Review Article

How to Perform Descemet's Membrane Endothelial Keratoplasty: A Step by Step Guide

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Abstract

Descemet's Membrane Endothelial Keratoplasty (DMEK) is a type of lamellar (partial thickness) corneal transplantation in which the endothelium, along with Descemet's membrane, is transferred. This technique has gained increased popularity in recent years and is expected to become more prominent and widely used among the various types of corneal transplantation. This review article provides a step-by-step guide for corneal surgeons on conducting DMEK. Like any other surgical procedure, gaining experience and completing consecutive surgeries can improve the delicate and precise execution of this procedure. Watching videos, observing live surgeries performed by experienced surgeons who have sufficient expertise in this procedure, and ultimately performing the surgery under the guidance of experienced individuals are factors that contribute to better surgical outcomes. This text serves solely as a guide for performing the continuous stages of DMEK.

Keywords: Descemet's Membrane; Endothelial; Keratoplasty; Guide.

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Introduction

Descemet's membrane endothelial keratoplasty (DMEK) introduced in 2006 by Melles et al., is recognized as a revolutionary advance in corneal transplantation techniques, specifically in treatment of disorders affecting the endothelial layer [1]. Unlike traditional full-thickness transplantation, DMEK involves the selective replacement of the diseased endothelium and its underlying Descemet's membrane, preserving the structural integrity of the recipient's cornea [2]. The advantage of this approach lies in its ability to mitigate common transplantation complications while achieving faster visual rehabilitation and more predictable refractive outcomes [3].

As DMEK finds more recognition, its adoption is increasing across ophthalmic centers globally [4]. However, the DMEK's intricate nature necessitates a thorough understanding of the procedure and an advanced skill set, which become available only through systematic learning and practice [5]. This review comprehensively describes the sequential steps of DMEK, serving as a guide for corneal surgeons aspiring to master this procedure. Yet, it is important to recognize that theoretical knowledge alone does not suffice. Aspiring surgeons must follow a multifaceted training regimen; scrutinizing procedural videos, participating in live surgical observations, and ultimately, navigating the complexities of surgery under expert supervision. This article, therefore, is not an endpoint but a catalyst in the surgeon's approach to DMEK proficiency.

Choosing the right patient

The ideal candidate for initiating DMEK is a patient experiencing corneal endothelial dysfunction due to conditions like dystrophy (e.g., Fuchs' endothelial dystrophy) or complications arising from intraocular surgeries (such as those encountered in phacoemulsification) [6]. For the optimal commencement of this surgical technique, it is advisable to choose a patient who has clear demarcation between the anterior and posterior chambers, a standard-sized and adequately deep anterior chamber, and an unscathed iris diaphragm and lens [7]. When selecting a suitable patient, the following factors should be taken into account:

A) Certain circumstances may complicate the surgical process, including extensive iris damage (as seen in conditions like aniridia or after a sectoral iridectomy), a history of glaucoma surgery (such as the insertion of a tube shunt), aphakia (the absence of the natural lens), an unstable intraocular lens, or an intraocular lens positioned in the anterior chamber or sulcus, lacking support from the posterior capsule, and instances of vitreous prolapse [8].

These considerations are crucial as they impact the technical execution of DMEK, potentially hindering the procedure or affecting its outcomes. By carefully evaluating these aspects in prospective candidates, surgeons can better anticipate challenges and strategize the surgical approach, thereby ensuring improved procedural success and patient recovery.

B) Patients with high myopia may have a significantly deep anterior chamber, which can make manipulation within the anterior chamber more difficult. Additionally, patients who have undergone a deep vitrectomy may face challenges in reducing the anterior chamber depth for maneuvering during DMEK [9].

Methods of anesthesia and sedation

To perform DMEK, general anesthesia is an option. However, based on the patient's ocular health, mental state, and the surgeon's

proficiency, the procedure might be conducted using retrobulbar or peribulbar anesthesia, or even topical anesthesia with tetracaine eye drops [10,11].

Donor Graft Preparation

Tissue selection

If the tissue is obtained from an eye bank prior to DMEK, surgery can be performed faster. Additionally, detailed information about the tissue will be available after its preparation. It is advisable to avoid using tissue from diabetic patients as it may be more prone to tearing during the procedure [12]. Younger tissue results in a tighter rolled tissue tube, which can make the unrolling and positioning process more challenging during the procedure [13]. The ideal endothelial-descemet graft tissue is obtained from donors above 50 years of age, especially for surgeons undergoing DMEK training [14,15]. Older tissue tends to be thicker (due to increased Descemet's layer thickness), which makes it more resistant to tearing, easier to separate, and easier to unfold. If the endothelial cells of the donor tissue exhibit high quality and specifications, even tissue up to the age of 80 can be used [16,17].

All tissues suitable for eye banks are also suitable for DMEK tissue processing [18,19]. If the eye bank applies an 'S' mark to the surface of the Descemet's tissue, it is advisable to utilize it within a 3-day period [20]. This is to prevent the mark from potentially fading or being washed away over time.

Preparing the injector for DMEK

Preparing the injector for DMEK involves considering various methods and options. Some commonly suggested approaches include a modified Jones tube, preloaded butterfly injectors, and foldable lens cartridge injectors with a 2.3-millimeter opening [21,22]. These options provide flexibility and convenience during the procedure.

When utilizing a cartridge or Jones tube, it is advisable to incorporate an intermediate tube. This can be a size 14 catheter or a piece of a serum set. This addition helps facilitate the smooth transfer of tissue. At the opposite end of the tube, a small 2 ^{cc} syringe is preferred for optimal control [20].

Several significant characteristics should be considered when selecting a DMEK injector. First and foremost, the material used should not cause any harm or damage to the delicate endothelial tissue, ensuring its integrity during the procedure. Additionally, it is desirable for the injector to eliminate the need for viscoelastic substances, simplifying the process and reducing potential complications [23-26].

The chosen injector should also enable easy insertion and transportation of the tissue, ensuring efficient delivery to the target site. The diameter of the injector plays a crucial role as well, as it should be appropriate to avoid exerting excessive pressure on the tissue, which could lead to complications. Moreover, the opening of the injector should be large enough to completely cover the incision site, promoting accurate and secure placement. Creating a sealed system at the entry point is of the utmost importance as it prevents fluid and tissue leakage, maintaining the procedure's stability [23-26].

By considering these factors and selecting an injector that meets these criteria, surgeons can enhance the success and efficiency of the DMEK procedure. In addition, they can minimize potential risks or complications associated with the injector itself.

Preparing the Host Cornea

Surgical markers can be used to delineate the

locations of incisions on the limbus. Typically, a primary incision is made on the temporal side, with two additional incisions on the superior and inferior limbus [18,27]. Following points should be considered when preparing the host cornea:

A) The incisions for DMEK must be self-sealing. These types of cuts help maintain the stability of the anterior chamber during manipulations and tissue adhesion [18]. Paracentesis should be parallel to the iris and have a square configuration (with the tunnel width equal to the incision width) [24].

B) For performing descemetorhexis, the anterior chamber must be deep. If it does not remain deep, a cohesive viscoelastic material (such as sodium hyaluronate) can be used, ensuring Descemet's membrane can be completely removed after the descemetorhexis [28].

C) The primary incision is made temporally, sized 2.3 millimeters, and occurs at two levels, with the initial incision being 250 to 300 microns and vertical [11]. Considering that the largest corneal diameter is usually horizontal, the temporal incision does not create interference with tissue placement during the subsequent invasive surgery. From within the incomplete cut, a full incision is made with keratome, especially if the tissue is to be injected into the anterior chamber with a cartridge or Jones tube [29]. The size of the incision should be such that the cartridge or Jones tube can easily enter and move. If the insertion is performed with difficulty, the tubed endothelial tissue might be expelled before entering the anterior chamber. Conversely, if the incision is too wide, because of increased pressure in the anterior chamber the tissue might be ejected from around the cartridge. If a wide primary incision has been made, the path of the cartridge tube can be narrowed by angling it toward the superior or inferior cornea, and then the graft tissue is injected [2,24,29,30].

D) Inferior iridotomy (or iridectomy) is necessary to prevent pupillary block due to end-of-surgery injected gas or air. The methods used include:

1- Laser iridotomy which can be done a few days before surgery. If this method is employed the surgeon should ensure the hole is complete during surgery.

2- Iridotomy with a 30-gauge needle bent upwards. In this method after constricting the pupil, the bent needle is introduced through the pupil's margin to behind the iris, and by lifting it, an iridotomy is performed at 6 o'clock. It's better not to use pilocarpine as it causes postoperative inflammation and pupillary adhesion [18,27,31]. By applying pressure with a Sinskey hook on the bent needle, the surgeon can ensure it exits the iris and that the iridotomy is complete. The needle movement shouldn't be such that it pulls on the iris root, and care should be taken with the iris vessels along the way to avoid bleeding [24]. If bleeding occurs, the blood should be washed out quickly, and tamponade is performed with air or Healon injection [32]. During this time, the surgeon can perform tissue preparations and should not place the tissue inside the anterior chamber until the bleeding has completely stopped.

E) Corneal surface marking is done based on the smaller corneal diameter [33]. After staining, the appropriate round marker is placed on the corneal surface so that after the tissue adheres, there is at least a 1-millimeter distance from the anterior chamber angle, and it doesn't pass over the corneal limbal incisions [20,34]. The most common marker size used is 8 millimeters. The advantage of this tissue size is that a significant number of endothelial cells are grafted. If the donor tissue is larger, opening and flattening the scrolled tissue will be more

challenging. After marking the epithelium for graft placement, the paracentesis sites can be marked for identification during surgery [29].

F) Removal of the host's Descemet-endothelium: For this step, an inverted Sinskey hook or similar instrument initially separates the Descemet's membrane from the endothelial side under the epithelial marks. Care should be taken to ensure the central Descemet's membrane is completely detached from the peripheral section [20,29,35]. Also, the surgeon should be careful not to damage the underlying stroma because the presence of free stromal fibrils prevents tissue adhesion. The stromal bed should be as smooth as possible. For this step, it's better to enter the anterior chamber from the paracentesis cut [36]. The Descemet's membrane and endothelium should ideally be removed in one piece. The removal should start from the edges. It's best not to apply pressure on the Descemet's membrane to avoid contact with the stroma. The removal motion should be towards the corneal center, and after ensuring complete detachment, Descemet's membrane should be removed from the main cut [20,29]. The area where the recipient's Descemet's membrane is removed should be slightly larger than the donor tissue size. Overlapping of donor and recipient Descemet's membranes causes tissue separation [36]. The presence of stromal tags leads to fluid accumulation behind the tissue, causing its separation. Areas without Descemet's membrane are covered by the migration of the donor endothelium, and corneal edema will gradually disappear over this area [20].

G) Removal of viscoelastic (sodium hyaluronate) from the anterior chamber, along with aspiration of the posterior stroma of any remaining Descemet's tags and residual viscoelastic, should be performed carefully [29].

Before preparing the donor tissue, check this list again to ensure no step has been missed: 1- Has the Descemet's membrane been completely removed? 2- Is the iridotomy complete? 3- Has the pupil become miotic? 4- Does the head of the injector and the cartridge easily fit inside the main incision? 5- Has all the viscoelastic been washed out from the anterior chamber?

Preparing the Donor Tissue

1 - The surgeon should remove the corneo-scleral segment from the storage solution and place it on a Teflon block. Excess fluid should be absorbed from the cornea's edge with a sponge. After a few seconds, the donor Descemet's membrane will adhere to the corneal stroma [37].

- If the surgeon wants to separate the Descemet's membrane first trabecular meshwork should be separated from the scleral spur, then the Schwalbe's line and Descemet's membrane should be carefully separated (360 degrees) from the posterior stroma (Melles method) [38].
- In another method, a sharp blade cuts the Descemet's membrane close to the scleral spur, and then the medial edge is separated from the stroma all around with a round blade (Kruse method) [24].
- In another method, considering that the Descemet's adhesion to the central corneal stroma is weaker, the Descemet's is first gently punched out with a properly sized punch, and then lifted and removed with a cannula from the donor tissue's periphery (Fogla method) [39].
- Another method for separating and removing the donor Descemet's and endothelium is called SCUBA (Submerged Cornea Using Background Away) method, where the corneo-scleral tissue is submerged in

a corneal storage solution (e.g., Optisol GS) for better visibility. For the SCUBA method, the surgeon can submerge the tissue in a larger container or inside a Teflon block while holding the tissue with forceps, performing freeing motions around the Descemet's, with only the central part of the Descemet's remaining attached until after punching [13]. Excess fluid should be absorbed with a sponge [40].

2 - Trypan blue should be placed on the tissue for at least 30 seconds to fully stain it. This will highlight the edges and any damaged or torn areas [41].

3 - Excess trypan solution should be absorbed from around the cornea with a sponge. Under a microscope, the surgeon should ensure that the Descemet's tissue is completely smooth and flat against the stroma [42].

4 - If the surgeon wants to place an "S" mark on the Descemet's side, the donor Descemet's tissue should be folded to one side and a hole should be punched in the donor cornea (endothelial side) with a sharp 4 mm punch. Then he should re-flatten the Descemet's with Ringer's solution or Balanced Salt Solution (BSS) [18,43]. After absorbing the fluid from the epithelial side, the whole corneo-scleral tissue should be placed concave side up on the Teflon block (epithelium up). The surgeon should remove the punched 4 mm stroma, mark it with an "S" on the back (Descemet's side), then reposition the 4 mm stroma and place the cornea and sclera with the epithelium side on the block (endothelium up) [44].

5 - The surgeon should spread the donor tissue flat on the stromal bed, positioning it so that the punch blades do not reach uneven areas or tears during the cut. Also, it should be ensured that the punch includes the "S" mark but does not cross the 4 mm punched edge [24,45].

6 - When the surgeon is sure about the position and centrality of the punch blade, he should lower it gently to place it on the graft and tap gently on all edges to cut the graft, but not in a way that the blade penetrates the stroma [24,29].

7 - The punch should be new and sharp to easily cut the graft. The healthy part of the graft should be placed in the center of the Teflon block in a way that torn and extra edges of the cut are outside of the punch area [46].

8 - Usually, a 7.5 mm punch is used to easily fit in an 8 mm Descemetorhexis. The size of the punch should be such that it ultimately does not cover the inner opening of the paracentesis, not causing detachment in case of the need for re-bubbling [18, 20,46].

9 - The surgeon should control the edges of the graft tissue with a Sinskey hook 360 degrees around and ensure the completeness of the cut [24,29,46].

10 - The peripheral graft should be separated from outside the punch area, then the central graft - endothelium tissue should be removed and placed in BSS solution. The removal motion should be rotational, similar to the rhexis motion. To lift the graft tissue, the surgeon can use a stream of BSS towards the tissue edge and hold the graft in the air for a few moments before dyeing it.

11 - If the graft tissue has not taken up enough dye, the surgeon can reapply Trypan Blue and allow 3-4 minutes for dyeing (depending on the concentration of the used Trypan Blue) [29]. While the main tissue is dyeing, the surgeon can use the loop of Descemet's tissues around the main tissue to test the injector. A shallow container (like a Petri dish) can be used to insert the tissue into the tube or remove it if necessary [24,29,47]. For transplant in recipient corneas that are more opaque, a longer dyeing time is needed.

12 - The excess dye should be absorbed with a sponge and separated from around the graft

tissue.

13 - To increase the absorption power of the sponge, first, it is advised to soak up some liquid with it, then squeeze it [29].

14 - The surgeon should approach the head (curved part) of the graft. If he brings the sponge close from the side, the graft may suddenly be pulled towards the sponge and stick to it [20,29]. To separate it, the surgeon should gently insert the sponge into the BSS solution. The separated tissue will gently float.

15 - The shallow container can be tilted to move all the dye to one side.

16 - At this stage, it's better to change the shape of the graft tissue with drops or a jet of BSS, so that it forms a double scroll [48].

Inserting the Tissue into the Injector

1. The graft tissue should be pulled into the injector from the punch block or Petri dish gently and with short intermittent movements, without making contact with the tweezers [20,29].

2. For this step, it is preferable to have the bevel opening of the injector towards the head and not the body of the graft tissue [20].

3. If this step is difficult to perform, the surgeon can reinsert the graft tissue into a Petri dish containing BSS [24,29].

4. If the aspirated graft tissue goes too high into the injector, by holding the injector vertically and keeping its opening downward, the tissue will gradually return to the end of the opening (but care must be taken not to let the tissue come out) [24].

5. Then, the surgeon should place the injector horizontally so that no liquid comes out of the tip of the injector (and naturally the graft tissue). A cap for the tip of the injector should be considered if available [24,46,47].

Injecting the Rolled Tissue

1. At the time of tissue injection, the anterior chamber should be formed (shaped) but should not be under high pressure.

2. The surgeon should grasp the anterior edge of the main incision with a 0.12 mm corneal forceps and enter the cartridge into the eye while the bevel is downward [24,47].

3. The incision around should cover the cartridge and not be loose, and the depth of the anterior chamber should be maintained during tissue injection [29].

4. The surgeon should hold the injector with both hands for better control and send the tissue into the anterior chamber with slow and gradual injections of BSS [49].

5. The pressure inside the anterior chamber should not increase (as it increases the chances of the tissue being ejected). Excess fluid can be removed by pressing on the posterior edge of one of the paracentesis. It is better for intraocular pressure to be low during injection [29].

6. To insert the rolled tissue into the eye so that it is perpendicular to the main incision, the injector tip should preferably be dimmed towards 6 or 12 o'clock. This ensures that the tissue cannot easily exit the eye when removing the injector [20].

7. When removing the injector from the eye, it is better to quickly seal the anterior edge and the incision with a cannula in the other hand.

8. It is preferable for the rolled tissue to be placed inside the container and then the injector tube in such a way that it is injected into the anterior chamber in the appropriate direction [20].

9. The proper method of DMEK tissue rolling should ideally be such that the endothelial side is outside the scroll tubes facing the posterior stroma of the recipient cornea [20].

10. After tissue injection, it is preferable to immediately suture the main incision so that the tissue is not ejected during manipulation [20,29,49].

11. If the anterior chamber becomes shallow before suturing, a very small amount of fluid can be injected into the anterior chamber. Care should be taken not to eject the graft tissue with a sudden increase in intraocular pressure [20].

Unfurling the Rolled Graft Tissue

Unfurling the tissue scroll and centering it is one of the most crucial steps in DMEK surgery. There are different methods for this stage. All these techniques are based on pressure applied to the cornea and eye from the outside and injections into the eye. The goal of these maneuvers is to ensure that the graft tissue is placed in the appropriate location and position [20]. At this stage, the effort is to have the endothelial surface on the iris while the scrolled part faces up, and the recipient's posterior stroma is positioned. The basis of many of these maneuvers can be in the following forms:

1. The anterior chamber should be shallow but not completely without depth. When the anterior chamber is shallow, the iris acts as a support to prevent the unfolding tissue from returning to the scrolled state [29].
2. Shallowing the anterior chamber is done by pressing on the posterior edge of the paracentesis cuts. In some eyes, like those with high myopia, it is difficult to shallow the anterior chamber [50-52]. In this situation, gentle pressure with a finger or cannula on the equator of the globe in the temporal area, bringing the iris diaphragm and lens forward, can be helpful. This maneuver is not effective for eyes that have had a vitrectomy or a cadaver eye with a clear vitreous [2,29,52].
3. By injecting a small and rapid amount of BSS and tapping lightly on the corneal surface, the surgeon tries to unfold the graft tissue. The aim of these maneuvers is to create gentle currents within the anterior chamber to unscroll the tissue and place it correctly [31].
4. During the unscrolling of the tissue, it is better to keep the tissue centered so it doesn't go into the anterior chamber angle. Sometimes, when the tissue reaches the angle, it gets stuck, and it has to be moved again with the flow of fluid [29].
5. In addition to being centered, the orientation of the tissue is also important. The endothelium should face the iris, and the Descemet's tissue and stromal fibers should be towards the posterior stroma of the cornea [20].

Various methods to determine the orientation of the tissue

1. Closely examining how the graft tissue has scrolled and with gentle taps on the corneal surface, the subtle wave created at the tissue edges indicates its scrolling direction [20].
2. By shining a thin light, using a hand-held slit, utilizing a slit attached to the surgical microscope, or with a laser pointer on the middle parts of the scrolled tissue, one can determine its twist direction. Additionally, for a precise diagnosis of the tissue's position, one can use an intracameral light probe on the limbus and observe more tissue details due to the indirect illumination created [53,54].
3. Moutsouris sign or "Blue Cannula": A fine air cannula is placed on the tissue. If it can, in this state, get under the scrolled tissue colored with trypan and appears "blue", then the tissue orientation is correct. However, if it cannot get inside the tissue scroll and appears "silver", it indicates the wrong side of the tissue [47].
4. Using intraoperative OCT that's added to the surgical microscope quickly shows the tissue's scrolling state, but the drawback of this method is its cost [55,56].
5. Methods of marking the stromal side of the DMEK tissue scroll are effective for each stage of the graft's orientation. Marking the tissue

with an "S" that is placed at the beginning of tissue preparation or in the eye bank on the back surface of the tissue (non-endothelium) has been described. If the tissue is misoriented, with a quick BSS injection and fluid flow, the shape and direction of the tissue changes [26,57].

Opening the graft tissue scroll

The taps made on the corneal surface should be directed towards its center and parallel to the curvature of the tissue scroll. These gentle taps create a liquid pressure inside the tissue scroll, producing a force perpendicular to the direction of the tap, thereby aiding in unrolling the scroll (or scrolls). Once one of the scrolls is opened on one side, the other half is opened with short taps while holding a cannula over the cornea [29].

The tissue should open in the center and in the area where a descemetorhexis has been performed, ensuring that the graft tissue edges do not overlap the area with the remaining Descemet's membrane [24,29,36]. If the donor tissue sits on the host's Descemet's membrane and endothelium, that particular point poses the highest risk for detachment. Considering the air bubble coverage at the end of the surgery, a slight shift of the tissue towards the upper part of the cornea is acceptable [34,46].

Methods of Unfolding Tissue

When the tissue is injected into the anterior chamber, it appears in various shapes. Various techniques are employed to unfold different scrolled tissue formations in the anterior chamber [58].

1. Complete Scroll Tissue: The tissue unfolds by injecting BSS or air into the center of the scroll. Occasionally, applying brief pressure during the injection, perpendicular to the length of the scrolled tissue, appropriately unfurls it [58].

2. Double Scroll Formation (the ideal scenario): At times, without the need for intraocular manipulation, just by slightly shallowing the anterior chamber and applying pressure or taps on the cornea, the tissue unfolds. If the tissue partially opens, consistent pressure is maintained on the cornea to hold the tissue between the cornea and the iris, then another cannula is used to unfold the second scroll through pressure on the cornea [57,58].

3. Tri-fold Tissue (resembling a traditional French military cap): A small air bubble is injected beneath the tissue, followed by short taps from each side to unfold the tri-folded edges (Minuteman sign) [24].

4. Injecting Air Bubble Under the Tissue: If the centering and orientation is correct, one can stabilize it by injecting 0.5 cc of air (microbubble) and then use short taps on the cornea to unfold it. These taps produce small waves in the anterior chamber, which help in unrolling the complex scrolled tissue [29].

5. Injecting Air Bubble on Top of the Tissue: A small air bubble can be placed on the scrolled tissue, followed by taps on the cornea to unfold it. Once the tissue is completely open, a part of the bubble is drained, and then a larger bubble is injected beneath it to continue the process [46].

Injecting Gas or Air

After fully unfolding and ensuring the centering and correct orientation of the graft tissue, the anterior chamber is filled with air or gas [24,29]. Once the position of the graft tissue is confirmed, a long cannula attached to a syringe is aligned parallel to the iris surface, directed to the eye's center, and sterile air or a 20 % mixture of sulfur hexafluoride (SF6) is slowly injected [46]. During gas injection, the eye should remain in the primary position, and the iris should be entirely parallel to the ground; otherwise, the tissue will move

towards the limbus, which is elevated and will decentralize. Ensure the iridotomy path is open before injecting gas or air. The gas injection and dispersion should originate from the center of the graft tissue. The most critical complication of gas injection is a pupillary block. This happens due to the large volume of gas, disrupting the aqueous flow from the posterior to the anterior chamber [59-61].

Relocating Adhered Tissue

To move tissue, the surgeon must utilize the physical properties of liquids and create appropriate pressure. The tissue should be separated in a shallow anterior chamber to limit extensive movement. When the corneal curvature is flattened due to external pressure, a direct path is created between the cornea and the iris, allowing fluids and, consequently, tissue to move more easily. Short taps move the tissue to the desired location [24,29].

DMEK Tissue Detachment

The most common complication of DMEK, challenging for corneal surgeons, is the detachment of previously adhered tissue. In the early DMEK learning curve, the need for reinjection of air or gas (Rebubble) might occur in 20 % to 80 % of cases [36,39,46,47]. This rate decreases to 4.4 % to 14 % as the surgeon gains experience. Some surgeons relate a decrease in this complication to retaining the gas inside the eye for 45 to 60 minutes. Tissue detachment can be observed from the first day, mainly in its lower part [62,63]. Limited detachment should not be ignored, as it might lead to full tissue detachment. The complete absorption of air filling 80 % to 90 % of the anterior chamber takes 3 to 5 days, and for 20 % SF6, it takes 6 to 10 days. It's better to use 20 % SF6 to prevent excessive volume increase, leading to a pupillary block and elevated eye pressure (despite a proper iridectomy). The toxic effects of SF6 and air on endothelial cells are minimal and similar [64]. The toxic effects of these two gases are due to the prevention of nutrients in the aqueous from reaching the endothelial cells. If the edge of the graft tissue begins to detach, it can be reattached using a gas bubble for tamponade by positioning the head correctly [60.65].

After the Procedure

Some surgeons keep the patient in a supine position for 30 to 90 minutes at the conclusion of DMEK [66,67].

Tissue Adhesion: Typically, the first area to adhere is the central part, followed by the lower, temporal, nasal, and finally the upper tissue. The lower tissue usually adheres with difficulty; therefore, to direct the air bubble to the lower tissue, the chin can be raised and the head tilted backward. If maintaining this position is challenging for the patient, they can alternate sleeping on their left and right sides [67].

Initial Examination: In the first examination, approximately one hour after the procedure, the condition of the tissue, the manner of its adhesion, the state of the bubble, pupil size, iridectomy, and eye pressure are evaluated.

Home Care: Until the air bubble (or gas) is absorbed, the patient should lie face up, except when eating or using the bathroom. This period usually lasts about 2 to 3 days. Patients should consume plenty of fluids and absolutely avoid rubbing their eyes [20]. Flying and traveling to places with altitude differences from sea level are prohibited.

Post-Operative Medication: Initially, ciprofloxacin or chloramphenicol antibiotic drops and steroids (betamethasone or dexamethasone 1 %) are started four times a day [20]. The antibiotic drop is discontinued after

7 to 10 days, and the steroid continues for a month, then gradually decreases over 3 months. Subsequently, fluorometholone or loteprednol drops are continued twice a day [20,30].

Conclusion

This review described the sequential steps of DMEK, serving as a guide for corneal surgeons. Aspiring surgeons must follow a multifaceted training regimen. This article, therefore, is not an endpoint but a catalyst in the surgeon's approach to DMEK proficiency.

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Footnotes and Financial Disclosures

Conflict of interest:

The authors declare no conflict of interest regarding the subject matter of the present study.