Small-Incision Descemet Stripping Automated Endothelial Keratoplasty: A Comparison of Small-Incision Tissue Injector and Forceps Techniques

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**Purpose:** To describe a novel, small-incision, no-fold Descemet stripping automated endothelial keratoplasty (DSAEK) graft injector and to compare complications, visual acuity, and endothelial cell loss with a forceps technique.

**Methods:** An Institutional Review Board–approved, interventional, nonrandomized, consecutive case series analysis of 175 eyes undergoing DSAEK for Fuchs dystrophy and bullous keratopathy. The injector arm is prospective, and the forceps arm is retrospective. Seventy grafts were performed with a DSAEK graft injector, and 105 grafts were performed using a small-incision forceps technique. Preoperative and postoperative visual acuities at 3 and 6 months, 6-month endothelial cell counts, and complications, including graft dislocation, failure, and rejection, were recorded. Fifty-seven of 232 eyes met exclusion criteria for previous incisional corneal or glaucoma surgery.

**Results:** There were 4 eyes (5.7%) in the injector group and 29 eyes (27.6%) in the forceps group that required a re-bubble procedure because of graft detachment. One graft (1.4%) failed in the injector group and 7 grafts (6.5%) failed in the forceps group. Excluding eyes with other ocular comorbidities (43), in the injector group 74% were 20/40 or better at 6 months and 100% were 20/60 or better. In the forceps group, 72% were 20/40 or better at 6 months and 98% were 20/60 or better. Six-month postoperative endothelial cell counts were available for 84 (46 injector and 38 forceps) eyes, with an average cell loss of 28.3% in the injector group and 44.1% in the forceps group.

**Conclusions:** DSAEK is an effective treatment of endothelial dysfunction. Surgical technique is important to limit endothelial cell loss and prevent complications, such as graft dislocation. The injector device has several advantages over the trifold forceps technique, including decreased endothelial cell loss, graft dislocation rate, and graft failure rate, and it reduces the DSAEK learning curve. DSAEK graft injectors likely will have a role in the future of endothelial keratoplasty.

**Key Words:** Descemet stripping automated endothelial keratoplasty, Descemet stripping endothelial keratoplasty, Descemet stripping automated endothelial keratoplasty, Descemet stripping automated endothelial keratoplasty injector, small incision, injector

Descemet stripping automated endothelial keratoplasty (DSAEK) is rapidly becoming the preferred treatment of selective corneal endothelial cell dysfunction associated with failed penetrating keratoplasty, bullous keratopathy, and Fuchs endothelial dystrophy. Originally described by Melles et al as “descemetorhexis,” the Descemet stripping endothelial keratoplasty procedure has been refined by several surgeons. In its most popular form (DSAEK), a microkeratome is used to predissected donor corneas for implantation. Despite this advancement, the learning curve for the procedure has been steep.

A variety of tissue insertion techniques for DSAEK has been described using both small (2.8–4 mm) and large (5 mm or larger) incisions. Debates remain over the ideal incision size and location. Larger incisions (5–6 mm) are less likely to damage endothelial cells because of less folding and compression but have several disadvantages. In our experience, larger corneal wounds often require suturing, induce cylinder, promote iris prolapse, and have a greater risk of a flat anterior chamber during graft insertion, making it exceedingly difficult to avoid damaging intraocular structures or the graft itself, although others have reported none of these problems using a 5-mm scleral incision with forceps insertion.

Smaller incisions (2.8–4 mm) are more likely to damage endothelial cells because of tissue compression and manipulation but are less likely to require suturing, are topical anesthesia-friendly, and are more convenient to combine with clear corneal phacoemulsification.

In addition to incision size, graft insertion technique is important for endothelial cell preservation. Forceps, glide, and suture fixation techniques have been described in an effort to limit difficulties with graft unfolding. Newer DSAEK graft injector devices could potentially reduce the DSAEK learning curve, improve endothelial cell loss, hasten postoperative visual recovery, and decrease graft detachment and
Small-Incision DSAEK

Failure rates. They also may facilitate very thin graft insertion, including the potential for Descemet membrane endothelial keratoplasty.17–19

Our trifold technique uses sodium hyaluronate (Healon; AMO, Santa Ana, CA) with a 4-mm clear corneal incision that provides anterior chamber stabilization, minimizes potential natural lens trauma, and facilitates unfolding.20 A high endothelial cell loss (44.1%) and dislocation rate (27.6%) prompted the development of a graft injector designed to minimize endothelial cell loss while maintaining the convenience of our small-incision forceps technique.

In this study, we compare 2 small-incision graft insertion techniques at our institution. Our previously described forceps technique uses a trifold insertion technique through a 4-mm clear corneal incision in comparison with a novel 4-mm clear corneal DSAEK graft injector.

Patients and Methods

This was an Institutional Review Board–approved, interventional, nonrandomized, consecutive case series of 175 eyes of 159 patients who underwent DSAEK at the Wake Forest University Eye Center by an experienced surgeon (K.A.W.). A total series of 232 eyes were analyzed, with 57 eyes meeting exclusion criteria for previous incisional corneal surgery, such as failed penetrating keratoplasty or Descemet stripping endothelial keratoplasty (38), incisional glaucoma (13), or incisional retinal surgery (6) (Table 1). Seventy eyes underwent the graft injector procedure (March 2009–October 2009), and 105 eyes underwent the forceps procedure (January 2007–February 2009) as detailed. Corneal tissue diameter ranged from 7.25 to 8.5 mm in both the groups. The forceps series was performed immediately before the injector series and was consecutive. The forceps series was a retrospective analysis, and the injector series was prospective.

The majority of eyes (162) underwent DSAEK for Fuchs endothelial dystrophy. We noted preoperative and postoperative visual acuities at 3 and 6 months, endothelial cell counts (injector, 6 months; forceps, 6–10 months), and intraoperative and postoperative complications, including graft detachment rates. Statistical analysis was performed with Microsoft Excel (Redmond, WA) and GraphPad (La Jolla, CA) using Student t and χ² tests. P < 0.05 was considered statistically significant.

Surgical Technique

Forceps

All cases in both the groups were 50% marcaine–lidocaine retrobulbar blocks or general anesthesia. The pupil was dilated preoperatively and remained dilated throughout the procedure. A 4.0-mm clear corneal incision was made with 2 paracentesis wounds at 3-o’clock and 9-o’clock positions, and the anterior chamber was filled with Healon. A descemetorhexis was performed, and the donor graft was prepared on the side table using precut tissue and a disposable trephine. Healon was placed on the endothelium, and one-third of the graft was folded over. Noncompressing phakic intraocular lens insertion forceps (Storz; Bausch & Lomb, Rochester, NY) were used to grasp the donor, and the remaining graft was folded around the forceps and inserted through a 4-mm incision. A Simcoe IA cannula was used to center the graft and remove all viscoelastic. A microvitreoretinal (MVR) blade was used to make 4 transcorneal slits, as described by Price and Price.21 Filtered air was then injected to keep a firm eye pressure for 10 minutes. The air bubble was then reduced to 40% for the postoperative period. The injector series immediately followed the forceps series. The surgeon had experience at the start of the study, with more than 500 cases performed.

Injector

The pupil was dilated preoperatively. A superior 4-mm corneal groove and paracentesis wounds were created with a diamond blade. Healon was injected into the anterior chamber. A descemetorhexis was performed with a 90-degree stripper. The Healon was completely removed. Precut tissue was trephined to the appropriate diameter using a disposable trephine. The injector device was connected to a balanced salt solution (BSS) infusion line. The tissue was loaded onto the injector platform (Figs. 1, 2; OSI, Winston-Salem, NC) endothelial side-up with Maumanee forceps taking care not to touch the endothelial surface. A ribbon of Healon was placed on the graft. The platform was retracted into the injector sheath, rolling the graft endothelial side in. This platform was 7.5 mm across and completely retracted into the lumen of the device, so that the tissue rested inside the outer insertion sheath. The device was rotated 180 degrees, so that the endothelium was facing downward. The BSS infusion was started while the insertion sheath was introduced through the corneal incision and gently run through the lumen of the rolled tissue, thereby deepening the anterior chamber. Once the sheath reached the distal internal cornea, it was retracted manually using an incorporated wheel. As the graft was unsheathed, it deployed endothelial side-down in the anterior chamber. A deep chamber was maintained with continuous BSS infusion. Filtered air was injected to fix the graft against the cornea. Transcorneal slits were performed for the first 20 cases and were abandoned for subsequent cases because of better graft attachment than with the forceps method. Firm air

FIGURE 1. Tissue injector illustration.
pressure was maintained for 8 minutes, and the air bubble was reduced to 40%. The epithelium was typically debrided if necessary to allow for better visualization and to promote a smooth epithelial surface postoperatively. Wounds were verified to be air-tight and water-tight, and a suture was placed if necessary (10%). A bandage contact lens was placed at the time of surgery. The patient was kept in recovery and examined 1 hour postoperatively (see video on Eyetube available at http://www.eyetube.net/videos/default.asp?ramabi.)

RESULTS

Graft dislocation was 5 times more likely in the forceps group compared with the injector group (Fig. 3). There were 4 dislocations (5.7%; \( P = 0.0003 \)) in the injector group and 29 (27.6%) in the forceps group. However, of the 4 injector dislocations, 1 patient admitted to eye rubbing during the first postoperative week and an additional 2 patients received a 6-minute air bubble as part of an additional Institutional Review Board study on decreased bubble time. No patients in the forceps group admitted to eye rubbing.

Donor endothelial cell density was measured on every graft preoperatively (OSI). Postoperative endothelial cell density was obtained by noncontact specular microscopy (Tommy USA, Phoenix, AZ). Six-month endothelial cell density was available for 48 eyes in the forceps group and 36 eyes in the injector group (Table 2). There was a substantial loss to follow-up for 6-month endothelial cell counts, particularly in the retrospective arm, likely because of the referral nature of the practice.

Primary graft failure is an important complication of DSAEK. Among the forceps group, there were 7 graft failures (6.5%; \( P = 0.147 \)) that required repeat DSAEK. One of these failed a second time and required a third DSAEK surgery that was successful. Among the injector group, there was 1 primary graft failure (1.4%). This was an uncomplicated case, and we could not identify a reason for the graft failure. The patient underwent uncomplicated repeat DSAEK with the injector.

The visual outcomes at 3 and 6 months were similar in the 2 groups, as shown in Figure 4. Excluding ocular comorbidities, only 1 patient in the injector group and 2 patients in the forceps group achieved 20/20 visual acuity at 6 months.

Other Complications

In the forceps group, there was 1 case of air bubble–induced pupillary block glaucoma. This was treated immediately postoperatively by air bubble reduction with a cannula at the slit lamp. There were no cases of pupillary block in the injector group. In the third injector case, the graft was propelled quickly out of the device because the BSS bottle height was too high. The graft unfolded normally and was 100% attached postoperatively. There were no known cases of retinal detachment, suprachoroidal hemorrhage, epithelial ingrowth, or endophthalmitis in either group.

<table>
<thead>
<tr>
<th>TABLE 1. Patient Demographics</th>
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<tr>
<td></td>
</tr>
<tr>
<td>Eyes</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Age, yr</td>
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<tr>
<td>DSAEK only</td>
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<tr>
<td>DSAEK/phacoemulsification</td>
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TABLE 2. Endothelial Cell Data

<table>
<thead>
<tr>
<th></th>
<th>Forceps</th>
<th>Injector</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>48</td>
<td>36</td>
<td>—</td>
</tr>
<tr>
<td>Preoperative endothelial cell density (SD)</td>
<td>2907 (248)</td>
<td>2913 (233)</td>
<td>—</td>
</tr>
<tr>
<td>Postoperative endothelial cell density</td>
<td>1630 (426)</td>
<td>2083 (287)</td>
<td>0.0000004</td>
</tr>
<tr>
<td>% Loss</td>
<td>44.1</td>
<td>28.3</td>
<td>—</td>
</tr>
<tr>
<td>Range</td>
<td>10.0%–73.7%</td>
<td>12.0%–46.8%</td>
<td>—</td>
</tr>
<tr>
<td>Eyes ≥20% cell loss (%)</td>
<td>2 (4.2)</td>
<td>8 (22.2)</td>
<td>0.017</td>
</tr>
</tbody>
</table>

DISCUSSION
The key to long-term successful endothelial transplantation is the protection and preservation of as many donor endothelial cells as possible. In addition, one of the most challenging aspects of the surgery is insertion and positioning of the donor lenticule in the anterior chamber to enable attachment to the host stromal bed. During this step, the surgeon must try to protect the donor endothelial cells while unfolding the graft in the proper orientation without damaging the graft, lens, iris, or host stromal bed.

Further loss of endothelial integrity can occur with manipulation of donor tissue after insertion. Unfolding and positioning can be especially difficult in eyes with a shallow anterior chamber, posterior vitreous pressure, and larger grafts. Other intraoperative complications include inversion of graft tissue and tissue prolapse out of the wound. The most frequently encountered postoperative complication is graft detachment, typically within the first few days after surgery. Management of the dislocated graft is time-consuming, stressful, and costly. Many theories as to why some grafts resist initial attachment have been proposed, although none have been fully elucidated.

In our opinion, there are several ideal features of a donor insertion device. These include the ability to use a self-sealing incision no larger than 4 mm, rolling the tissue without causing a crease, fold, or tissue overlap, insertion without endothelial exposure to ocular structures or implants, minimizing inversion or compression of tissue on insertion, and central placement of tissue, maintaining a deep anterior chamber with parallax flow, and, finally, the ability to handle grafts up to 8.5 mm in diameter. Our DSAEK graft injector was designed with these parameters in mind. With respect to graft size, there is a slight overlap of tissue on grafts 8.0 mm in diameter and larger, which has less exposure to or incision contact with endothelium than a typical 60/40-fold during forces insertion. Overall, we have found that unfolding of the graft in the anterior chamber usually occurs without any manipulation at all. Because the tissue is loaded onto a retractable platform, it remains in the confines of a rigid tube. Once this tube is inserted into the eye, gentle irrigation through the center of the rolled graft deepens the anterior chamber, allowing ample room for tissue deployment. This tube is then retracted or “unsheathed,” allowing the tissue to remain in the anterior chamber in the proper orientation without sticking to the injector. Typically, the graft automatically opens and is fairly well-centered after initial deployment; however, sometimes, external massage with a cannula is needed for centration. More rarely, a reverse Sinskey hook is used at the very edge of the graft to facilitate alignment. Since we began using this injector device, graft manipulation after insertion has decreased. Graft thickness is also important. Very thick tissue (>200 μm) is difficult to roll and manipulate, whereas very thin tissue (<80 μm) wrinkles very easily. Postcut pachymetry performed by the eye bank can be helpful to ensure that tissue is appropriate.

The majority of published series on DSAEK use a 5-mm corneal or scleral tunnel. Insertion is easier because the tissue can be performed under topical anesthesia. Sutures are usually not needed, and the wound is less prone to iris prolapse than larger corneal incisions. Insertion is easier because the tissue automatically unfolds in the proper orientation in a deep anterior chamber, thereby reducing the stress experienced by the surgeon. The cost-savings over traditional DSAEK include no cautery, no sutures, no anterior chamber maintainer, and less time spent in the operating room.

In the past, DSAEK through a 3- to 4-mm clear corneal incision required tissue folding. Some surgeons have reported

<table>
<thead>
<tr>
<th>Patients</th>
<th>Incision</th>
<th>Endothelial Cell Loss (6/12 mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busin Glide</td>
<td>100</td>
<td>3.2-mm clear corneal tunnel</td>
</tr>
<tr>
<td>Forceps underfold</td>
<td>305</td>
<td>5-mm scleral tunnel</td>
</tr>
<tr>
<td>Forceps overfold</td>
<td>263</td>
<td>5-mm scleral or clear corneal tunnel</td>
</tr>
<tr>
<td>Forceps overfold</td>
<td>80</td>
<td>5-mm scleral tunnel</td>
</tr>
<tr>
<td>Forceps trifold</td>
<td>38</td>
<td>4-mm clear corneal tunnel</td>
</tr>
<tr>
<td>Injector</td>
<td>46</td>
<td>4-mm clear corneal tunnel</td>
</tr>
</tbody>
</table>

FIGURE 4. Postoperative visual acuity.
that folding may damage endothelial cells even though noncompressing forceps are used, whereas others have reported low detachment rates using folding techniques. Most authors report an improvement in graft dislocation rates with time, as in our forceps series. This is likely because of improved surgical experience. A variety of factors likely contribute to graft dislocation. There may be focal endothelial crush damage where the graft is grasped with the forceps, and damage to the endothelium along each fold, as demonstrated by in vitro vital dye testing.

It seems that one of the key elements to promoting graft attachment is protecting the endothelium during insertion. Our drastic reduction in graft dislocation in the injector group can most likely be attributed to reducing endothelial damage. Every aspect of each technique (forceps vs. injector) was identical with respect to surgeon experience, tissue size and source, preinsertion procedure, wound size, no peripheral scraping, and postoperative management. Transcorneal slits were performed routinely in the forceps group but were abandoned after approximately 20 cases in the injector group because it became evident that they were no longer necessary.

We propose that excessive manipulation and folding of the graft tissue potentially destroys enough endothelial cells either focally or diffusely that endothelial pump function is adversely altered. There may be a threshold of actively pumping cells required to "suck" and maintain adherence. This could also explain why experienced surgeons have a lower rate of detachments versus those just learning DSAEK.

Although our endothelial cell counts and dislocation and failure rates have improved significantly with the use of the injector and now are similar to those of the 5-mm forceps insertion in larger series (Table 3), there is potential room for improvement. Two of our surgical practices could potentially result in unnecessary cell loss. We routinely dilate the pupil preoperatively in phakic and pseudophakic patients and maintain dilation throughout the surgery to lessen the risk of pupillary block. We have been publicly criticized for this practice because if the graft comes in direct contact with the intraocular lens, then additional endothelial cell loss would result. In addition, although graft inversion is rarely an issue, our precut tissue has a gentian violet stromal marking to ensure proper orientation. Some have proposed that such markings could result in additional cell loss. It is possible that our endothelial cell counts would be even better if we eliminated these steps.

Several authors have reported early results from Descemet membrane endothelial keratoplasty. Introducing the very thin Descemet membrane endothelial keratoplasty graft into the anterior chamber with the proper orientation can be even more difficult than DSAEK. Descemet membrane endothelial keratoplasty tissue has a tendency to spontaneously roll endothelial side outward, whereas the tissue injector rolls the tissue endothelium inward and may be more protective. There may be a future role for tissue injectors to lessen the difficulty of graft placement while improving endothelial cell preservation.

There are several limitations to this study. The forceps arm was a retrospective chart review, and neither arm was concurrent or randomized. The evaluators were not masked. Automated cell counts were used, and these are not as accurate as manual counts in nonnormal eyes.

Endothelial keratoplasty has experienced significant advances since its introduction. We have seen a similar evolution at our center with the transition from a forceps technique to a small-incision tissue injection and are excited about its potential to make DSAEK more predictable with less complications. Delivering graft tissue through a small incision provides anterior chamber stability and often eliminates the need for suture. Our tissue injector helps minimize the endothelial trauma that is inherent with forceps manipulation through incisions smaller than 5 mm in particular. Further work is ongoing to validate this new technology.

REFERENCES


