Descemet Membrane Endothelial Keratoplasty (DMEK)

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Purpose: To describe Descemet membrane endothelial keratoplasty (DMEK) with organ cultured Descemet membrane (DM) in a human cadaver eye model and a patient with Fuchs endothelial dystrophy.

Methods: In 10 human cadaver eyes and 1 patient eye, a 3.5-mm clear corneal tunnel incision was made. The anterior chamber was filled with air, and the DM was stripped off from the posterior stroma. From organ-cultured donor corneo-scleral rims, 9.0-mm-diameter "DM rolls" were harvested. Each donor DM roll was inserted into a recipient anterior chamber, positioned onto the posterior stroma, and kept in position by completely filling the anterior chamber with air for 30 minutes.

Results: In all recipient eyes, the donor DM maintained its position after a 30-minute air-fill of the anterior chamber followed by an air–liquid exchange. In the patient's eye, 1 week after transplantation, best-corrected visual acuity was 1.0 (20/20) with the patient's preoperative refraction, and the endothelial cell density averaged 2350 cells/mm^2.

Conclusion: DMEK may provide quick visual rehabilitation in the treatment of corneal endothelial disorders by transplantation of an organ-cultured DM transplanted through a clear corneal tunnel incision. DMEK may be a highly accessible procedure to corneal surgeons, because donor DM sheets can be prepared from preserved corneo-scleral rims.

Key Words: Descemet membrane endothelial keratoplasty, posterior lamellar keratoplasty, corneal transplantation, Descemet membrane, endothelium, surgical technique

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In 1998, we described a technique for posterior lamellar keratoplasty (PLK) through a scleral incision for the management of corneal endothelial disorders.[1–3] The technique, since 2001 popularized in the United States as deep lamellar endothelial keratoplasty (DLEK),[4] enables transplantation of an unsutured, 7.5-mm-diameter, posterior lamellar disc through a 9.0-mm sutured scleral incision. In 2000, we reported a sutureless modification of the technique in which a folded, taco-shaped 9.0- to 9.5-mm-diameter posterior transplant was inserted through a self-sealing 5.0-mm scleral tunnel incision.[5] Since 2005, this technique has been popularized in the United States as small incision DLEK.[6] In 2003, we reported how a folded posterior transplant insertion could be combined with removing the recipient endothelial layer by means of stripping of Descemet membrane (DM; descemetorhexis).[7,8] The latter technique is currently referred to as Descemet stripping endothelial keratoplasty (DSEK).[9,10]

Although the various techniques mentioned above proved that the concept of unsutured posterior corneal transplants was surgically feasible, the best possible restoration of the visual performance of a cornea with an endothelial disorder may be obtained by selective transplantation of only DM and endothelium.[11,12] Recently, Dr. Tappin described the clinical transplantation of DM using a carrier device.[13] This study describes the first clinical results of DM transplantation through a self-sealing corneal incision that may be referred to as Descemet membrane endothelial keratoplasty (DMEK).

MATERIALS AND METHODS

Patients

DMEK (Fig. 1) was performed in a male patient, age 63, with Fuchs endothelial dystrophy. The patient signed an Institutional Review Board–approved informed consent.

Human Cadaver Eye Model

Ten human cadaver eyes with corneas unsuitable for transplantation were used as recipient eyes. Each globe was placed in an eye holder equipped with a suction ring to immobilize the posterior globe and to control the intraocular pressure (IOP).[1] Globes were oriented with the 12 o'clock anatomic position toward the surgeon. The epithelium was gently removed with a cellulose sponge. Corneas were dehydrated by subjecting the globes to an IOP of 50 to 60-mm Hg at room temperature for 10 minutes, until central thinning was achieved to 0.60- to 0.65-mm.[1]

Donor Tissue

From 11 donor globes less than 36 hours postmortem, corneo-scleral buttons were excised and stored by organ culture in modified minimum essential medium (EMEM) at 31°C.[14] Donor age averaged 61 ± 12 (SD) years; the donor cornea used for clinical transplantation was from a 54-year-old donor and had an endothelial cell count of 3000 cells/mm^2.

After 2 weeks of culture, the endothelial cell morphology and viability were evaluated, and the corneo-scleral buttons were mounted endothelial side up on a custom made

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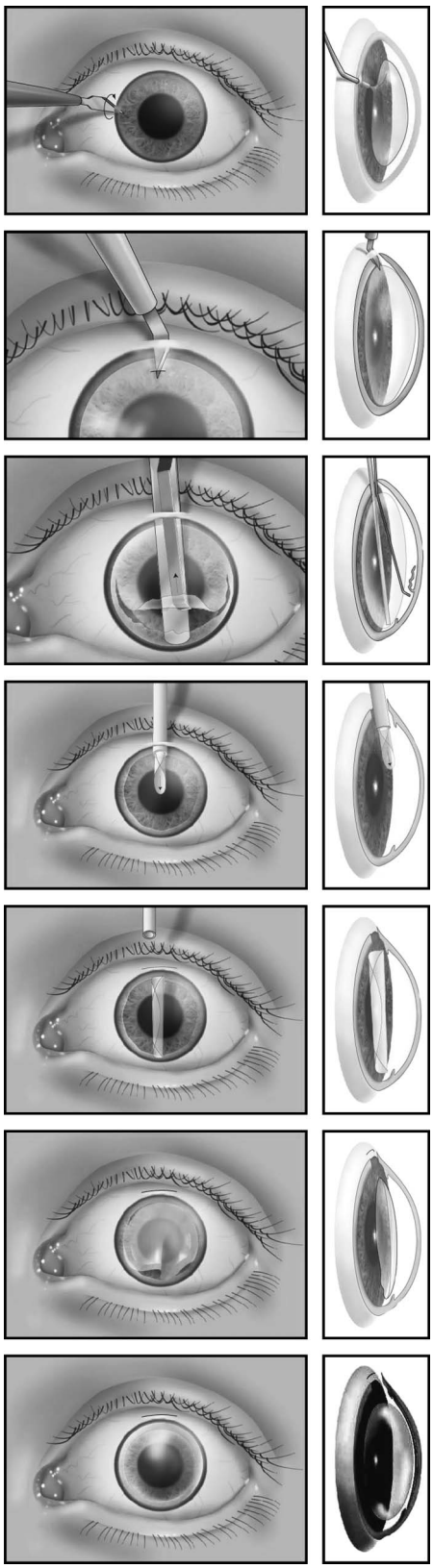

holder with a suction cup. After trephination, a DM was stripped from the posterior stroma with microforceps, so that a 9.0-mm-diameter flap of posterior DM with its endothelial monolayer was obtained.[11,12] Because of the elastic properties of the membrane, a "DM roll" formed spontaneously, with the endothelium at the outer side. Each DM roll was stored in organ culture medium until the time of transplantation.

Operative Procedure

In recipient eyes, a 9.0-mm-diameter epithelial mark was made to outline the area of DM excision. A 3.5-mm tunnel incision was made just within the limbus, entering the anterior chamber just at the mark. With a custom-made scraper (Melles scraper; D.O.R.C. International, Zuidland, The Netherlands), a circular portion of DM was stripped from the posterior stroma, so that a 9.0-mm-diameter descemetorhexis was created, and the central portion of the DM was removed from the eye.[7]

The donor DM roll was stained with a 0.06% trypan blue solution (VisionBlue; D.O.R.C. International) and sucked into a custom-made injector (Hippocratech, Rotterdam, The Netherlands).[11,12] Using the injector, the donor DM roll was inserted into the anterior chamber and gently spread out over the iris. An air bubble was injected underneath the donor DM to lift the DM onto the recipient posterior stroma.[11,12] The anterior chamber was filled with air completely for 30 minutes followed by an air–liquid exchange.

Endothelium Evaluation

Donor endothelial cell viability was evaluated with an inverted light microscope (Axiovert 40; Zeiss, Göttingen, Germany). After provoked swelling with sucrose 1.8% and staining with trypan blue 0.04%, digital photographs were made (PixeLINK PL-A662; Zeiss).[14]

In the patient's eye, the endothelium was photographed and evaluated using a Topcon SP2000p noncontact autofocus specular microscope (Topcon, Tokyo, Japan). Images of the central corneal window were analyzed, and 3 measurements of endothelial cell density were averaged.[14]

RESULTS

In the patient's eye, the surgical procedure was uneventful. After a complete air fill of the anterior chamber for 30 minutes, the donor DM kept its position in the patient's eye and in the recipient eyebank eyes.

FIGURE 1. The DMEK procedure consists of the following steps. A, A side port is made at 3 and 9 o'clock, and the anterior chamber is filled with air. B, A 3.5-mm scleral or clear corneal tunnel incision is made to gain access into the anterior chamber. C, The recipient DM is stripped from the posterior stroma from the 6 o'clock surgical position toward the entry incision at 12 o'clock (descmetorhexis). D and E, Using a custom-made inserter, a donor DM roll carrying autologous endothelium on its outer side is inserted into the anterior chamber. F, The donor DM is carefully manipulated and spread out over the recipient iris. G, Air is injected underneath the donor DM to lift the membrane onto the recipient posterior stroma. The anterior chamber is completely filled with air, and the microscope is turned off. After 30 minutes, the air is removed, and the eye is pressurized with BSS.

In the patient's eye, the visual acuity was 0.25 (20/80) at 1 day and 1.0 (20/20) at 1 week after transplantation with the patient's preoperative refraction. The IOP was normal. The endothelial cell density averaged 2350 cells/mm^2. The far periphery of the recipient cornea showed some DM tags with mild residual edema overlying these areas. Although a reflective "sheen" was observed over the donor DM, it proved difficult to identify the transplant at the slit-lamp examination, and true confirmation that the donor tissue was in situ had to be obtained by visualization of the endothelium through specular microscopy.

DISCUSSION

We previously reported that transplantation of DM was technically feasible in a human cadaver eye model.[11,12] However, harvesting a DM from a donor corneo-scleral rim is a delicate procedure that is sometimes complicated by inadvertent tearing of the membrane. Therefore, it may be preferable to perform the surgical preparation of the donor DM in an eyebank before the transplantation than as a part of the surgical routine itself. With the start of Amnitrans Eyebank Rotterdam in January 2004, this logistic problem was solved, because DM carrying a viable endothelial cell layer could be routinely prepared before transplantation.

Recently, Dr. Tappin in the United Kingdom showed that transplantation of an isolated DM was feasible with the use of a custom-made carrier device by which a 7.5-mm-diameter DM sheet was introduced into the anterior chamber through an 8.0-mm sutured incision (M Tappin, personal communication, 2006).[13] In 3 patient eyes, a DM transplant was positioned onto the recipient posterior stroma and was found to keep its position. In this study, we describe the transplantation of a DM with autologous endothelium through a small corneal tunnel incision. With regard to the popular nomenclature to distinguish the various surgical procedures for PLK,[4,6,9,10,14] the procedure currently described may be referred to as DMEK.

In comparison with the techniques for PLK previously designed by us,[1–10] DMEK may have several advantages. As in DSEK, the surgical trauma to the recipient's eye is minimized, but DMEK also provides a near normal restoration of the grafted cornea. Although adding donor posterior stroma and thereby increasing the thickness of the host cornea may not have too much effect on the final visual acuity in DSEK, an anatomic restoration of the recipient optical system in DMEK may be expected to result in faster and more complete visual rehabilitation.[12] With DMEK, the visual performance of the eye will probably be limited only to the preoperative condition of the recipient anterior cornea that is left in situ, but donor tissue adaptation and dehydration as must occur in DSEK is no longer an issue. DMEK may also better fit the current requirements of modern anterior segment surgery, because the transplantation can be performed through a clear corneal tunnel incision widely used in phacoemulsification surgery, which is known to induce minimal astigmatism.[15,16] Finally, as in DSEK, DMEK allows the transplantation of a graft 9.0 to 10.0 mm in diameter, so that a nearly complete endothelial cell sheet can be transplanted, which theoretically should benefit long-term graft survival.[12]

As in all modifications of PLK, implantation of donor tissue should be atraumatic in DMEK. Over the years, various carriers were evaluated as a supportive means for the donor DM. Lange et al[17] described bovine DM as a carrier for the endothelium; more recently, Shimmura et al[18] used a synthetic carrier, and Tappin[13] designed a supporting device. A carrier may have the advantage of introducing the donor tissue into the anterior chamber in the desired orientation but the disadvantage of limiting the final diameter of the graft to 6.0- to 7.5-mm and requiring a relatively large entry incision. In addition, positioning the DM onto a carrier may require more surgical time than drawing it into the inserter originally described by us.[11,12] With design improvements, our DMEK inserter now allows implantation of the donor tissue through a 3.0- to 3.5-mm incision, and as such, the approach may compare favorably to the 4.0- to 5.0-mm incision required for DSEK.

Because donor attachment has been described to be incomplete with the DSEK technique[9,10] (in which a posterior transplant consisting of donor posterior stroma, DM, and autologous endothelium is positioned onto the recipient posterior stroma), a larger part of our pilot studies focused on achieving complete donor attachment. In our DSEK series, incomplete donor attachment did not occur with the use of fresh tissue.[7,8] With organ-cultured grafts, the attachment of the donor tissue was found to be more critical, although complete attachment was obtained by completely filling the anterior chamber with air for 15 minutes at the end of the surgery.[14] In DSEK and DMEK, we found that the single, most important factor to interfere with donor attachment was the intraoperative use of hyaluronic acid (unpublished data). When hyaluronic acid is avoided or when just a limited amount of hydroxypropylmethylcellulose is used, complete donor attachment is routinely achieved at the time of surgery, and detachment in the immediate postoperative course is rare. The method of tissue preservation could also be speculated to affect donor tissue adherence. Furthermore, it is important to note that while an air-fill of the anterior chamber for 15 minutes is sufficient to obtain complete donor attachment in DSEK, in vitro testing showed that an air-fill of at least 30 minutes may be required to secure an isolated DM sheet onto the recipient posterior cornea in DMEK.

For DMEK to become feasible for corneal surgeons, it is important that isolated donor DM sheets can routinely be prepared with acceptable damage to the endothelial cell layer. With our technique of stripping 9.0-mm DM sheets from donor corneo-scleral (concave) rims, cell damage as expressed in the percentage of damaged surface area averaged 3.4%.[11,12] Accordingly, acceptable induced cell damage was observed by Ignacio et al,[19] using a technique for harvesting DM from rims pushed into a convex shape, and Zhu et al,[20] who excised rectangular strips from concave rims. All studies used preserved tissues, either by cold storage or organ culture, which may indicate that cultured endothelial cells survive in vitro dissection of the underlying DM from the donor cornea stroma. This may be an important observation from a logistic point of view, because a drawback of the DSEK procedure is that manual dissection of a posterior lamellar disc from a corneo-scleral rim is bothersome or requires the use of

a microkeratome.[14,21] Because donor DM sheets can be stripped directly from a corneo-scleral rim, DMEK may be far more accessible to most corneal surgeons than DSEK.

In conclusion, DMEK may allow quick and complete restoration of the visual potential in patients with corneal endothelial disorders. For corneal surgeons, accessibility to DMEK may be better than to DSEK, because preparation of the donor tissue can be done from preserved corneo-scleral rims and does not require expensive instrumentation.

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