Endothelial Keratoplasty

A Simplified Technique to Minimize Graft Dislocation, Iatrogenic Graft Failure, and Pupillary Block

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Purpose: Endothelial keratoplasty is an exciting alternative to full-thickness penetrating keratoplasty for replacing the diseased endothelium, yet 3 of the major complications seen are dislocation of the donor tissue, primary graft failure (PGF), and pupillary block from the residual, supportive air bubble. Surgical strategies were developed to reduce the likelihood of occurrence of these complications in our first 200 consecutive Descemet's stripping automated endothelial keratoplasty (DSAEK) cases.

Design: Prospective, noncomparative, interventional case series.

Participants: Two hundred eyes of 172 patients with corneal edema.

Methods: An institutional review board–approved, prospective protocol of endothelial keratoplasty was initiated. Four different surgeons performed DSAEK for the initial 200 consecutive cases using a technique of peripheral recipient bed scraping for donor edge adherence and leaving a residual supportive air bubble, which was freely mobile, and ≤9 mm in diameter. The incidence of early postoperative complications was then determined.

Main Outcome Measures: Postoperative donor graft dislocation, iatrogenic PGF, and pupillary block glaucoma.

Results: There were only 3 dislocations into the anterior chamber in this series of 200 consecutive eyes (1.5% dislocation rate) and all were successfully reattached with a second air bubble. There were no dislocations in the last 115 consecutive cases. There were two cases of donors that were attached but decentered in this series. There were no PGFs. There was not a single case of pupillary block in the entire series.

Conclusion: The surgical technique described in this series, which utilized peripheral recipient bed scraping, has an acceptably low dislocation rate (1.5%) and yielded no cases of iatrogenic PGF. The complication of pupillary block was never seen in this series, likely due to our technique of utilizing a freely mobile, ≤9 mm residual air bubble at the conclusion of surgery. *Ophthalmology 2008;115:1179–1186 © 2008 by the American Academy of Ophthalmology.*

Endothelial keratoplasty (EK) has emerged as a leading surgical remedy in the treatment of corneal edema from endothelial dysfunction.[1–7] Although the current technique of Descemet's stripping automated EK (DSAEK) seems to be the most commonly practiced form of EK, there have also emerged variations in technique of DSAEK surgery that differ in their methods used to avoid the complication of donor dislocation.[8–18] Another important complication reported with DSAEK surgery has been postoperative pupillary block, which requires intervention.[17,18] Preoperative treatments such as placement of an inferior peripheral laser iridotomy or intraoperative placement of a peripheral iridectomy[17] have been suggested to prevent this complication in DSAEK, but to date there have been no published reports on the success of prophylactic measures for the elimination of pupillary block. Finally, the incidence of primary graft failure (PGF) after DSAEK surgery has been reported as much higher than after standard penetrating keratoplasty surgery, and surgical strategies to reduce this complication rate are needed.[10,11,14,15,18]

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We began our investigation of EK for the treatment of endothelial disease with laboratory work in 1999 and with the first patient surgeries in the United States in March of 2000.[19,20] Our EK techniques progressed from large incision deep lamellar EK (DLEK),[5,21–23] to small incision DLEK,[24–28] and then to Descemet's stripping EK (DSEK), followed by DSAEK.[13] In the large and small incision techniques of DLEK, we routinely removed the entire air bubble at the end of each surgery, and therefore did not experience a single case of pupillary block in >250 consecutive DLEK cases, yet we were able to limit our donor dislocation rate to 5% in our first 100 cases.[24,27] In our initial 100 cases of DSEK and DSAEK, we left in place at the end of surgery an air bubble for support of the tissue that was only ≤9 mm, and we published our 4% rate of dislocation in these cases that used peripheral recipient bed scraping for donor edge adherence.[13]

In this report, we detail our technique for our first 200 cases of DSAEK surgery alone, and include cases that were performed by novice surgeons. We feel that the steps outlined in this technique have been simplified for a novice surgeon and specifically designed to reduce the complications of graft dislocation and graft failure, as well as virtually eliminate the occurrence of pupillary block owing to a retained air bubble.

Materials and Methods

Protocol

This series of DSAEK patients is a continuation of our prospective study of EK. All patients signed an 8-page, institutional review board–approved, consent form that complied with the Health Insurance Portability and Accountability Act of 1996. All surgeries were performed between September 2005 and March 2007. There were a total of 200 DSAEK surgeries performed during this period at our institution and these were our very first DSAEK cases. All eyes are ≥4 months out from their surgery to detect any cases of late dislocation or PGF.

One surgeon (MAT) performed 140 operations; 60 surgeries were performed by the other surgeon authors (NS, EC, KH) as their novice DSAEK cases under the direction of Dr Terry. There were 142 (71%) DSAEK cases where the donor was prepared with a microkeratome by the surgeon in the operating room and 58 (29%) of cases where the tissue was "precut" by the distributing eye bank. We began our DSAEK study with the first 100 eyes of the series receiving our "standard" 8.0-mm size disc, and then decided that later cases would receive a donor disc size that was felt to be most suitable for the size of the recipient cornea. One hundred seventy-six eyes (88%) received an 8.0-mm donor disc, 21 received an 8.5-mm donor disc (10%), 2 received a 9.0-mm donor disc, and 1 received a 7.0-mm donor disc.

There were 103 eyes (52%) that underwent cataract surgery concurrent with their endothelial replacement surgery. In all cases, the phacoemulsification cataract extraction was done just before the EK portion of the surgery, and was performed through the same 5-mm temporal scleral incision, but with only a 2.8-mm opening into the anterior chamber. This opening was then subsequently enlarged to the full 5.0 mm for the insertion of the donor tissue.

Inclusion criteria for patients involved any eye with vision loss owing to endothelial dysfunction that otherwise would be considered for full-thickness penetrating keratoplasty. Exclusion criteria included eyes with significant anterior stromal scarring. Eyes with a history of cystoid macular edema, age-related macular degeneration, controlled glaucoma, and other comorbidities were not excluded.

We have previously reported on the dislocation rate and iatrogenic PGF rate in the first 100 case series that combined our DSEK cases (manually prepared donor tissue) and our DSAEK cases (microkeratome-prepared donor tissue).[13] Those initial 68 DSAEK eyes from that report are included in this series of our first 200 cases of DSAEK surgery.

Descemet's Stripping Automated Endothelial Keratoplasty Surgical Technique

In this article, we present our current method of DSAEK surgery (Fig 1). A video of our DSAEK technique (with the surgeon preparation of donor tissue) was presented at the 2006 annual meeting of the American Academy of Ophthalmology and can be found on their Web site (http://aao.scientificposters.com/vodAbstract.cfm?id=21). For our DSAEK technique using "precut" donor tissue, see Videos 1 to 5 (available at http://aaojournal.org).

All cases were performed with retrobulbar injection anesthesia. Antibiotic drops are given preoperatively, and the pupil is only dilated preoperatively if concurrent cataract surgery is planned.

The DSAEK surgery begins with a temporal limbal peritomy to allow a 5-mm scleral incision, 1 mm peripheral to the limbus. A scleral tunnel pocket is dissected into clear cornea. Two paracentesis incisions are made through the clear corneal limbus on either side of the pocket. The chamber is filled with Healon (Advanced Medical Optics, Santa Ana, CA). It is imperative that only a very cohesive viscoelastic such as Healon be used for EK surgery, because dispersive viscoelastics such as Viscoat (Alcon, Fort Worth, TX) can coat the recipient bed and prevent later adhesion of the donor. By using Healon for DSAEK, an irrigating anterior chamber maintainer was not used in any case.

It is at this point that the anterior chamber can be entered with a 2.8-mm blade through the scleral pocket incision and phacoemulsification cataract surgery can be performed using the surgeon's preferred method. It is advised, however, that the anterior capsulotomy be only 4 or 5 mm in diameter to fully stabilize the intraocular lens for the subsequent DSAEK surgery. If the crystalline lens does not have a significant cataract, then DSAEK can be performed alone, leaving the lens in place.

After cataract surgery, the surface epithelium of the cornea is marked with an 8.0-, 8.5-, or 9.0-mm circular template mark. The template size is determined by the relative size of the recipient cornea, with care taken not to cover the posterior entrance site of the paracentesis incisions. A blunt-tipped, angled, reverse Terry-Sinskey hook (Bausch and Lomb, St. Louis, MO) is then placed through the paracentesis site and used to break through Descemet's membrane and score the membrane, following just central to the path of the overlying 8.0 mm template mark. It is important to use a blunt hook, as a sharp hook or needle will penetrate into the overlying stromal tissue and make the scoring and stripping of Descemet's membrane very difficult. Once scored for 360 degrees, the same hook is used to easily peel Descemet's membrane off, and it is then removed from the eye. At this point in the surgery, our technique differs from other well known EK surgeons. We advocate scraping the peripheral recipient bed to promote later donor adherence and have previously described the histology and rationale behind this approach.[13] With Healon filling the anterior chamber, a Terry Scraper (Bausch and Lomb, St. Louis, MO) is used to scrape the peripheral 1 mm of the recipient bed, leaving the central 6 mm of the recipient bed glassy smooth for vision. The peripheral tufts of white fibrils created by the Terry scraper are easily seen and are not subtle. The entrance wound of the scleral pocket is then enlarged to the full 5 mm length and a temporary

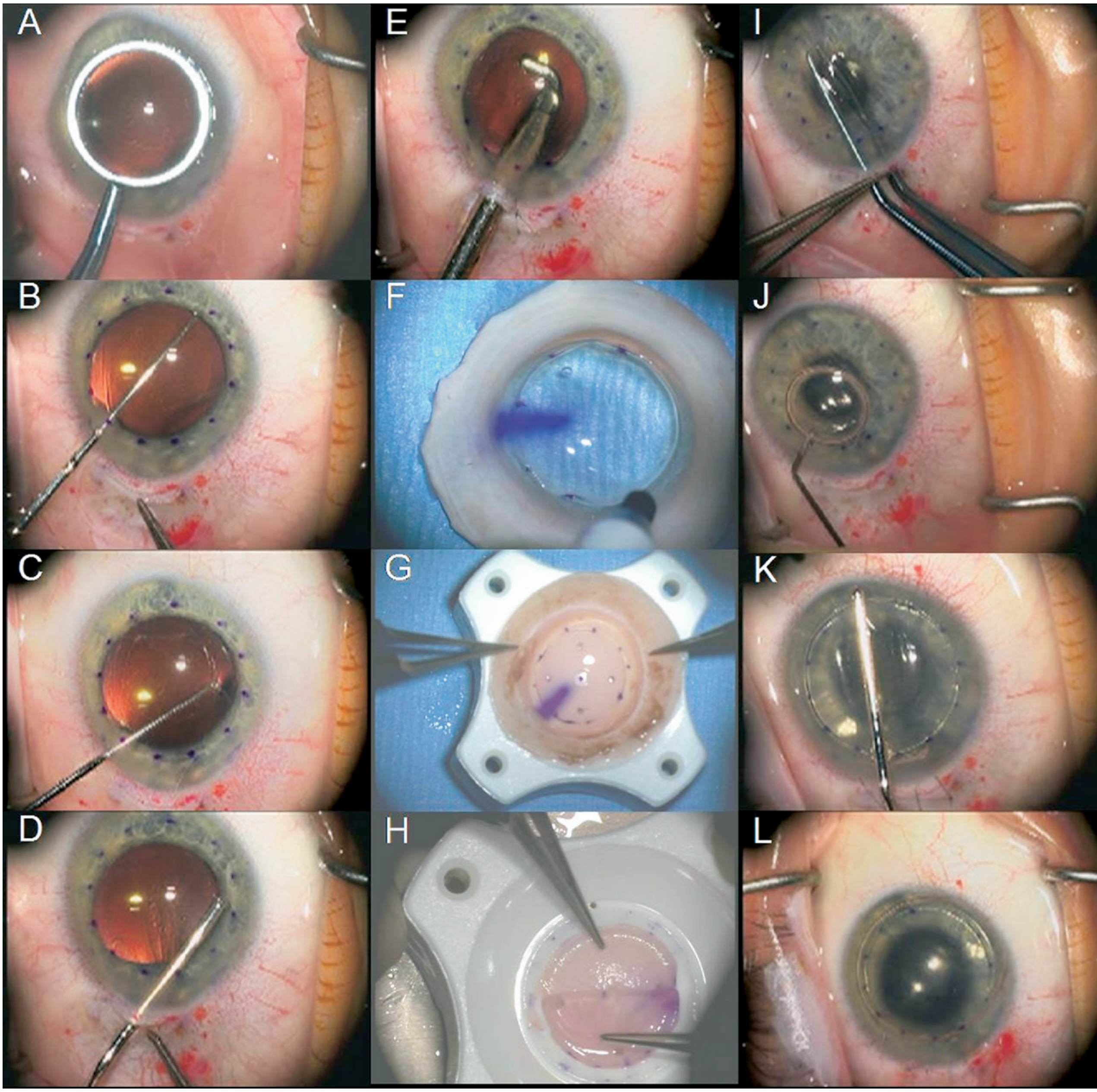

Figure 1. Current Descemet's stripping endothelial keratoplasty technique using precut tissue. **A**, Surface template marked for Descemet's scoring and donor positioning. **B**, The anterior chamber is filled with Healon and a Blunt Terry-Sinskey hook is used to score Descemet's membrane following the overlying template circular mark. **C**, Same blunt Terry-Sinskey hook is used to strip Descemet's membrane from periphery to center. **D**, After Descemet's membrane is removed, a Terry scraper is used to create white fibrils of exposed stroma by scraping the peripheral recipient bed, leaving the central bed untouched. **E**, Healon is completely removed from eye with a standard irrigation–aspiration cannula. **F**, Donor tissue is placed endothelial side down and surface dried. The edges of the microkeratome resection bed are marked. **G**, The donor tissue is centered on the punch to ensure the marks are outside the trephine bore. **H**, The donor posterior disc folded into a 40%/60% "taco" configuration, with the Healon strip on the folded endothelium. **I**, The donor disc is inserted through a 5.0-mm incision with Charlie insertion forceps. **J**, After the chamber is deepened with solution, tissue unfolding is completed with a small air bubble injected on the endothelial side of the donor tissue. **K**, With a chamber full of air, a Cindy sweeper is used on the surface to compress fluid out of the interface. **L**, After 10 minutes with the chamber completely filled with air, all air is removed. An 8.0-mm, freely movable residual air bubble is reinjected to stabilize graft.

10-0 nylon interrupted suture is placed to secure the wound. Healon is completely and meticulously removed from the anterior chamber with an irrigation/aspiration cannula. The pupil is then constricted with the short-acting agent Miochol (Alcon) to minimize exposure of the recipient intraocular lens surface during donor insertion, as well as to further stabilize the intraocular lens from forward displacement. The operating microscope is then moved to the donor table for preparation of the donor tissue.

We currently use donor tissue that has been precut with a microkeratome by the Lions Eye Bank of Oregon (Portland, OR) and have found it to be comparable to tissue cut by the surgeon in the operating room. Care must be taken by the surgeon, however, to personally mark the edges of the microkeratome resected bed to aid centration during donor trephination and avoid an eccentric cut (Fig 1).

If the surgeon cuts the donor tissue himself, we have used a Moria microkeratome system (Moria, Doylestown, PA), exclusively selecting a 300-micron CB head to achieve the ideal thickness of about 150 microns for the donor lenticule. Great care is taken to protect the donor endothelium by filling the artificial anterior chamber with Optisol GS (Bausch and Lomb, Emeryville, CA) and coating the endothelium with Healon before mounting the tissue for cutting. After the microkeratome cut, the tissue is carefully dismounted to avoid collapse of the chamber with attendant endothelial damage and placed on a trephine block, endothelial side up. The same size (8.0–9.0 mm) donor punch trephine is used to cut the tissue. A thin strip of Healon is placed on the endothelium and the tissue is folded into a 60%/40% "taco" shape with the endothelium on the inside. The trephination block with the tissue is brought over into the surgical field.

The "taco"-shaped donor tissue is then gently grasped with specialized "Charlie" insertion forceps (Bausch and Lomb, St. Louis, MO), which are designed to coapt only at the distal tips, with a space between the forceps blades that prevents crushing of the donor tissue. The tissue is then inserted into the anterior chamber with the 60% side of the taco anterior. The chamber usually collapses over the tissue, but only the stromal surfaces are exposed and the endothelium is protected inside the taco. Unfolding of the donor tissue should be very, very slow and controlled. To accomplish this, balanced salt solution (BSS) is slowly injected through the right paracentesis site (the stromal side of the taco) to deepen the chamber. As the chamber deepens, the posterior 40% side of the taco begins to unfold. When the taco unfolds to an 80° angle (with the posterior edge of the taco nearly perpendicular to the iris), then irrigation with BSS is immediately stopped. An air bubble is then injected very, very slowly through the left paracentesis site (on the endothelial side of the taco); this easily completes the unfolding, with the taco usually in excellent centration and orientation. If the donor disc is off from centration by ≤2 mm, gentle sweeping and compression of the surface of the cornea across the entire length of the donor disc diameter ballots and moves the tissue in the direction of the sweep until the desired position is obtained. Once the taco is unfolded, the donor tissue is locked into place by filling the entire anterior chamber with air and the wound is closed with 3 interrupted 10-0 nylon sutures.

It is at this point that measures are taken to ensure that the donor tissue remains adherent. With the chamber completely filled with air, the specialized "Cindy Sweeper" (Bausch and Lomb, St. Louis, MO) is used to compress the surface of the cornea and sweep from the center to the periphery, repeatedly for about 2 minutes. This maneuver "milks" any interface fluid out to the edge of the graft and into the anterior chamber, thereby stabilizing the graft. Sweeping of the surface is performed until the surgeon feels that the edges of the graft remain perfectly aligned with the overlying template mark and without any movement of the graft at all. We have not found it necessary to perform transcorneal stab incisions to remove interface fluid in the vast majority of cases. However, if after 3 minutes of sweeping the surface with the Cindy sweeper, we find persistent and significant "sliding" movement of the donor disc on the recipient bed, then we may place 4 slightly beveled stab incisions from the surface to the interface in the pericentral zone using a 1-mm wide diamond paracentesis knife. With the graft stabilized, we then turn off the microscope light and leave the tissue completely undisturbed for 10 minutes with air filling the anterior chamber and the pressure normalized. Dilating drops of cyclopentolate 1% and phenylephrine 2.5 % are placed at this time.

After 10 minutes, the air bubble is completely removed and replaced with BSS, and the pressure normalized. A final air bubble of only 8 or 9 mm is then placed into the anterior chamber to support the graft, making sure that this final air bubble is freely movable and that the pressure in the eye is normal. A 24-hour collagen shield soaked in antibiotic and steroid is then applied, the eye is gently patched, and the patient taken to the recovery room. The patient is instructed to remain completely supine for 1 hour after surgery and then as much as reasonably possible (allowing meals and toilet activity) until seen the next day when the patch is removed for the first time.

Results

The 200 eyes in this prospective, nonrandomized series were from 172 patients with a mean age at surgery of 69±11 years (range, 42–96). There were 126 eyes (63%) females and 74 (37%) from males. One hundred sixty-five eyes (82%) required DSAEK surgery owing to Fuchs' dystrophy; 29 eyes (15%) had no history or evidence of Fuchs' dystrophy and required surgery owing to pseudophakic bullous keratopathy. Six eyes (3%) had DSAEK for late failure of a prior graft. Two eyes of a young Fuchs' dystrophy patient had reduced vision owing strictly to central corneal edema; the eyes had a clear crystalline lens, with no cataract and some residual accommodation ability. In these 2 eyes, DSAEK was performed without cataract surgery, leaving the natural lens in place. Only 4 eyes (2%) received corneal fenestration incisions pericentrally in each quadrant at the time of surgery to drain suspected persistent interface fluid.

There were 3 dislocations of the donor tissue into the anterior chamber in this series. One of the donor tissues (DSAEK case 86) was found to have interface fluid and completely dislocated on the first day postoperatively. This tissue also was the fourth precut tissue in the series and had been eccentrically punched by the surgeon because he lined up the centering dot placed by the eye bank technician properly, but the cap had shifted position during transit to the operating room, resulting in the eccentric punch and a 1-mm-thick edge. The edge was manually trimmed to a beveled edge, and the tissue inserted. The other two dislocations (DSAEK cases 28 and 56) were earlier in the series and were both attached on the first postoperative day with no interface fluid anywhere. Dislocation in case 28 occurred approximately 36 hours after surgery for no apparent reason. Dislocation in case 56 occurred approximately 3 days after the surgery shortly after a "sneezing fit" reported by the patient. All dislocated discs were reattached with a single repeat air bubble. There have been no further donors dislocated into the anterior chamber in the 115 final consecutive DSAEK cases in this series.

There were two cases in the series where the donor tissue was attached with no interface fluid, but significantly decentered superiorly. In case 91, the donor tissue was decentered about 1 mm superiorly. This was remedied with repeat operation under topical anesthesia consisting of placement of an initial small 4-mm air bubble followed by irrigation of the interface to separate the attached donor tissue and movement of the tissue with a Sinskey hook into proper centration. After surface sweeping to remove interface fluid and 10 minutes of a full air bubble in the anterior chamber, that the anterior chamber air was completely replaced with BSS, followed by placement of a residual 9.0-mm freely mobile air bubble. Postoperative supine positioning by the patient was done as usual. The tissue attached with good centration and the graft cleared the entire recipient cornea. The second case of decentration was in a very large diameter recipient cornea (>12 mm); the 8.0-mm donor tissue was decentered dramatically superiorly, but was fully attached and without interface fluid. The surgeon (MAT) had not encountered such a dramatic decentration before, and felt that perhaps a disparity existed between the donor curvature and the recipient posterior curvature, and that this had caused the extreme decentration. The surgeon elected to replace the 8.0-mm donor tissue with a 9.0-mm donor in this large recipient cornea, rather than simply move the original tissue back into centration. Paracentral corneal fenestration incisions were also added. The second donor also decentered postoperatively, but was recentered with a third operation (with the same donor) and resulted in a clear cornea and 20/20 vision at 6 months. The histopathology of the original first DSAEK donor tissue revealed an excellent endothelial cell density, and in retrospect, replacement of the tissue to remedy decentration was an error in judgment by the surgeon (MAT).

There were 23 cases where the day after surgery, the graft was found to be well centered and attached, but there was found to be an edge of the graft where a small cleft of interface fluid was present. In the vast majority of cases, this cleft measured less than ½ clock hour at the edge and extended <1 mm centrally, without involvement of the pupillary zone. In the worst case, the cleft involved the inferior 20% of the graft. These grafts were observed closely, and no intervention was performed. All grafts resolved these clefts spontaneously, usually by 2 weeks postoperatively, leaving just a visually insignificant, small line of adhesion visible in the periphery.

There were no cases of PGF or donor endothelial failure in this entire DSAEK series, and excellent clearing of the recipient cornea occurred in every case.

There were no cases of pupillary block in this entire DSAEK series.

Discussion

Endothelial keratoplasty has provided rapid visual rehabilitation for our patients suffering from endothelial failure; however, the complications of donor dislocation, PGF, and postoperative pupillary block by the residual air bubble are still a challenge in most reported series.[9–11,15,17,18] Any modification of DSAEK surgical technique that can safely minimize the occurrence of these specific complications should be reported. In this study, we have presented a simplified technique of DSAEK surgery that does not require an anterior chamber maintainer device, surface corneal stab incisions for interface fluid venting, preoperative or intraoperative peripheral iridectomies, or remanipulation of the eye 1 hour after surgery with "burping" of air. We believe that eliminating these steps in addition to the use of Healon viscoelastic for preparation of the recipient bed has simplified the execution of DSAEK surgery. Using this simplified DSAEK technique, we prospectively evaluated the dislocation rate, iatrogenic PGF rate, and pupillary block complication rate of eyes undergoing this method of DSAEK surgery.

Dislocation

The 3 most commonly described DSAEK techniques here in the United States have been advocated by Gorovoy,[10] Price and Price,[12] and Terry et al.[13] In his initial published series of 16 cases, Gorovoy describes a technique of placing a supportive air bubble at the end of surgery that completely fills the anterior chamber; he leaves the bubble in place for 1 hour. The patient is then positioned at the slit-lamp biomicroscope and the air is partially evacuated through a previously placed paracentesis site. The dislocation rate in this series was 25%; pupillary block was not reported in this small series.[10] Gorovoy has recently modified his technique by adding surface corneal stab incisions to vent interface fluid and further reduce his complication rate, but his data have not been published in a peer-reviewed journal. Koenig and Covert[17] reported on their first 26 DSAEK cases using a 4.2-mm access incision for insertion of an 8.5-mm donor, with removal of about 50% of the air bubble at the end of surgery. They experienced a dislocation rate of 35% (9/26 eyes).[17] Despite the use of a temporal intraoperative peripheral iridectomy used in this series, there was one case of pupillary block that was felt to have led to macular visual loss owing to an induced branch vein occlusion.[17] Price and Price have advocated the use of corneal "fenestration" incisions as well as corneal surface "massage" to remove interface fluid before the end of surgery.[9] The rate of dislocation in their first 10 cases without using these maneuvers was 50%,[18] but when combining these two technique modifications (fenestration incisions and massage) the dislocation rate was 13% (17/126 eyes), with a 6% (4/64 eyes) rate of dislocation in the final cases of that 200 case series.[18] They also reported 2 cases in a series of 200 eyes with substantially elevated intraocular pressure, requiring intervention, and one of these was known to be due to pupillary block by the residual air bubble.[18] Outside the United States, Nieuwendaal et al[11] have reported a 14% rate (4/22 eyes) of donor dislocation in 22 eyes using the Melles technique of DSEK with tissue that had been manually precut from a whole globe and then stored in warm conditions from 10 to 21 days using their standard organ culture medium. Their reported DSEK technique involves removing 50% of the air at the end of surgery; they did not report on the complication of pupillary block.

The specific mechanisms of donor tissue attachment in EK surgery are not well established, but likely are a combination of physical, biochemical, and physiologic processes.

In terms of a physical process for donor attachment, we have shown by scanning electron microscopy that the recipient stromal bed after DLEK surgery has the entire surface covered with exposed stromal fibrils that result from the manual dissection process.[13] Compared with the glassy smooth recipient surface of DSEK, the effective surface area of the same diameter recipient bed in DLEK is dramatically increased by these fibrils. We postulated that these stromal fibrils aid in donor attachment in DLEK by way of a physical process of interaction of cut donor stromal fibrils with cut recipient stromal fibrils, and that this attachment process is independent of endothelial pump function. We believe that because of the apposition of these two rough, enhanced surface area tissues, that we were able to minimize our detachment rate in DLEK surgery to only 5% in our first 100 DLEK cases, without the need for a postoperative residual air bubble.[24,27] Despite the total removal of the air bubble at the end of DLEK surgery and the elimination of any air bubble support of the DLEK graft postoperatively, the donor tissue adhered 95% of the time. In our DSAEK series, we used peripheral bed scraping to recreate the DLEK form of physical attachment of the graft, but left the central recipient bed pristinely smooth for better optics.[13] This peripheral scraping, in combination with other surgical maneuvers, may be primarily responsible for the low dislocation rate of 1.5% in our first 200 DSAEK cases.

The biochemical process of donor tissue attachment in DSAEK is the least understood, but would also be independent of endothelial function. One suggestion is that the influx of water into the stroma of both the donor and the recipient tissues causes the interstitial proteoglycans to uncoil,[29] and the interaction of these uncoiled large molecules provides a biochemical "glue" that holds the two surfaces together (Edelhauser H, personal communication, May 15, 2007). It is possible that the peripheral scraping that is performed in our recommended DSAEK technique also makes more macromolecular interaction available, enhancing the biochemical "glue" effect.

The most likely physiologic process that enhances donor attachment is the endothelial pump mechanism. It has been our clinical impression that dislocated donor tissue that has detached and remained floating in the anterior chamber aqueous for >1 day seems to attach quite readily and clear the overlying corneal edema after reattachment even more quickly than tissue that is attached the first postoperative day. We postulate that the interval between detachment and reattachment with a second air bubble procedure has allowed the donor tissue to gain some further recovery of function after the trauma of eye bank processing, storage, and surgical manipulations. It seems reasonable, therefore, that any surgical maneuvers that allow minimal trauma and high endothelial cell survival will result in better donor adhesion by providing more pumps for physiologic attachment.

The incidence of dislocation has rapidly decreased in the hands of experienced EK surgeons with the attention to the removal of interface fluid at the time of surgery. Price and Price have shown that sweeping of the corneal surface with the addition of pericentral corneal stab incisions to vent interface fluid can reduce the dislocation rate to ≤6%.[18] In our series, we also utilized surface sweeping with the Cindy sweeper to remove interface fluid. However, we chose to avoid routinely placing any form of corneal surface incision and instead substituted peripheral recipient bed scraping to promote donor adhesion.[13] With this technique of surface sweeping coupled with peripheral recipient bed scraping, we experienced only 3 out of our first 200 consecutive cases (1.5%) of donor tissue dislocation. Two of these dislocation cases were in our first 100 DSAEK cases and had absolutely no interface fluid or dislocation on postoperative day 1. The third dislocation case also occurred in our first 100 cases and likely dislocated due to the trauma of trying to trim the edge of an eccentrically punched donor button. Importantly, using the technique described in this series, we did not experience a single dislocation in the final 115 consecutive DSAEK cases in this series, despite the addition of two additional "novice" surgeons (EC, NS) to this series during that time period. In addition, all of the dislocations in this series occurred in cases performed by the most experienced DSAEK surgeon of the series (MAT). The other surgeon authors of this report performed 60 of the 200 cases, and despite their status as "novice" DSAEK surgeons, have not had a single dislocation using this technique. Obviously, it is impossible to determine in our series if the low dislocation rate is due primarily to the surface sweeping maneuver or to the peripheral scraping maneuver. However, our low (5%) rate of dislocation in our first 100 DLEK surgeries, which did not have the benefit of air bubble support or surface sweeping, suggests that the increased surface area of two cut stromal surfaces can play an important role in donor adhesion.[13,24,25,27] Although a randomized, controlled series comparing eyes with and without peripheral recipient bed scraping would help to determine the relative contributions of this maneuver, the authors currently have a DSAEK surgical technique that works, with a 1.5% dislocation rate, and are hesitant to jeopardize that success.

Pupillary Block

Over the past 7 years, we have performed >600 cases of EK surgery and we have not experienced a single case of pupillary block. Obviously, in DLEK cases where our technique involves the complete removal of the air bubble at the end of surgery, pupillary block (from an air bubble) would not be possible. It is also important to note that in the absence of an air bubble, the DLEK procedure achieved a low 5% rate of donor dislocation into the anterior chamber.[27] This low dislocation rate without air bubble support was felt once again to be largely due to the increased mechanical adhesion over the entire donor stromal interface, which was afforded by the manual cut fibrils of the recipient stromal bed.

In the 200 cases of DSAEK surgery reported herein, we intentionally placed an air bubble that was large enough to support the graft, but small enough to only fill about ≤50% of the volume of the anterior chamber. Importantly, we made sure that there was no air remaining attached to the pupil margin or hiding behind the iris by first removing nearly all of the air bubble at the end of surgery and then adding back the amount of air we desired to just cover the edges of the graft. We always made sure that the final air bubble we left behind at the end of surgery was also freely movable. Moving the patients head from side to side allowed the surgeon to also verify that the bubble moved freely before placing the patch. As a further precaution against pupillary block, we temporarily dilated the pupil with cyclogyl 1% and phenylephrine 2.5% drops at the end of surgery to add the safety of a larger pupil size in the immediate postoperative period. Using these methods, although it was possible that the residual air bubble could block the pupil while the patient was in the supine position, as soon as the patient sat upright to eat or use the toilet after surgery, the air bubble would rise in the anterior chamber, the air bubble inferior edge would be in the mid-pupil position, and any supine position pupillary block that could occur would immediately resolve. None of the patients in this 200-case prospective series complained of pain or discomfort during the hours from the conclusion of surgery to the first examination the next day, and no eye had any other evidence (e.g., peripheral iris synechiae, iridocorneal adhesions, narrowed angles) of prior pupillary block when examined the day after surgery. The air bubble technique described in this series seems to have eliminated the need for preoperative inferior laser iridotomies or other medical or surgical interventions that have been described for prophylaxis and treatment of pupillary block in DSAEK surgery.[17]

Primary Graft Failure

Primary graft failure is quite rare with traditional penetrating keratoplasty, but has been a serious problem with EK surgery, especially with surgeons' initial cases. Koenig and Covert[17] reported a 12% rate (3/26 eyes) of PGF in their initial cases of DSAEK surgery using a 4.2-mm access incision for an 8.5-mm graft. Gorovoy[10] reported a 6% rate of PGF in his initial 16 cases of DSAEK. Nieuwendaal et al[11] reported a 14% rate (3/22 eyes) of PGF in their DSAEK cases using the Melles technique and precut tissue stored in organ culture medium. Price and Price[9] reported an initial PGF rate of 6% in their first 50 cases of DSEK, but the overall series of DSEK/DSAEK eyes had a 2% rate (7/330 eyes) of PGF.[12] In our initial series of 100 eyes with either DSEK or DSAEK, we experienced only one case of PGF (1%), and that PGF was a DSEK case.[13] In the series reported here of our first 200 purely DSAEK cases, we have not experienced a single case of PGF. Clearly, because the incidence of PGF seems to decrease with DSAEK surgeon experience, the failure of a graft after DSAEK surgery is more likely iatrogenic and rarely related to eye bank processing. Therefore, any DSAEK technique that can reduce intraoperative trauma and minimize iatrogenic PGF should be reported and advocated.

The absence of PGF failure rate in this series is likely due to our attempts to minimize trauma to the endothelial cells during donor processing, insertion, unfolding, and centering. The use of a 5.0-mm limbal incision, rather than a shorter 3.0-mm incision, likely produces less trauma to the endothelium as the 8.0-mm (or larger) folded donor tissue is passed through to the anterior chamber.[1,30,31] Our slow method of initiating the unfolding of the tissue by deepening the anterior chamber with BSS at the folded stromal side of the graft, and completing the slow unfolding with an air bubble on the open endothelial side of the graft minimizes the risk of unfolding the tissue upside down and seems to be very atraumatic. If unfolded properly, further centering of the tissue is not necessary and endothelial trauma from touch with a hook for tissue centration is avoided. We cannot determine at this time which step of the procedure is most important for protection of the endothelium, but our DSAEK technique as a whole and as described herein has prevented the occurrence of PGF for every novice EK surgeon at this site.

We have described in detail a DSAEK technique that has allowed an experienced EK surgeon and 3 novice EK surgeons to achieve a low complication rate of only 1.5% dislocations and no cases of PGF or pupillary block in their first 200 cases. The field of EK has rapidly expanded over the past 2 years and, as more surgeons become experienced with EK, further modifications in technique certainly will be introduced. In particular, the introduction of techniques and instrumentation that minimize or avoid tissue compression by the wound during donor insertion hold the most promise.[30–32] Although technique modifications that enable DSAEK surgery to be performed easier and faster are to be encouraged, care must be taken to ensure that the safety of the endothelium is not compromised in the process. Careful documentation of the PGF rate, the donor dislocation rate, and the rate of pupillary block must be performed to truly know what initial price the patient is paying for increased surgeon speed and ease of surgery. Ideally, prospective studies of long-term donor endothelial cell survival should be done to obtain even more specific data to support (or condemn) our current and future EK technique modifications.

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