Surgical Technique for DMEK

Kevin J. Shah, Michael D. Straiko, Mark A. Greiner

Key Concepts

- A closed-system injector is ideal for controlled delivery of a DMEK graft.
- Creating a recipient stromal bed of slightly greater diameter than the donor graft improves graft attachment.
- Creating a peripheral iridotomy is vital in preventing pupillary block.
- Obtaining correct graft orientation is critical for a successful outcome.
- The primary techniques used to unfold and center a DMEK graft include fluid or air injection, corneal tapping, and/or anterior chamber depth modulation.
- The use of sulfur hexafluoride 20% has decreased graft detachment rates.

Introduction

Descemet membrane endothelial keratoplasty (DMEK) is the only surgical procedure that provides a true anatomic exchange of diseased endothelium and Descemet membrane with healthy donor tissue. There are several advantages of DMEK compared to Descemet stripping endothelial keratoplasty (DSEK), including faster visual recovery, lower rejection rate, and higher quality of vision. However, graft preparation, iatrogenic graft failure, and previously reported high rates of graft detachment are obstacles that have prevented many corneal surgeons from adopting this surgery. With eye banks now preparing DMEK tissue, more corneal surgeons are beginning to adopt DMEK as the risk of preoperative tissue loss has been eliminated.

A similar closed-system injector can be created with the AMO Emerald One Series IOL cartridge (Abbot Laboratories Inc., Abbott Park, IL), with a few key differences compared to other IOL cartridge injectors (Fig. 131.1D). Assembled with a standard Luer-Lok syringe filled with BSS and 14-French gauge nasogastric tubing, the Emerald One Series IOL cartridge is large enough that it can be used to aspirate the graft into the injector and small enough to be used through a 2.75 mm clear corneal incision. Similar to other injectors...
Chapter Outline

- Introduction
- Injectors
- Recipient Preparation
- Wound Creation
- Graft Orientation
- Unscrolling and Centering
- Graft Tamponade With Air or Sulfur Hexafluoride 20%
made of clear or translucent materials, graft orientation can often be maintained during injection. The authors suggest using a 1 mL or 3 mL Luer-Lok syringe with this injector to further enhance controlled delivery into the anterior chamber. An optional 3-way stopcock can also be added to the injector for safety to remove air bubbles and refill the syringe without disturbing the loaded graft (Fig. 131.1D).

Glass injectors have been promoted in the European literature. Several European techniques utilize glass injectors such as the curved glass pipette made by the Dutch Ophthalmic Research Center (DMEK surgical disposable set; DORC, Zuidland, The Netherlands) or the Geuder glass injector (Geuder AG, Heidelberg, Germany). Glass potentially offers a smoother surface than plastic and may cause less endothelial cell damage. Surgeons have also adopted off-label use of a glass Jones tube (DMEK Jones tube #80000-DMEK, Gunther Weiss Scientific, Portland, OR). Jones tubes are FDA approved for lacrimal surgery. Similar to the modified AMO injector, the Jones tube can be used to aspirate the graft into the inserter, reducing forces contact with the graft and the risk of endothelial cell trauma. Coupled with 14-French gauge nasogastric tubing, the Jones tube is attached to a 3 mL or 5 mL syringe full of BSS, creating a closed system with a fluid reservoir for tissue injection and chamber maintenance (Fig. 131.1C). The technique also allows slow, controlled delivery of tissue with optimal anterior chamber maintenance. An additional feature of the DMEK Jones tube is a central dilation, which results in decreased fluid velocity in the central portion of the injector relative to the tip. This differential in velocity helps to prevent excessive graft aspiration and maximize control of graft delivery.

With all closed-system DMEK injectors, care must be taken to avoid over-pressurization of the anterior chamber. Injection of excess BSS creates an unfavorable pressure gradient that can result in ejection or incarceration of the graft when the injector tip is withdrawn. To avoid this situation, the authors recommend releasing fluid from a paracentesis prior to withdrawing the injector, or at any time the surgeon feels the eye is becoming over-pressurized. Additionally, shallowing the anterior chamber after graft insertion and prior to injector removal can maintain graft orientation and simultaneously begin the unfolding process. Another technique for reducing graft ejection is by pressing a second instrument (e.g. 30-G cannula) atop the main incision while withdrawing the injector, essentially creating a “trap door” at the wound. It is also helpful in many situations to position the graft near the opening of the injector so that it is introduced into the eye with minimal influx of BSS (Video 131.1).
Akin to DSAEK surgery, there are multiple ways to insert DMEK graft tissue. Whether the injector material is a key component as suggested by Dapena et al. or the injector design is more important as suggested by Kim et al., it remains to be seen. Interestingly, in their small series, Kim et al. found a postoperative endothelial cell loss (ECL) of 28 ± 16% with an Alcon B cartridge attached to a syringe of BSS. This finding compares favorably to the ECL of 12–29% found by Ham et al. in their larger study using a closed-system glass injector. These data suggest that the design features of an injector (e.g. a closed system) may prove more important than its material properties. Furthermore clinical trials and laboratory work with vital dye staining for endothelial damage will be required to better inform this important topic.

Recipient Preparation

Preparation of the recipient eye for successful DMEK surgery involves creation of surgical incisions, removal of the recipient’s Descemet membrane and corneal endothelium, constriction of the pupil, and creation of a peripheral iridotomy.

Wound Creation

The authors prefer a temporal approach, in the widest corneal dimension, to help ensure the primary incision will not interfere with graft implantation. The number of total incisions needed for DMEK surgery varies based on surgical technique. The majority of DMEK surgeons will create two to four paracentesis incisions in addition to the primary incision. Paracentesis incisions of 1 mm are created superior and inferior to the main temporal incision. All wounds for DMEK should be self-sealing, as this aids greatly in chamber stability and subsequent positioning of the graft. Making the incisions parallel to the iris plane facilitates the creation of self-sealing paracenteses. It is helpful to mark the entrance of the incisions with a surgical marking pen so that the paracenteses can be located and accessed easily during the surgical procedure. The internal opening of the paracenteses should not overlap with the area where the graft will be placed. After the paracentesis incisions are made, the primary incision is created. The primary incision is sized to fit the injector chosen by the DMEK surgeon (Table 131.1). The primary incision should allow a snug fit with the DMEK injector and prevent fluid egress, which could risk flushing the graft out of the main incision during graft injection. Although a self-sealing stable incision is ideal, the authors recommend suturing even the smallest main incisions to avoid any potential loss of the graft, air, or gas during later maneuvers.

Endothelium-Descemet membrane resection

After creating the surgical incisions, the diseased endothelium-Descemet membrane complex (EDM) is stripped from the host cornea. This step can be accomplished in numerous ways but it is widely agreed that the creation of a smooth area of resection without residual Descemet membrane (DM) or stromal fibrils is of utmost importance. Residual tags of DM and stromal fibrils may allow fluid to collect between the graft and the recipient stroma, thereby preventing attachment of the graft. It may also result in a suboptimal interface, which can compromise the visual quality in DMEK patients. Kruse was the first to report a lower rate of graft separation and subsequent re-bubbling when the graft does not overlap with host DM. To avoid overlap, the area of stripping on the host cornea should be slightly larger than the diameter of the planned DMEK graft (Fig. 131.2). This results in a small area of bare posterior stroma devoid of any DM coverage. Initially, there may be corneal edema overlying the uncovered areas; the edema typically resolves over days to weeks, likely as donor endothelial cells migrate to cover the bare stroma. The potential increase in graft attachment may result in a loss in cell density as donor cells

<table>
<thead>
<tr>
<th>Table 131.1 Characteristics of various DMEK injectors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Injector</strong></td>
</tr>
<tr>
<td>Viscodot IOL injector</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Staar Microinjector</td>
</tr>
<tr>
<td>DMEK Jones tube</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Modified AMO Emerald One Series injector</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Alcon B cartridge</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

ISBN: 978-0-323-35757-9; PII: B978-0-323-35757-9.00131-1; Author: Mannis & Holland; 00131
to cause miosis. Gentle stroking of the iris surface with a blunt instrument can also be used to augment the miotic effect; however, this may predispose the patient towards greater intraocular inflammation and development of cystoid macular edema postoperatively. The authors recommend against application of carbachol and pilocarpine as the prolonged effect may encourage development of posterior synechiae. Due to the importance of a small pupil in DMEK, some have advocated for staged surgery only, and avoidance of the triple procedure when visually significant cataracts are present concurrently with endothelial decompensation.

For DMEK triple procedures, adequate visualization of the p0170 lens is necessary for the cataract surgery portion of the case. The authors avoid preoperative NSAIDs and exclude dilating agents from the irrigating solution as both prolong dilation. Dilatation for the cataract surgery portion of a DMEK triple procedure can be achieved with intraocular epinephrine alone, or with preoperative instillation of topical phenylephrine 2.5% drops and a topical cyclopentolate agent such as a single drop of mydriacil 0.5%. The authors recommend avoidance of more potent topical cycloplegic agents, as their effects are not readily reversible.

There are several additional considerations when performing DMEK surgery in conjunction with cataract surgery. Following DMEK surgery there is a hyperopic shift, likely due to deturgescence of the cornea. Ham et al. have reported a hyperopic shift of 1/3 of a diopter on average.13 When selecting an IOL, the authors target mild myopia of −0.5 D to −0.75 D to accommodate this shift and achieve a favorable emmetropic or slightly myopic result in the majority of patients. DMEK triple procedures can provide additional challenges, especially early in the surgeon’s learning curve. The intraocular lens is not fully stabilized just after insertion, which can make the procedure challenging. A smaller capsulorhexis can help keep the lens implant from prolapsing and improve lens implant stability. In a highly myopic eye, the anterior chamber will be considerably deeper after the cataract portion of the case and can contribute to difficulty unscrolling the graft tissue. In such cases, consideration may be given to staging the surgery instead of a combined procedure. Additionally, it is possible to inadvertently fill the entire capsular bag and anterior chamber with air or gas in DMEK triple procedures. Should this occur, all of the air or gas can be evacuated and replaced with BSS and a smaller bubble left in the anterior chamber at the conclusion of surgery. This situation can be best avoided by refilling the eye with BSS prior to placing the final air or gas bubble.

**Peripheral iridotomy**

Pupillary block is a reported complication of all types of p0180 endothelial keratoplasty.14,15 With DSEK surgery, pupillary dilation is often employed to prevent pupillary block.16 However, with DMEK surgery, pupillary constriction is used during surgery to prevent graft damage. Pupillary constriction increases the risk of pupillary block from an air or gas bubble in the anterior chamber. As pupillary dilation is not desired during DMEK surgery, it is of great importance that the recipient eye has a patent peripheral iridotomy. This can be accomplished in many ways. The authors prefer to create the peripheral iridotomy as inferior and peripheral on the
patient’s iris as possible. This ensures that the peripheral iridotomy will be uncovered by gas when the patient sits upright. A peripheral iridotomy can be created preoperatively with a YAG laser, but it is critical to pass an instrument through the PI intraoperatively to assure its patency. A peripheral iridotomy may also be created at the time of DMEK surgery. The authors prefer to bend the tip of a 30-gauge needle, then pass it through the pupil behind the iris, and scratch down on top of the needle with a Sinskey hook to establish an opening. The opening can be stretched using a bimanual technique to assure its patency. For phakic DMEK cases in which this maneuver cannot be performed, a peripheral iridotomy can be created using a fine-toothed forceps to grasp the peripheral iris through a fairly vertical paracentesis incision, and Vannas scissors to resect the peripheral iris tissue. It is important to ensure that the iridotomy is full thickness. A risk of all intraoperative peripheral iridotomy techniques is bleeding. Techniques that use a cohesive viscoelastic to maintain the anterior chamber can be advantageous in this setting as this device can be used to tamponade any bleeding that may occur during creation of the peripheral iridotomy (Video 131.2).

**Graft Orientation**

When separated from the stromal surface, DMEK grafts typically scroll with the endothelial cell side facing outwards. Correct graft orientation occurs when the curls of the scroll(s) face the posterior stroma. Achieving correct orientation before unfolding and inflating the anterior chamber is vital for successful DMEK surgery. Depending on the characteristics of the scroll and visibility through the host cornea, this task can present several challenges. Several techniques have been described to facilitate and confirm proper graft orientation.

**Orientation before insertion**

Injecting a DMEK graft in the correct orientation is ideal and should be attempted in all cases. Several steps can be taken to aid in confirming graft orientation prior to injection. Before loading into the desired injector, staining the graft with trypan blue 0.06% (VisionBlue, Dutch Ophthalmic USA, Exeter, NH) is essential to increase contrast and maximize visibility of the graft edges. The authors recommend between 1 and 3 minutes of graft immersion in trypan blue for adequate staining. When the stained graft is loaded into an injector, a double or single scroll will form. In cases with a double scroll, orientation can often be confirmed by direct visual inspection and the graft should be injected with the scrolls facing up (e.g. facing the posterior stroma). The orientation of a single scroll is more difficult to ascertain, but can be accomplished by observing the movement of the overlapping areas of the scroll when rotating the tip. In the correct position, the overlapping edges of the graft will be on the top of the scroll and will appear to move in the same direction as the tip is rotated (e.g. rotating the tip clockwise will result in rightward movement of the overlapping area). If the graft is upside down, the overlapping edges will move in the opposite direction of the tip (e.g. rotating the tip clockwise will result in leftward movement of the overlapping area). After rotating the tip to position the graft in the correct orientation, the tissue is injected into the anterior chamber. This graft orientation technique was first described by Peter Veldman, and named the “Veldman Venn” technique. The overlapping DMEK graft edges are similar in appearance to a Venn diagram (Fig. 131.3).

Krusk et al. described creating three semicircular marks at the edge of the graft in an identifiable order. The marks are created in succession with a small round punch blade, but the distances between the marks vary. The order of the three marks changes when looking from the corrected orientation versus the inverted position. The loss of endothelial cells in the marked areas and the potential increase in peripheral detachments has limited its use.

Recently, eye banks have begun to place an S-stamp on the stromal side of Descemet membrane when preparing DMEK tissue. Similar to the orientation markings made on the stroma on DSAEK grafts, the stamp provides definitive graft orientation regardless of scroll characteristics. The S-stamp remains visible for days to weeks after being placed at the eye bank. One concern is the loss of endothelial cells with this technique from the markings itself and the additional manipulation required by the ophthalmic
technicians. A recent study conducted at the Devers Eye Institute compared the rate of ECL in 19 patients who received DMEK tissue with the S-stamp with 32 patients who received a standard DMEK graft. At 6 months postoperatively, equivalent rates of ECL were found in both groups. The initial studies are promising for its safety and efficacy compared to previous methods of ascertaining graft orientation. Use of the S-stamp is increasing among surgeons and eye banks throughout the US.

Orientation after insertion

When the graft is injected into the anterior chamber, graft orientation can change and can be difficult to assess. An edematous host cornea or a poorly stained graft can further impede visualizing graft orientation.

A technique using a cannula in the lumen of a double scroll to confirm graft orientation has been described. When the graft is oriented correctly with the scrolls facing up, the tip of the cannula will appear blue when moved towards the scroll edge because of the overlying stained graft. If the graft is position upside down (e.g. scrolls facing down), the tip of the cannula will not change color when moved to the edge of the scroll. Coined the Moutsouris sign, this technique is useful, but can also cause cell loss with inadvertent touch of the cannula to the endothelium (Fig. 131.4).

Several no-touch techniques have been described to detect graft orientation. Burkhard described using a handheld slit lamp to enhance visualization of the scrolls. When the slit beam is placed over a correctly oriented double scroll (e.g. scrolls facing up), two adjacent arcs can be seen (two scrolls) with a distant slit beam connecting the two arcs. If the graft is inverted, only one continuous beam is noted. Agarwal et al. described the use of an endoilluminator or light probe to aid in graft orientation. Typically used in retinal cases, a 20-, 23-, or 25-gauge light probe is placed obliquely on the corneal epithelium to enhance visualization. The probe is rotated around the limbus and gentle tapping of the cornea is performed. The operating microscope light is turned down or completely off. The dynamics of the graft is observed and light reflexes from graft folds and edges provide information to assess graft orientation. This technique is particularly useful in edematous corneas.

The use of intraoperative optical coherence tomography during DMEK surgery is increasing in popularity. Handheld devices and integrating the OCT into the operating microscope have been described. High-resolution images from OCT provide very accurate and detailed information about graft positioning (Fig. 131.5). In addition, OCT can be used to evaluate graft attachment to the posterior stroma. While the cost of OCT is prohibitive in most settings, its accuracy in ascertaining graft orientation and versatility in obtaining real-time details about graft position and attachment makes it a unique and useful adjunct for DMEK surgeons.

Changing orientation after insertion

If a graft is inverted after insertion, several steps can be used to flip the tissue back to its correct orientation. First, fill the anterior chamber with BSS. This deepening of the anterior chamber will provide space for the graft to rotate. Next, move the graft toward the center of the pupil with gentle tapping (See Unscrolling and centering section). Finally, through a paracentesis site, use a burst of BSS to create an internal fluid wave to rotate the graft in the desired direction. For example, if the graft is oriented on its side akin to the letter "C", a burst of fluid towards the superior aspect of the "C" will cause the superior edge to move in the direction of the fluid wave and the graft will subsequently rotate counterclockwise. While this technique can be used with the graft near the angle, centering the graft and deepening the anterior chamber can facilitate this technique.

Unscrolling and Centering

After achieving proper orientation of the DMEK graft, the surgeon can proceed with a set of unfolding and centering maneuvers to unscroll and position the graft tissue with the endothelium facing the iris, in correct anatomical conformation. Just as obtaining the correct graft orientation is essential to preventing graft detachment, unscrolling and centering the graft using prescribed techniques are essential to minimize postoperative stromal edema due to endothelial cell traumatization during surgery, graft decentration, or both.

Generally, unfolding of the graft is achieved with the assistance of BSS, an air bubble, or a deliberately shallowed anterior chamber. All three approaches manipulate the effective force of fluid (liquid or gas) within the unscrolled graft tissue, and result in the application of force perpendicular to the DM surface of the unscrolled graft to open up the graft leaflets. This principle also governs the efficacy of corneal tapping and stroking maneuvers – external compression forces applied to the anterior corneal surface with a cannula – that virtually all DMEK surgeons use at some point during surgery to assist with graft unfolding. Each approach aims to eliminate direct contact between the graft tissue and metal instrumentation to minimize donor endothelial cell

**Fig. 131.4** Moutsouris sign. The instrument is placed on top of the graft and moved side to side. If it disappears under a scroll and looks blue (as in the picture above), correct graft orientation has been confirmed. (Courtesy of Mark A. Terry, MD.)
CHAPTER 131
Surgical Technique for DMEK

Fig. 131.5 Intraoperative OCT. While the surgeon’s view is similar in both photos on the left, iOCT reveals that the graft in the top photo is upside down (scrolls down), while the bottom is in the correct orientation (scrolls up).

Fluid assisted unscrolling

Güell et al. have described a systematic approach using p0245 BSS fluid to unfold the donor graft.\textsuperscript{16} In their technique, a Gills cannula is connected to an automated irrigation-aspiration system (Constellation, Alcon Laboratories Inc., Fort Worth, Texas). The instrument tip is introduced through the main incision after suturing it closed. Continuous irrigation is set high at 60–100 mmHg, but the actual fluid pressure is much lower due to the small caliber of the Gills cannula. Low-pressure irrigation flow is used both to center the graft scroll, and to unfold the leaflets. As described above, the instrument tip is placed within the overlapping graft leaflets, and the irrigation is applied from within the scrolled graft to open the leaflets. As grafts from younger donors are more tightly scrolled and unfolding generally is more difficult in this setting, higher flow pressures can be required. This technique can be combined with injection of an air bubble within the scroll prior to complete unfolding, or with gentle cannula-assisted compression of the anterior corneal surface while low-flow irrigation is applied.

**Bubble-assisted unscrolling**

Small volumes of air from a 30-gauge cannula on a 1 mL syringe can also be used to open the graft. Although this can be achieved in several ways, fundamentally, air is injected either above the graft or below the graft to facilitate its unfolding. In the technique described by Price et al., after the edges of the graft are partially unscrolled with irrigating jets of BSS, a small volume of air can be placed underneath the graft, floating it upward so that the Descemet surface is apposed to the recipient stroma. An initial air bubble of approximately 0.02 mL or less injected beneath the graft is used to secure its orientation, yet is small enough to allow the graft to continue to be unfolded and moved as needed for proper centering. BSS can be injected into the interface between the Descemet surface of the graft and the recipient stroma, as needed, to help center and fully unscroll the donor tissue. Subsequently, a cannula can be used to stroke or tap the anterior corneal surface to help unfolding the graft edges.\(^{25}\) Again, as noted with fluid-assisted maneuvers, a shallow anterior chamber during bubble-assisted unscrolling is helpful in keeping the edges of DMEK graft from recurling.

Tight scrolls can present several challenges and the use of air can facilitate atraumatic unscrolling in these cases. The tight scroll can be positioned so a cannula tip can be placed...
within the lumen of the scrolled DMEK graft. A small air bubble is then delivered within the scroll(s) such that the bubble will be on top of the Descemet surface of the graft during the unscrolling process.20,21 Alternately, as long as the graft is positioned with the scroll(s) facing upward, a small air bubble can be placed on top of the graft tissue, so that with external application of a cannula it becomes trapped with the scrolled graft. External taps are used to begin the unscrolling process. Then, external strokes on the anterior corneal surface are used to direct the bubble to unfold the graft. As the bubble is pushed along the DM toward a curled edge of the graft, that edge becomes unscrolled. The air bubble is enlarged subsequently as needed to help facilitate graft unscrolling, until the central endothelium of the DMEK graft is flattened over the iris surface. Once unscrolling is complete, the bubble on top of the graft is evacuated, and the graft can be recentered as needed using corneal taps on the peripheral cornea, limbus, or anterior sclera if needed. Of note, as described by Kruse, an air bubble can be preloaded in the scrolled DMEK graft and the tissue is then injected with the “bubble in the roll” to facilitate unscrolling.

In the event a small edge is not unfolded completely, it is possible to utilize an air bubble equal to or smaller than the graft diameter to maintain the graft’s position while unfolding the curled graft edge. Termed “bubble bumping,” the folded edge is submerged in BSS, while the anterior corneal surface overlying the folded edge is tapped with a cannula.22 Grasping the limbus with a 0.12 forceps and rotating the eye toward the unscrolled edge, to ensure its complete submersion in fluid, can be helpful.

**Chamber assisted unscrolling**

Tapping on the anterior cornea of an eye with a very shallow anterior chamber can also be used to open the DMEK graft. Neither irrigation with BSS nor injections of air are used to assist with unfolding the graft in this technique, first described by Yoeu et al.23 After confirming the graft’s orientation and releasing aqueous from the paracentesis incisions, a 30-gauge cannula is used to tap on the anterior corneal surface to unfold the graft. Whether the graft leaflets are overlapping (single scroll) or nonoverlapping (double scroll), typically the initial corneal taps are applied centrally with the long axis of the cannula parallel to the long axis of the graft. Corneal tapping increases the pressure of fluid trapped within the unscrolled graft tissue, and redirects the fluid force perpendicular to the Descemet surface within the unscrolled leaflet(s) to open them. Once one leaflet is opened, a bimanual technique can be used, wherein one cannula applies pressure over the unscrolled graft and another cannula is used to tap the anterior cornea to unfold the curled graft edge. In order to recenter the graft (whether fully or partially unfolded) during the process, a 30-gauge cannula is used to tap the limbus or stroke the peripheral cornea, usually toward the desired location. External maneuvers have greater effect, and result in greater graft movement, in a shallow chamber than a fully formed chamber.

This chamber assisted unscrolling technique requires that the anterior chamber is sufficiently shallow to prevent rescrolling of the tissue. In order to maintain a shallow chamber during the unscrolling process, fluid is released or aspirated from the paracentesis incisions as often as needed. Additionally, if needed, pressure can be applied at the equator of the globe using a digit or a larger-bore cannula to displace the lens–iris diaphragm anteriorly and shallow the chamber further.

### Centering and centration

Surgeons may need to recenter the graft several times prior to injecting the final air bubble. This centration can be accomplished whether the graft is fully or partially unscrolled, as long as a layer of fluid is bathing both sides of the graft. In the bubble-assisted techniques, BSS first is injected into the anterior chamber, either into the interface between the recipient stroma and DM (if the bubble is beneath the graft) or beneath the graft to make it float up (if the bubble is on top of the graft). Reducing the volume of the air bubble may achieve the same effect. Then, the graft is repositioned by tapping or stroking gently on the anterior corneal surface, the limbus, or the anterior sclera with a cannula, tapping or swiping the graft toward the desired location. In addition, slow limbal indentation followed by a rapid release of the indentation can be very effective in moving a graft towards the direction of the cannula. For example, if a graft is nasally displaced, indenting the temporal limbus will deepen the chamber nasally. A quick release of this indentation will result in an internal fluid wave traveling temporally that will reposition the graft in the desired temporal direction. As noted above, a shallow chamber will accentuate the effect of external compression forces and result in greater graft movement compared to a deep anterior chamber.

It is ideal for the final graft position to be centered within the area of stripped DM on the recipient cornea. Tourtas et al. have shown that the absence of overlap between the DMEK graft and host Descemet membrane correlates with reduced edge detachments and lower rebubble rates.27 Regardless of the surgeon’s strategy for sizing the graft and performing the descemetorhexis, it may be of particular importance to minimize edge overlap at the inferior quadrant, as this edge is least protected by air or gas tamponade in the early postoperative period. Conversely, gaps of uncovered recipient stroma between a slightly decentered graft and host DM are more acceptable. Such gaps will result in stromal edema that will generally subside, as donor endothelium and/or recipient endothelial cells migrate to repopulate the uncovered stroma.28 As long as the central cornea is covered, slight decentration of a DMEK graft does not seem to impact the final visual outcome.

### Graft Tamponade With Air or Sulfur Hexafluoride 20%

Immediately after unscrolling and positioning the DMEK graft, a bubble of air or sulfur hexafluoride 20% is placed in the anterior chamber. The purpose of the bubble is to maintain apposition of the graft tissue with the posterior stroma of the host, while the pump function recovers and the graft can maintain its adherence in aqueous humor. A variety of technical considerations to avoid complications of air or gas
tamponade, chiefly pupillary block, are employed during and sometimes before surgery.

To instill the air or gas bubble once the graft is unscrolled, the surgeon slides a small bore cannula or needle (typically 30-gauge) along the anterior iris beneath the graft tissue. The chamber volume typically is low at this point. Once the cannula tip is centered beneath the graft in the pupillary axis, the surgeon inflates the anterior chamber. The initial bubble can be small or large, depending on the surgeon’s needs. Ultimately, once the graft is positioned, the bubble is enlarged to occupy nearly the entire anterior chamber (Fig. 131.7). Some surgeons will insufflate the chamber to a higher intraocular pressure and use a second instrument to compress the cornea externally and evacuate any fluid trapped between the thin DMEK graft and the recipient corneal stroma. After a period of time, typically 10 minutes, the bubble is reduced to 80–90% of the anterior chamber volume so that it encompasses the entire graft.

The primary complication of air or gas tamponade is pupillary block. Pupillary block can occur when the anterior chamber is overfilled with air and causes impedance of aqueous flow from the posterior chamber across the pupillary margin and into the anterior chamber. To prevent this potentially blinding complication, a peripheral iridotomy in the inferior iris is created prior to insertion of the graft, either intraoperatively or preoperatively (see section on host preparation). Care should be taken to ensure that a cuff of aqueous is present in the peripheral anterior chamber that encompasses the peripheral iridotomy at the end of surgery. This will ensure free communication of fluid across the peripheral iris. The surgeon should also attend to the creation of a sufficiently large iridotomy to maintain patency; stretching the peripheral iris with blunt instruments such as Sinskey and/or reverse Sinskey hooks can be helpful. Some surgeons will utilize topical dilating drops (phenylephrine 2.5% and cyclopentolate 1%) intraoperatively, typically after the graft is unscrolled and centered, to dilate the pupil and minimize the risk of developing pupillary block. Additionally, some surgeons perform a gas-fluid exchange after the initial period of tamponade, prior to placement of the final bubble, to ensure no air or gas is trapped behind the iris.

**DMEK detachment**

Graft detachment is the most frequent complication of DMEK and remains a challenge for surgeons performing and considering adoption of this surgical technique. Reports from surgeons early in their surgical experience with DMEK indicate there is a high rate of graft dislocations requiring reinjection of air to support the graft (a “rebubble” procedure), ranging from 20% to 82%.40-42 As surgeons gain experience the graft detachment drops, ranging from 4.4% to 14% after passage of a “learning curve” period.40,43,44 This complication has prompted surgeons to make additional modifications to initial graft tamponade strategies. For example, Dapena
et al. attribute their reduced graft dislocation rate, in part, to an increase in the duration of complete air fill postoperatively, from 30 minutes to 45–60 minutes. However, it is important to note that the centers most experienced with DMEK have used room air as the tamponade agent. In order to reduce the risk of graft detachment and need for rebubble procedures, other centers have adopted the use of sulfur hexafluoride (SF₆) at a 20% concentration, rather than room air, to increase the duration of the bubble and graft tamponade in the early postoperative period. Detachments after DMEK tend to start with lifting of a graft edge—often the inferior edge—and can be observed as early as the first postoperative day. Because edge lifts can progress over days to weeks to a complete dislocation of the graft, increasing the duration of the anterior chamber bubble in the early postoperative period is advantageous.

Longer lasting gases have been attractive alternatives to air to support and achieve tissue tamponade. SF₆, first synthesized in 1902, is an inert, inorganic, water-insoluble gas first described in the ophthalmic literature for use in retinal detachment repair by Norton in 1973. It is used routinely in modern retinal detachment and macular hole surgeries. Vitreoretinal surgeons successfully utilize SF₆ at a non-expansile concentration of 20%, which effectively doubles the period of postoperative tamponade compared to air in vitrectomy surgery. SF₆ was first described for use in anterior segment surgery in 1987, in the repair of Descemet detachments after cataract surgery, and has since been reported on extensively for this indication. SF₆ has also been described for the treatment of acute hydrops in keratoconus as well as complex DSAEK surgery. Most recently, Güell et al. have reported on the use of SF₆ 20% for the initial graft tamponade in their initial series of 15 cases of DMEK. They report good resultant corneal clarity, mean ECL comparable to other groups, and rate of rebubble of 6.6%. The authors routinely use SF₆ 20% as the initial agent to achieve graft tamponade, with similar results as reported by Güell. When the anterior chamber is filled to 80–90%, an air bubble lasts approximately 3–5 days, while a SF₆ 20% bubble lasts approximately 6–10 days. It is vital that a concentration greater than 20% is not used as this will result in an expansile gas that can lead to puploady block despite placement of a peripheral iridotomy.

SF₆ has been shown to be nontoxic by inhalation in rats, mice, guinea pigs, rabbits, and humans, and nontoxic in the intraperitoneal cavity of humans. Clinically and histologically, the effects of air and sulfur hexafluoride on the corneal endothelium have been under investigation since the 1970s. Histological analyses of corneal endothelium in rabbit and cat models have demonstrated that both air and SF₆ cause ultrastructural damage and ECL. In Van Horn et al.’s landmark investigation of the in vivo effects of air and sulfur hexafluoride on rabbit corneal endothelium, both air and SF₆ were shown to cause proliferation of rabbit endothelium. SF₆ did not appear to have any specific toxic effect on the corneal endothelium when compared with air. These results appear to be as valid in a cat model—a species, like humans, without regenerative endothelium—as shown by Foulks. Of note, in an updated investigation of the effects of SF₆ 20% compared to air in cats, greater ECL was noted in the group exposed to SF₆ 20% compared to air, especially in the superior corneal endothelium. That study could not control for positioning, and unlike in humans, both air and SF₆ exposed groups demonstrated substantial intraocular inflammation beginning on day 1. Taken altogether, the literature suggests that SF₆ appears to be as toxic to the corneal endothelium as air, and that sequestration of the corneal endothelium from nutrients in aqueous likely contributes to cell damage and cell loss. Repositioning and normal patient movement should help ensure that the corneal endothelium is exposed to aqueous and mitigate possible damage.

Positioning strategies to maintain support of the air or gas tamponade in the postoperative period vary substantially. A common practice is for the patient to be instructed to maintain a supine position for 45 to 60 minutes after surgery in the postoperative unit. Some surgeons will recheck the patient at that time to ensure appropriate intraocular pressure and perform an air-fluid exchange routinely or as needed. The authors currently keep the patient’s eye shielded and do not examine the patient until the first postoperative visit the following day. Patients are often instructed to maintain supine positioning for some time postoperatively, ranging from as little as 24 hours postoperatively to as much as every 2 hours for up to 1 week postoperatively, with practices again varying from surgeon to surgeon. The postoperative positioning regimen described by Güell—which in patients are asked to position their head in various positions for 15 minute intervals while awake for the first week postoperatively—demonstrates the concept of using the bubble to tamponade the entirety of the graft surface. While the bubble is still present in the anterior chamber, should an edge lift present, the patient’s head can be positioned such that the bubble can be directed toward the area of concern (e.g. with the head hanging backward slightly to tamponade an inferior edge lift).

References