). Moreover,
evaluating the presence of posterior morphological features and considering their removal during surgery, may decrease intraoperative graft manipulations and facilitate its positioning (Fig. 2, E and F). In a smooth, non-bulging posterior surface of the corneal graft host interphase, it is worth considering oversizing the DMEK graft, and deliver more endothelial cells to the decompensated cornea (Fig. 2, A and B).

Intra-operative adjustments included injecting sub-tenon triamcinolone prophylactically (Fig. 3A). We believe that it significantly decreases post-operative intraocular inflammation affecting the early postoperative graft failure rate and the incidence of CME. CME is a well-known complication after intraocular surgery and has been reported to occur in 2.0–12.5% of cases after endothelial keratoplasty[25–27]. Heinzelmann et al.[28] observed a considerably elevated incidence of CME (13%) which influence visual rehabilitation. In our study, SD-OCT for macula was performed 1 month after surgery and CME was observed only in one eye (6.25%), which might be explained by the complicated clinical course of this case. Postoperative intraocular inflammation may also affect graft failure and rejection rates which are not negligible after secondary endothelial keratoplasties. Administrating a depo of corticosteroids during the surgery may also have a beneficial effect on graft survival and endothelial cells function.

In addition, paracentesis and main incision were performed in the host peripheral corneal rim without penetrating the PK graft to prevent potential graft-host wound dehiscence (Fig. 3B). No circumferential scoring of DM was performed and descemetorhexis was started from the center of the PK graft and completed in a curvilinear pattern along the PK wound in a manner resembling capsulorhexis (Fig. 3C). We believe, performing these adjustments without removing graft-host interphase sutures, may ensue in a smoother back surface, reduce the amount of Descemet remnants and may even facilitate posterior scar tissue removal. Moreover, scars in the graft-host interphase or anterior synechia, were selectively removed during surgery, if possible, based upon pre-operative AS-OCT (Fig. 3C).

After injecting the DMEK graft, the correct orientation was confirmed by intraoperative AS-OCT (Rescan), when available, or the “Montsouris” sign. Afterward, the graft was unfolded using careful indirect manipulations by tapping on the cornea surface. Then, the graft was elevated with a small air bubble beneath and was centered by the “wave maneuver”, an indirect L shaped tapping on the corneal surface (Fig. 3, D and E). We believe that these surgical steps lessen unnecessary extra manipulations on the graft and facilitate positioning it in the correct orientation and suitable position. This way of manipulating the graft on the posterior corneal surface with Descemet-stromal touch, helps to avoid endothelial-iris/IOL touch, which may also protect the graft endothelial cells.

Finally, the anterior chamber was 80–100% filled with 20% SF6 gas to pressurize the eye and support graft adherence for a longer period than air (Fig. 3F). After Two to three hours, intraocular pressure was checked and if necessary, an appropriate intervention was applied. Lavy et al.[19] attributed the tendency of delayed and extensive graft detachment, to insufficient pressurization during surgery or postoperative hypotonia. They recommended to pay attention for pressurizing the eye at the end of surgery or to extend
the air-bubble time if enough pressurization cannot be achieved. Compared to other studies, we had relatively low rebubbling rate (18.75%), this may be attributed to SF6 usage and the extended volume in the anterior chamber at the end of the surgery, but also may be due to a more conservative rebubbling policy of the surgeon.

In our study, we encountered relatively low complications rates. Graft failure rate was 6.25% (late), graft detachment rate and rebubbling rate were 18.75% respectively. Interestingly, glaucoma filtering surgeries were not a significant risk factor for graft failure. However, this conclusion may be applicable at least regarding early decompensation events and not for late decompensation events due to short-term study period. We believe, based on our experience, that these successful results are attributed to our careful pre-operative AS-OCT evaluation and intra-operative adjustments to the surgical technique in DMEK after PKP graft failure. In comparison to our results, higher rebubbling and failure rates were reported by other studies. Lifshitz et al.[18] had 43% rebubbling and 43% failure rates. Lavy et al.[19] found 34% and 36% rebubbling and failure rates respectively. Heinzelmann et al.[23] reported 37% and 21% rebubbling and failure rates respectively.

Visual recovery and central pachymetry improvement were relatively fast during the study period (Table 2). Those favorable clinical outcomes are consistent with other studies as well[16, 18, 22]. The visual recovery with DMEK under failed PK contrasts sharply with the delayed and unpredictable visual rehabilitation after re-PKP[29]. Moreover, the rapid visual recovery seen after DMEK under failed PK is consistent with the visual recovery that DMEK provides in virgin eyes as compared with PK[30].

There are some limitations to our study, including its retrospective nature, small sample size and short-term follow up. Moreover, visual acuity tests were done by technicians and not experienced optometrists. Therefore, uncorrected or partially corrected, rather than best corrected, visual acuity was assessed. In addition, ECD was done only for 7 cases after surgery and comparison between donors ECD and post-operative ECD may be inconclusive due to group size difference. This was mainly because specular microscopy test was not covered by the health insurance and not all study participants could afford it. However, we encountered a predictable decrease in ECD after surgery which may be attributed to cell migration and postoperative inflammatory response[19].

**Conclusions**

DMEK is a viable method to treat secondary PKP graft failure. It may provide faster and better visual recovery and clinical outcomes compared with re-PKP. Preoperative evaluation using AS-OCT, where available, plays a key role in planning the surgery based on each case characteristics. No less important is adhering to surgical adjustments during DMEK surgery. Both may further decrease the incidence of graft detachment, rebubbling and failure rates.

**Abbreviations**
EK: Endothelial keratoplasty (EK); DMEK: Descemet Membrane Endothelial Keratoplasty; DSEK/DSAEK: Descemet stripping (automated) endothelial keratoplasty; PKP/PK: Penetrating Keratoplasty; Re-PKP: Repeating Penetrating Keratoplasty; AS-OCT: Anterior-Segment Optical Coherence Tomography; ECD: endothelial cell density; VA: visual acuity; CME: Cystoid macular edema.

Declarations

Acknowledgements

The authors would like to thank the participants in the study.

Ethics approval and consent to participation

This study was conducted at Hadassah Medical Centre in Jerusalem, Israel. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Hebrew University of Jerusalem, Israel. The registration number is HMO-0695-19.

Availability of data and materials

Data will not be shared because the authors are performing other analyses that have not yet been published.

Competing interests

The authors declare that they have no competing interests

Funding

No funding or sponsorship was received for this study or publication of this article.

Authors’ contributions

KS was involved in the design and conduct of the study, collection and analyzing of the data and writing the manuscript. IL was involved in the management of the clinical cases and performing the surgeries, the design and conduct of the study and writing the manuscript. DW was involved in performing the surgeries. RK and EN were involved in collection of the data.

References

1. Straiko MD, Terry MA, Shamie N. Descemet stripping automated endothelial keratoplasty under failed penetrating keratoplasty: A surgical strategy to minimize complications. Am J Ophthalmol. 2011. https://doi.org/10.1016/j.ajo.2010.08.017.
2. Claesson M, Armitage WJ. Clinical outcome of repeat penetrating keratoplasty. Cornea. 2013;32:1026–30.
3. Lee WB, Shtein RM, Kaufman SC, Deng SX, Rosenblatt MI, Lum F. Boston Keratoprosthesis: Outcomes and Complications: A Report by the American Academy of Ophthalmology. Ophthalmology. 2015;122:1504–11.

4. Liarakos VS, Satué M, Livny E, Van Dijk K, Ham L, Baydoun L, Dapena I, Melles GRJ. Descemet membrane endothelial keratoplasty for a decompensated penetrating keratoplasty graft in the presence of a long glaucoma tube. Cornea. 2015;34:1613–6.

5. Ang M, Ho H, Wong C, Htoo HN, Mehta JS, Tan D. Endothelial keratoplasty after failed penetrating keratoplasty: An alternative to repeat penetrating keratoplasty. Am J Ophthalmol. 2014;158:1221–7.e1.

6. Price FW, Price MO. Endothelial keratoplasty to restore clarity to a failed penetrating graft. Cornea. 2006;25:895–9.

7. Covert DJ, Koenig SB. Descemet stripping and automated endothelial keratoplasty (DSAEK) in eyes with failed penetrating keratoplasty. Cornea. 2007;26:692–6.

8. Sellami D, Abid S, Bouaouaja G, Ben Amor S, Kammoun B, Masmoudi M, Dabbeche K, Boumoud H, Ben Zina Z, Feki J. Epidemiology and Risk Factors for Corneal Graft Rejection. Transplant Proc. 2007;39:2609–11.

9. Panda A, Vanathi M, Kumar A, Dash Y, Priya S. Corneal Graft Rejection. Surv Ophthalmol. 2007;52:375–96.

10. Einan-Lifshitz A, Sorkin N, Boutin T, Showail M, Borovik A, Alobthani M, Chan CC, Rootman DS. Comparison of femtosecond laser-enabled descemetorhexis and manual descemetorhexis in descemet membrane endothelial keratoplasty.Cornea. 2017;36:767–70.

11. Borovik AM, Perez M, Lifshitz T, Einan-Lifshitz A, Sorkin N, Boutin T, Showail M, Rosenblatt A, Rootman DS. Peripheral Blunt Dissection: Using a Microhoe-Facilitated Method for Descemet Membrane Endothelial Keratoplasty Donor Tissue Preparation. Cornea. 2017;36:1270–3.

12. Guerra FP, Anshu A, Price MO, Giebel AW, Price FW. Descemet’s membrane endothelial keratoplasty: Prospective study of 1-year visual outcomes, graft survival, and endothelial cell loss. Ophthalmology. 2011;118:2368–73.

13. Melles GRJ, Ong TS, Ververs B, van der Wees J. Descemet Membrane Endothelial Keratoplasty (DMEK). Cornea. 2006;25:987–90.

14. Yoeruek E, Bayyoud T, Hofmann J, Bartz-Schmidt KU. Novel maneuver facilitating Descemet membrane unfolding in the anterior chamber. Cornea. 2013;32:370–3.

15. Anshu A, Price MO, Tan DTH, Price FW. Endothelial Keratoplasty: A Revolution in Evolution. Surv Ophthalmol. 2012;57:236–52.

16. Anshu A, Price MO, Price FW. Descemet membrane endothelial keratoplasty and hybrid techniques for managing failed penetrating grafts. Cornea. 2013;32:1–4.

17. Keane MC, Galettis RA, Mills RAD, Coster DJ, Williams KA. A comparison of endothelial and penetrating keratoplasty outcomes following failed penetrating keratoplasty: A registry study. Br J Ophthalmol. 2016;100:1569–75.
18. Einan-Lifshitz A, Belkin A, Sorkin N, Mednick Z, Boutin T, Gill I, Karimi M, Chan CC, Rootman DS. Descemet membrane endothelial keratoplasty after penetrating keratoplasty: Features for success. Cornea. 2018;37:1093–7.

19. Lavy I, Liarakos VS, Verdijk RM, Parker J, Müller TM, Bruinsma M, Binder PS, Melles GRJ. Outcome and histopathology of secondary penetrating keratoplasty graft failure managed by descemet membrane endothelial keratoplasty. Cornea. 2017;36:777–84.

20. Dapena I, Moutsouris K, Droutsas K, Ham L, Van Dijk K, Melles GRJ. Standardized “no-touch” technique for descemet membrane endothelial keratoplasty. Arch Ophthalmol. 2011;129:88–94.

21. O’Donnell FT. Preoperative Evaluation of the Surgical Patient. Mo Med. 2016;113:196–201.

22. Pasari A, Price MO, Feng MT, Price FW. Descemet Membrane Endothelial Keratoplasty for Failed Penetrating Keratoplasty: Visual Outcomes and Graft Survival. Cornea. 2019;38:151–6.

23. Heinzelmann S, Böhringer D, Eberwein P, Lapp T, Reinhard T, Maier P. Descemet membrane endothelial keratoplasty for graft failure following penetrating keratoplasty. Graefe's Arch Clin Exp Ophthalmol. 2017;255:979–85.

24. Rosenfeld C, Price MO, Lai X, Witzmann FA, Price FW. Distinctive and pervasive alterations in aqueous humor protein composition following different types of glaucoma surgery. Mol Vis. 2015;21:911–8.

25. Heinzelmann S, Maier P, Böhringer D, Hüther S, Eberwein P, Reinhard T. Cystoid macular oedema following Descemet membrane endothelial keratoplasty. Br J Ophthalmol. 2015;99:98–102.

26. Phillips PM, Phillips LJ, Much JW, Maloney C. Descemet stripping endothelial keratoplasty: Six-month results of the first 100 consecutive surgeries performed solo by a surgeon using 1 technique with 100% follow-up. Cornea. 2012;31:1361–4.

27. Suh LH, Yoo SH, Deobhakta A, Donaldson KE, Alfonso EC, Culbertson WW, O'Brien TP. Complications of Descemet's Stripping with Automated Endothelial Keratoplasty. Survey of 118 Eyes at One Institute. Ophthalmology. 2008;115:1517–24.

28. Heinzelmann S, Maier P, Böhringer D, Hüther S, Eberwein P, Reinhard T. Cystoid macular oedema following Descemet membrane endothelial keratoplasty. Br J Ophthalmol. 2015;99:98–102.

29. Al-Mezaine H, Wagoner MD. Repeat penetrating keratoplasty: Indications, graft survival, and visual outcome. Br J Ophthalmol. 2006;90:324–7.

30. Deng SX, Lee WB, Hammersmith KM, Kuo AN, Li JY, Shen JF, Weikert MP, Shtein RM. Descemet Membrane Endothelial Keratoplasty: Safety and Outcomes: A Report by the American Academy of Ophthalmology. Ophthalmology. 2018;125:295–310.

Figures
Figure 1

Pre-operative Anterior Segment OCT: A (arrow) points to anterior synechia adjacent to graft-host interphase. B (arrow) point to bulging and scarring in the graft-host interphase. C (arrow) points to the recommended DMEK graft size according to the original PK graft size. D (arrow) points to a tilted PCIOL. E (arrow) points to deep internal stromal cleft in a severely edematous cornea.
Figure 2

A – Pre-operative AS-OCT showing relatively smooth posterior surface without bulging scars in the PKP-interphase, suitable for over-sized graft. B – Post-operative AS-OCT for the same patient (A) showing fully attached oversized graft. C – Pre-operative AS-OCT showing bulging scars in the PKP interphase suggesting the need for removal during surgery and possible transplantation of over-sized graft. D – Post-operative AS-OCT for the same patient (C) showing fully attached oversized graft after scars removal. E – Pre-operative AS-OCT showing anterior synechia and bulging scars in the PKP interphase suggesting the need for additional surgical adjustments and under-sized graft. F – Post-operative OCT for the same patient (E) showing fully attached under-sized graft after releasing anterior synechia and scars removal.
Figure 3

A - Sub-tenon Triamcinolone 40 mg injected at the beginning of the surgery after sub-tenon local anaesthesia, B - 2.4-mm wide corneal incision performed in the host peripheral corneal rim, C - Descemetorhexis performed from the center of the PK graft and completed in a curvilinear pattern along the PK wound, D – Injected donor descemet-roll to the anterior chamber in a double scroll fashion, and confirmed correct orientation by the “Montsouris” sign, E - A small air bubble injected underneath the donor DM and centered graft by “wave maneuver”, F – At the end of the surgery, the anterior chamber filled 80-100% with 20% SF6 gas.