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Graft-repositioning technique using infusion and small bubbles during Descemet's membrane endothelial keratoplasty

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Abstract

Background Descemet's membrane endothelial keratoplasty (DMEK) is a highly effective procedure for corneal endothelial dysfunction; however, once a DMEK graft is deployed, repositioning can be challenging. Therefore, this study aimed to evaluate the efficacy of a technique that utilizes infusion and small air bubbles to reposition a misaligned deployed graft.

Methods This retrospective interventional case series enrolled patients who underwent DMEK between January 2022 and July 2023, including cases where the DMEK graft was attached and unfolded in off-center positions". Experienced surgeons performed DMEK by inserting an infusion cannula and positioning a small bubble in the anterior chamber after the graft unfolded off-center. The eye was tilted in a deviated direction, and the cornea was massaged from the corneal limbus to the center using a 27-gauge blunt needle. Before and after DMEK, we measured the best spectacle-corrected visual acuity (BSCVA), central corneal thickness (CCT), and endothelial cell density (ECD). Additionally, we monitored the incidence of postoperative complications.

Results Six eyes of six patients were included in this study. Postoperatively, the overall BSCVA and CCT of the eyes improved ($P < 0.001$). However, one eye developed recurrent uveitis and required a sub-Tenon's capsule triamcinolone acetonide injection. No eyes required re-bubbling, and no instances of primary graft failure were observed.

Conclusion The described technique enables the safe and feasible repositioning and unfolding of the DMEK graft.

Keywords Corneal transplantation, Graft dislocation, Descemet's membrane endothelial keratoplasty

Background

Descemet's membrane endothelial keratoplasty (DMEK), a procedure in which Descemet's membrane and corneal endothelium are inserted into the eye, was first reported by Melles et al. in 2006. Studies conducted in Europe and the United States have shown that [1, 2] DMEK has significant advantages over penetrating keratoplasty and Descemet's stripping automated endothelial keratoplasty (DSAEK), including better visual acuity and a lower rejection rate [3]. However, graft detachment and unfolding are challenging steps in this procedure. If the unfolding process takes too long, such as in the case of tight-roll

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grafts, it may lead to primary graft failure [4, 5]. Consequently, many techniques for unfolding grafts have been investigated, and various DMEK techniques have been reported.

When performing DMEK, the graft should be attached as close to the center of the cornea as possible to achieve good vision and avoid graft detachment [1, 2]. Off-center attachment of the graft places it over the patient's existing Descemet membrane, increasing the risk of graft detachment [6]. However, it is challenging to precisely control the position of the rolled graft as it is deployed within the eye, often resulting in the graft being positioned in an unexpected location.

Therefore, in this study, we aimed to evaluate the efficacy of using infusion and a small air bubble to reposition a misaligned graft.

Materials and methods

Patients and examinations

This retrospective case series was approved by the Ethical Review Board of Nihon University School of Medicine (approval no: RK-230411-8) and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Patients who underwent DMEK using this technique between August 2022 and July 2023 were enrolled in this study. To evaluate the effectiveness of this technique, we measured the best spectacle-corrected visual acuity (BSCVA), corneal endothelial cell density (ECD), and central corneal thickness (CCT) before and 6 months after the surgery. After measuring the BSCVA, its decimal values were converted to logarithmic values for statistical analysis. Additionally, the CCT and postoperative ECD were measured using corneal tomography (SS1000; Tomey, Aichi, Japan) and a specular microscope (FA3509; Konan Medical, Nishinomiya, Japan), respectively.

Surgical procedure

Procedures before graft repositioning

Three experienced surgeons performed the DMEK procedures, with all surgeries performed under local anesthesia. The pre-stripped donor tissue was prepared to an estimated size (approximately 8.0 mm) using a vacuum punch (Moria Japan, Tokyo, Japan) and subsequently stained with 0.06% trypan blue or 0.1% brilliant blue G dye. Descemet's membrane was stripped from the posterior stroma using a reverse Sinsky hook under air. A 25-G infusion cannula (Kobayashi 25 g DSAEK Chamber Maintainer, Catalog #AE-7802, ASICO, Westmont, IL) was used to preserve the anterior chamber depth by way of a paracentesis. Additionally, peripheral iridectomy was performed at the 6 o'clock position, and a DMEK shooter (G-3863; Geuder, Heidelberg, Germany) or intraocular lens inserter (WJ-60 M; Santen, Osaka, Japan) was used to insert the graft into the anterior chamber through the corneal incision.

Graft unfolding using the infusion and non-touch technique

In cases where the graft was deployed off-center, the volume of air was first reduced to an amount smaller than the graft (Fig. 1A, E). The infusion flow was then turned on and off several times to detach the graft from the posterior surface of the cornea (Fig. 1B, F). At this time, the graft was only detached but remained unrolled. Subsequently, the infusion cannula was grasped, and the eyeball was tilted toward which the graft was intended to be

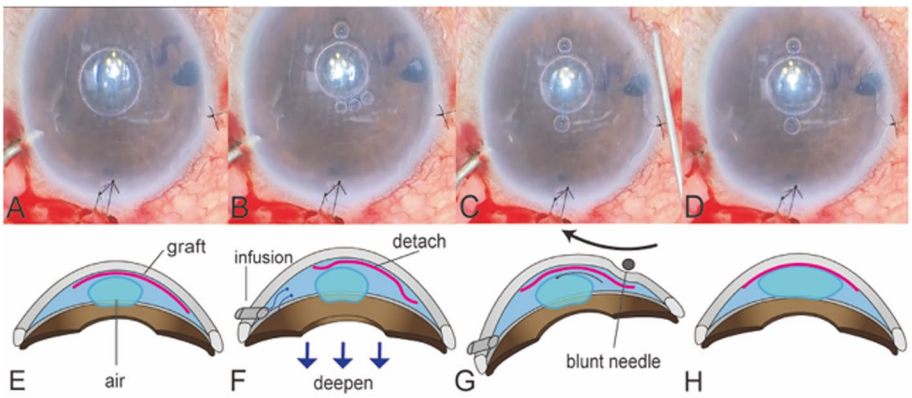

Fig. 1 Illustrations of the graft-repositioning technique using an infusion cannula (**A**, **E**) Before repositioning, the DMEK graft is dislocated to the upper right side. **B**, **F** The infusion cannula is inserted into the anterior chamber, and the infusion switch is turned on and off several times. The anterior chamber deepens, and the graft detaches from the posterior surface of the cornea through aqueous flow, with the air bubble smaller than the graft. **C**, **G** The eye is tilted in the displaced direction, and a blunt needle is stroked from the sclera to the center of the cornea. **D**, **H** After performing the repositioning technique, the graft moves to the center. As with conventional DMEK, the anterior chamber is replaced with gas or air, and the grafts are attached DMEK, Descemet's membrane endothelial keratoplasty

moved. Once the graft was detached, a blunt 27-G needle was stroked from the scleral side toward the center of the cornea (Fig. 1C, G), with slow, deliberate strokes guiding the graft toward the corneal center (Fig. 1D, H). After the graft was moved to the target position, sulfur hexafluoride gas was injected into the anterior chamber, and the graft was allowed to attach (see Video, Supplemental Digital Content 1).

Postoperative medications

Postoperatively, 1.5% levofloxacin (Cravit; Santen, Osaka, Japan) was administered four times daily for 2 weeks. Additionally, betamethasone (Sanbetason; Santen, Osaka, Japan) and 2% rebamipide ophthalmic solution (Mucosta; Otsuka, Tokyo, Japan) were prescribed four times daily for 3 months and were gradually tapered.

Statistical analysis

The Wilcoxon rank-sum test was used to compare the preoperative and postoperative values of the BSCVA, CCT, and ECD measurements. All analyses were performed using GraphPad Prism version 10.2.3 for MacOS Software (GraphPad Software, Boston, MA, USA). Statistical significance was set at a p-value of < 0.05.

Results

Table 1 summarizes the preoperative demographics and clinical characteristics of the enrolled patients. In total, six eyes of six patients (four female and two male; mean age, 74 years; range 65–83 years) were included in this study. Two eyes underwent cataract surgery 1 month prior to DMEK, while two other eyes had previously undergone cataract surgery. The remaining cases underwent intrascleral intraocular lens fixation and pars plana vitrectomy performed simultaneously with DMEK (Case no. 5). In all six cases, the intraocular lens was fixed in the capsular bag.

Table 1 also shows the postoperative clinical characteristics. Notably, the median (interquartile range) BSCVA (logarithm of the minimal angle of resolution) improved from 1.1 (0.30–2.00) preoperatively to 0.33 (0.09–0.1.3) 6 months postoperatively (Wilcoxon rank-sum test $P=0.02$). In contrast, the median CCT decreased from 731 (652–815) μm preoperatively to 487 (456–502) μm 6 months postoperatively (Wilcoxon rank-sum test $P=0.002$). Moreover, the median donor ECD was 2,553 (2,227–3,012) cells/mm^2 preoperatively and 1,407 (781–2,245) cells/mm^2 at the last examination, with a median ECD loss rate of 45.9% compared to the donor graft (Wilcoxon rank-sum test $P=0.004$).

Notably, no eyes experienced intraoperative complications. However, one patient developed recurrent uveitis and required a sub-Tenon's capsule triamcinolone acetonide injection. Additionally, Case No. 6 did not achieve improved visual acuity due to an advanced stage of glaucoma.

Discussion

The present study demonstrates that the "graft-repositioning technique assisted by infusion and tapping" for DMEK can safely and feasibly reposition a decentered graft.

During endothelial keratoplasty, the graft needs to be attached as centrally as possible to the cornea to avoid postoperative detachment and aberrations. In 2019, we investigated the effect of graft shifting on the corneal endothelium. We found that downward graft shifting was associated with a risk of graft detachment and a greater rate of corneal endothelial loss. Additionally, previous research has shown that attaching the graft as close to the center as possible during DSAEK is considered useful in reducing the possibility of antigen recognition and immune reaction [1]. Graft disorientation results in graft detachment and poor postoperative visual acuity [7, 8]. Moreover, complete graft detachment for repositioning can lead to primary graft failure due to the time required and the possibility of increased inflammation during graft deployment. To address these limitations, we propose a new technique to move DMEK grafts as easily and minimally invasively as possible, encompassing a combination of infusion and no-touch methods.

Direct grasping and movement of the graft is not as easy with DMEK as it is with DSAEK. If the graft is deployed off-center, it is typically removed from the posterior surface of the cornea, repositioned, and redeployed. This approach prolongs the operation time as the same procedure is repeated twice. To address this challenge, we recently developed the Kobayashi DMEK forceps, which feature a circular tip to prevent graft tearing [9, 10]. These forceps facilitate the easy repositioning of an off-center deployed DMEK graft; however, using forceps is not generally ideal because it requires preparation and can subject the graft to traction, posing a risk of corneal endothelial depletion.

As descemetorhexis is usually performed with the infusion turned on, this technique offers the advantage of not requiring any specialized devices. In addition, because the small bubbles slightly lift the graft and deepen the anterior chamber, the graft does not revert to a rolled shape. It can be positioned at the appropriate anterior chamber depth, even in a vitrectomized eye. When compared to other techniques, such as massaging, this technique has the following advantages: (1) no traction on the graft, (2) no specialized instrumentation, (3) ability to maintain appropriate anterior chamber depth through manipulation of food pedals to regulate the opening of

Table 1 Patient demographics and clinical characteristics

Case no.	Sex	Age (years)	Etiology for DMEK	Preoperative BCVA (logMAR)	Postoperative (6 M) BCVA (logMAR)	Pre-CCT (μm)	Postoperative (6 M) CCT (μm)	ECD of the donor graft (cells/mm^2)	Postoperative ECD (6 M) (cells/mm^2)	ECD loss rate (%)
1	Female	65	Uveitis	0.3	0.15	670	502	2,451	1,655	32.5
2	Female	83	LI BK	0.5	0.10	652	456	2,227	1,148	48.5
3	Female	73	FECD	2	0.15	787	502	2,350	781	66.8
4	Male	79	FECD	0.7	0.10	815	488	2,342	903	61.4
5	Male	76	PBK	1	0.2	843	567	2,941	2,245	23.7
6	Female	69	TLE	2	1.3	637	542	3,012	1,712	43.2

DMEK Descemet's membrane endothelial keratoplasty, *BCVA* best-corrected visual acuity, *MAR* minimal angle of resolution, *CCT* central corneal thickness, *M* month, *ECD* endothelial cell density, *LI BK* laser iridotomy-induced bullous keratopathy, *FECD* Fuchs endothelial corneal dystrophy, *PBK* pseudophakic bullous keratopathy, *TLE* trabeclectomy

the infusion cannula, and (4) no requirement to detach the graft completely. Thus, our technique allows us to achieve central fixation of the graft through controlling the depth of anterior chamber, intraocular pressure, amount of gas in the AC, and complete rotation of the operated eye. This technique can be applicable to all donors regardless of the donor age since the procedure is expected to be used after fixation. Even though we use donors older than 50 years, our technique can be beneficial, because this technique should be used in situations where grafts are almost attached to the posterior cornea. However, in cases of younger grafts, we do not have adequate experience to comment on it.

This study has some limitations. First, the sample size was small. Second, this study did not compare our technique with other existing surgical techniques.

In conclusion, our surgical technique for DMEK had good clinical outcomes in terms of visual acuity, corneal ECD reduction rate, and CCT. Therefore, our graft-repositioning technique presents a simple, reliable, minimally invasive, and reproducible method for DMEK.

Abbreviations

BSCVA	Best Spectacle-Corrected Visual Acuity
BCVA	Best-Corrected Visual Acuity
CCT	Central Corneal Thickness
DMEK	Descemet's Membrane Endothelial Keratoplasty
ECD	Endothelial Cell Density

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12886-025-03879-2.

Additional file 1: Video A 25-gauge infusion cannula is inserted into the anterior chamber, and a small air bubble is positioned under the graft. The infusion cannula is switched on, deepening the anterior chamber and detaching the graft, with the small bubble preventing the graft from curling up completely. After detaching the graft, a blunt needle is used to gently rub from the eccentric scleral side toward the center of the cornea.

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Authors' contributions
Toshiki Shimizu was a clinical investigator and contributed to data collection, mainly writing this paper. Itaru Oyakawa, Daisuke Tomida, and Hideaki Yokogawa were clinical investigators and critically reviewed the study proposal. Akira Kobayashi and Satoru Yamagami were participating investigators and critically reviewed the study proposal. Takahiko Hayashi was a clinical investigator, and critically reviewed the research content. All authors reviewed the manuscript.

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Data availability
Data are available upon reasonable request.

Declarations

Ethics approval and consent to participate
This retrospective case series was approved by the Ethical Review Board of Nihon University School of Medicine (approval no: RK-230411-8) and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Consent for publication
All patients provided informed consent.

Competing interests
I have received no competing interests.

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