Endothelial Lamellar Keratoplasty Using an Artificial Anterior Chamber and a Microkeratome

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Objective: To compare postoperative astigmatic change and graft stability using 2 different donor button diameters in endothelial lamellar keratoplasty to treat corneal endothelial failure.

Methods: A 200-µm-thick corneal flap keratectomy was performed in human donor corneoscleral rims (n=20; 10 donors and 10 recipients) using an artificial anterior chamber and a manual microkeratome (ALTK System; Moria USA, Doylestown, Pa). After flap reflection, stromal bed trephination was performed to obtain a disc consisting of posterior stroma, Descemet membrane, and endothelium. Host beds of 7.0 mm and 7.25-mm (n=5) or 7.50-mm (n=5) donor buttons were obtained using a freehand trephine. The graft was secured with 8 interrupted sutures (10-0 nylon) in the stromal bed. The flap was sutured with 3 interrupted sutures. Transplanted corneas were submitted to increasing intrachamber pressures to detect graft stability, and preoperative and postoperative videokerographic data were recorded to assess astigmatic change.

Results: The mean (SD) postoperative astigmatic change was 1.14 (3.17) diopters (D) in the 7.25-mm donor button group and 2.27 (1.77) D in the 7.50-mm donor button group (P=.69). Mean (SD) resisted pressures of 75.4 (44.81) mm Hg and 100.4 (46.86) mm Hg were observed in the 7.25-mm and 7.50-mm groups, respectively (P=.54).

Conclusion: Both donor button sizes exhibited similar graft stability and astigmatic postoperative change in this experimental model.

Clinical Relevance: As endothelial lamellar keratoplasty becomes further developed as a clinical alternative to penetrating keratoplasty, this laboratory model system should be useful in evaluating different mechanical factors that contribute to graft success.

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Penetrating keratoplasty is a safe and effective method for restoring corneal transparency in patients with disabling corneal opacities. Endothelial cell dysfunction accounts for most penetrating keratoplasties performed in developed countries. Endothelial cell failure has been frequently associated with either ocular trauma after intraocular lens implantation or endothelial corneal dystrophies. Other entities associated with corneal endothelial damage, such as pseudoexfoliation keratopathy, may affect these statistics in the future.

Endothelial cell transplantation has been attempted. With the development of new biomaterials, this method might be ideal to correct endothelial cell failure. However, present clinical applications appear to be feasible only using a posterior stromal lamellar carrier (posterior lamellar keratoplasty). In this approach, replacement of the posterior stroma, Descemet membrane, and endothelial cell layer is accomplished through a scleral pocket. The technique has shown promising results. However, it is laborious and requires a highly skilled surgeon.

Laser-assisted in situ keratomileusis (LASIK) has recently led to further developments in corneal lamellar surgery; LASIK instruments can be used to perform posterior lamellar transplantation using a corneal flap technique with trephination of the stromal bed, including Descemet membrane and the damaged endothelium. Several recent studies have shown promising results using these techniques in human subjects. Advantages include preservation of the original central corneal surface, avoidance of extensive superficial suturing, and a decrease in the amount of tissue transplanted. Thus, the potential exists for improvement in postoperative visual re-
covery, fewer problems related to sutures, and a lower rejection rate with endothelial lamellar keratoplasty.

The purpose of this study was to evaluate graft stability and postoperative astigmatism change with endothelial lamellar keratoplasty using 2 different donor button sizes.

### METHODS

#### DONOR TISSUE

After approval by the Institutional Review Board of the University of California, Irvine, donor corneoscleral rims (n=20) not suitable for transplantation were obtained from the Doheny Eye and Tissue Bank (Los Angeles, Calif). The corneas were preserved under standard eye bank conditions in Optisol-GS medium (Bausch & Lomb Surgical, Inc, San Dimas, Calif) at 4°C until the operation. The procedure was performed no longer than 15 days after death. Upon availability, corneas were sequentially assigned to 1 of 2 groups, the donor group (n=10) or the host group (n=10). Demographic data are shown in Table 1.

#### EXPERIMENTAL SETTING

A manual microkeratome (LSK One; Moria USA, Doylestown, Pa) was used to perform the hinged-flap keratectomy. Stainless steel blades were repeatedly used no more than 4 times to avoid cutting edge deterioration and cut surface irregularity.

A 200-µm head thickness was used in all corneas. An artificial anterior chamber (ALTK System; Moria USA) was used to support the corneoscleral rims, as described in previous reports. The gearless tracks on the base plate of the artificial anterior chamber are designed to fit into the microkeratome head, so that its pass across the cornea maintains the same plane and direction. All corneal buttons were obtained using a free-hand trephine. Hosts’ stromal beds were cut with a 7.0-mm trephine, whereas donor stromal buttons were oversized by either 0.25 mm (n=5) or 0.5 mm (n=5). As they became available, corneoscleral rims were placed on the base of the anterior chamber are designed to fit into the microkeratome for the donor buttons was used to perform a circular cut of the stromal bed. This was manually centered in the recipient bed to clear the residual air from the infusion line and underneath the cornea. The isotonic sodium chloride solution bottle was raised 1.5 m above the level of the chamber to obtain adequate intrachamber pressures (110 mm Hg) for the microkeratome pass. Corneas were centered according to circular guides in the base of the chamber. Mechanical epithelial scraping was performed with a Bard-Parker No. 11 surgical blade (Becton, Dickinson and Co, Hancock, NY) to avoid surface irregularities due to loose epithelium, which may introduce errors in pachymetric and videokeratographic measurements.

#### Flap Thickness Measurements

Applanation lenses were placed on the cornea to determine the diameter to be obtained, as described elsewhere. The artificial anterior chamber was set to achieve a 10-mm-diameter flap in all cases. The largest flap diameter was intended to leave as much area in the stromal bed as possible for performing trephination and donor button suturing in the host.

#### Stromal Bed Trephination

Intrachamber pressure was returned to 18 to 20 mm Hg by lowering the height of the isotonic sodium chloride solution bottle to 25 cm above the cornea level, and the trephine was centered according to the keratectomy edge. A freehand trephine of 7.0 mm for the host cornea and either 7.25 mm or 7.5 mm for the donor buttons was used to perform a circular cut of the stromal bed. This was manually centered in the recipient bed relative to the flap. The trephine blade was rotated until perforation, and the circular cut was completed with corneal scissors (Figure 1). Donor buttons were sutured in recipient beds with 8 interrupted sutures, the knots were buried, and the flap was replaced in the bed (Figure 2). The suturing technique (suture tightness and length) was the same in both groups to ensure comparable results. Eight sutures were successfully placed in all cases. However, because of the size of the flap and button, shorter than normal suture passes were required. The flap was secured with 3 interrupted sutures (Figure 3).

#### VIDEOKERATOGRAPHY AND GRAFT STABILITY

For surface curvature analysis, we used a commercial videokeratoscope (EyeSys Laboratories, Inc, Houston, Tex). The Placido disc was placed in a vertical position and the chamber centered according to the monitor control. This setting to obtain reproducible measurements was adopted from a previous

### Table 1. Data Collected From Donor and Host Corneas

<table>
<thead>
<tr>
<th>Age, y/ Sex</th>
<th>Trephination Size, mm</th>
<th>Central Corneal Thickness, µm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Donor</strong></td>
<td><strong>Host</strong></td>
<td><strong>Donor</strong></td>
</tr>
<tr>
<td>63/M</td>
<td>67/M</td>
<td>7.25</td>
</tr>
<tr>
<td>21/F</td>
<td>68/M</td>
<td>7.25</td>
</tr>
<tr>
<td>68/M</td>
<td>68/M</td>
<td>7.25</td>
</tr>
<tr>
<td>68/F</td>
<td>36/M</td>
<td>7.25</td>
</tr>
<tr>
<td>58/M</td>
<td>70/M</td>
<td>7.25</td>
</tr>
<tr>
<td>72/M</td>
<td>68/M</td>
<td>7.50</td>
</tr>
<tr>
<td>68/M</td>
<td>59/F</td>
<td>7.50</td>
</tr>
<tr>
<td>47/M</td>
<td>72/M</td>
<td>7.50</td>
</tr>
<tr>
<td>58/M</td>
<td>38/M</td>
<td>7.50</td>
</tr>
<tr>
<td>74/M</td>
<td>70/M</td>
<td>7.50</td>
</tr>
</tbody>
</table>
study. The orientation was preserved in preoperative and postoperative recordings. Three measurements were performed preoperatively and postoperatively for each recipient cornea (Figure 4).

To assess graft stability, intrachamber pressure was raised progressively by changing stepwise the height of the bottle, as previously reported. Under visual control with a surgical microscope at ×12 magnification (Ophthalmic 900S; Moeller-Wedel, Hamburg, Germany), presence of leakage was monitored, and the height at which leakage occurred was recorded. Intrachamber pressure was then calculated in millimeters of mercury, according to previous measurements performed using a Tonopen XL (Medtronic Xomed, Inc, Jacksonville, Fla).

**STATISTICAL ANALYSIS**

Calculations were made using StatsDirect, version 1.9.0, biostatistical software (CamCode, Ashwell, England). Mean, SD, and minimum and maximum values were described. Comparisons between groups were performed using the nonparametric Mann-Whitney U test for unpaired samples and the Wilcoxon signed rank test for paired samples. A Spearman rank correlation test was performed to assess the dependence of resisted pressure on donor size. \( P \leq 0.05 \) was considered statistically significant.

**RESULTS**

**SURGICAL TECHNIQUE**

The surgical procedure was simple and similar to a combination of a corneal flap technique and penetrating keratoplasty. Full-depth trephination of the stromal bed was performed in a similar fashion for both recipient and donor corneas. Some difficulties in suturing were encountered, because less space for suture placement was left under the flap. Likewise, a full-thickness perforating needle pass was more likely to occur because the donor button is considerably thinner than a normal cornea.

The technique is somewhat more laborious than a standard penetrating keratoplasty because of the microkeratome involvement. However, the suturing time is considerably shorter, which decreases the total surgical time.

**SURGICAL OUTCOME**

The mean (SD) flap thickness was 191.1 (70.55) µm in donors and 240.4 (102.82) µm in hosts.

The mean (SD) preoperative astigmatism in hosts was 1.41 (1.39) diopters (D), compared with 3.32 (1.51) D postoperatively. The mean (SD) postoperative astigmatic change was 1.70 (2.49) D. Keratometric data are shown in Table 2.

Comparing the 2 donor sizes, we found no statistically significant differences in postoperative astigmatic change. The mean (SD) postoperative astigmatic change was 1.14 (3.17) D for the 7.25-mm donor button group and 2.27 (1.76) D for the 7.5-mm donor button group. Despite a lower mean astigmatic change using the smaller donor button, this difference was not significant \( (P = .69) \).

There were very large variations in the preoperative and postoperative change in average keratometry values in both groups. The mean (SD) change in average keratometry value for the 7.25-mm donor button group was 1.45 (7.36) D; for the 7.5-mm group, the mean (SD) change was 2.76 (4.00) D.
In terms of stability of the graft, we observed great variability in both groups. A higher resistance with larger donor buttons was observed. The mean (SD) calculated pressure was 100.4 (46.86) mm Hg (range, 48-143 mm Hg) in the 7.5-mm donor button group, opposed to 75.4 (44.81) mm Hg (range, 37-147 mm Hg) in the 7.25-mm donor button group. However, this difference was not statistically significant ($P = .63$), and no correlation between size and intrachamber resisted pressure was found ($r_s=0.243; P = .49$).

**Comment**

New surgical techniques are being developed in parallel with advances in ophthalmic technology. Lamellar corneal surgery has become more popular recently because of the improvement in microkeratome instrumentation. Safety while using these instruments has improved considerably, and a remarkable cut quality has been achieved with the latest systems. Lamellar transplants, the smoothness of the cut surface may lead to a better surgical outcome with a clearer interface, which is essential to obtaining a good optical result. This has led to the proposal of endothelial lamellar keratoplasty as an alternative to penetrating keratoplasty in patients with endothelial cell dysfunction. Busin et al described the procedure in 7 patients; they secured the donor button in its recipient bed with an 8-bite running suture and the flap with an additional 8-bite running suture. In 4 cases, they used a full-thickness corneal donor button oversized by 0.5 mm, and in 3 cases, they used a partial-thickness button obtained by means of an artificial anterior chamber, a rotating blade microkeratome, and a trephine. All donor discs were obtained through a trephination from the endothelial side. In all cases, the cor-

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*Table 2. Keratometric Analysis of Host Corneoscleral Rims in the Artificial Anterior Chamber*

<table>
<thead>
<tr>
<th>Graft Oversize, mm</th>
<th>Preoperative Astigmatism, D</th>
<th>Postoperative Astigmatism, D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K1</td>
<td>K2</td>
</tr>
<tr>
<td>0.25</td>
<td>43.07</td>
<td>42.13</td>
</tr>
<tr>
<td>0.25</td>
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<tr>
<td>0.25</td>
<td>44.47</td>
<td>41.05</td>
</tr>
<tr>
<td>0.25</td>
<td>42.39</td>
<td>42.28</td>
</tr>
<tr>
<td>0.25</td>
<td>49.68</td>
<td>46.71</td>
</tr>
<tr>
<td>0.50</td>
<td>43.51</td>
<td>42.69</td>
</tr>
<tr>
<td>0.50</td>
<td>45.55</td>
<td>44.65</td>
</tr>
<tr>
<td>0.50</td>
<td>42.99</td>
<td>42.47</td>
</tr>
<tr>
<td>0.50</td>
<td>43.73</td>
<td>43.40</td>
</tr>
<tr>
<td>0.50</td>
<td>49.12</td>
<td>47.33</td>
</tr>
</tbody>
</table>

Abbreviations: D, diopters; K, corneal curvature keratometric value.
neal flap in the recipient was obtained with an oscillating blade microkeratome.

In our study, the same instruments for flap creation and trephination were used for both recipient and donor corneas. We believe that it is important to preserve the same conditions of the cut in both recipient and donor during corneal flap creation and trephination. Surface cuts have displayed considerable variation using different microkeratomes. We found a large variation in flap thickness even using the same microkeratome. This could be due to variations in stromal hydration before the microkeratome cut is created. Raising the pressure in the artificial anterior chamber to adequate levels to create the flap might induce significant amounts of stromal hydration. Even donor button orientation might be important to avoid cut surface mismatches in the interface. Moreover, donor button thickness may vary significantly in different sectors according to the quadrant location, which might introduce additional irregularities in overall corneal thickness. In our study, the buttons were excised with full-depth trephination and scissors. This could result in slightly ragged edges, which may compromise wound stability.

The resultant astigmatism after penetrating keratoplasty is variable. With standard trephination methods, the mean astigmatism fluctuates between 3 and 6 D. With excimer laser trephination, the mean keratometric astigmatism fluctuates between 3 and 3.5 D. In endokeratoplasty, the mean refractive astigmatism in the small series reported was 2.9 D, whereas in our series it was 3.3 D. Astigmatic change (preoperative astigmatism minus postoperative astigmatism), a more reliable method of comparison between techniques, is not usually presented in the literature. In addition, the terms “refractive,” “keratometric,” and “topographic astigmatism” are mistakenly used interchangeably, adding another source of error for comparative purposes.

In myopic LASIK, a flap is replaced on a stromal bed that has been flattened, and this flattening is transmitted to the surface by the flap. In endothelial lamellar keratoplasty, an irregular stromal bed is created by the sutured button. This irregularity is also transmitted to the surface by the flap, as we have shown in the shifts in average corneal power and astigmatism. In a human subject case report of this procedure, a large change in corneal power was observed in the early postoperative period. Thus, the challenge in this form of endothelial lamellar keratoplasty is to create as regular a stromal bed surface as possible before laying down the conforming anterior corneal flap. If interrupted sutures are insufficient, other possibilities include running sutures, glues, and sutureless buttons. Our initial goal was to place the sutures only in the graft bed, with a sutureless hinged flap, as is performed in LASIK. However, the endothelial pump function is severely altered in a donor button, which may compromise flap adherence and, therefore, promote flap slippage after the procedure. Because of this, we sutured the flap with 3 interrupted sutures in the 3 free quadrants (excluding the hinge) to add more stability. These sutures may be removed in the early postoperative period once the endothelial pump function is recovered and the epithelium has healed.

We found no statistical differences in bursting pressure using different donor sizes. On average, the bursting pressure was above physiologic levels and presumably would result in a watertight procedure. However, there was a wide range in bursting pressure, and the lowest (37 mm Hg) could potentially result in a leaking graft clinically. Thus, further refinements of the procedure, possibly more sutures in the flap, are required to obtain consistent results.

Limitations of this study include the effect of confounding variables other than donor size on induced astigmatism and bursting pressure. In particular, variations in the tightness of the flap sutures can have a profound effect on induced astigmatism. Because it is expected that these sutures would be removed early in the postoperative course, the true effect of the differences in astigmatism due to donor size may not be apparent. The tightness of these sutures was carefully controlled to minimize the effect of this variable. Also, the high variability in measured flap thickness may result in a mismatch of donor graft to button removed.

In conclusion, donor grafts oversized by either 0.25 mm or 0.50 mm exhibited similar graft stability and astigmatic changes. The wide variations in average keratometry resulted in significant differences in corneal power postoperatively. This could yield large refractive shifts in the clinical setting and minimize the benefit of reduced astigmatism in this procedure. Endothelial lamellar keratoplasty appears to be a feasible procedure that has several potential advantages over penetrating keratoplasty for endothelial cell layer dysfunction. Further testing is required to optimize this procedure before extensive use in the clinical setting.

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