Surgical Technique

A goat eye, wet lab model for training in Descemet membrane endothelial keratoplasty

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Here we describe a new, non-human, ex-vivo model (goat eye model) for training surgeons in DMEK surgeons. In a wet lab setting, goat eyes were used to obtain a pseudo-DMEK graft of 8 mm from the goat lens capsule that was injected into another goat eye with the same maneuvers described for human DMEK. The DMEK pseudo-graft can be easily prepared, stained, loaded, injected, and unfolded into the goat eye model reproducing the similar maneuvers used for DMEK in a human eye, except for the descemetorhexis, which cannot be performed. The pseudo-DMEK graft behaves similar to human DMEK graft and useful for surgeons to experience and understand steps of DMEK early in learning curve. The concept of a non-human ex-vivo eye model is simple and reproducible and obviates the need for human tissue and the issues of poor visibility in stored corneal tissue.

Key words: DMEK, learning curve, non-human model, training, wet lab

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Descemet membrane endothelial keratoplasty (DMEK) became the surgical treatment of choice for corneal endothelial dysfunction due to its better visual and refractive outcomes, lower risk of immunological rejection, and similar endothelial cell loss compared to descemet stripping automated endothelial keratoplasty (DSAEK).[1-3] However, wider adoption of DMEK has been limited due to the steep and long learning curve.[4-6] Debellemanière *et al*.[4] reported that the number of cases necessary to reach 90% of the plateau of the learning curve was 68 for preparation time and 46 for un-scrolling time. The learning curve may be steep even for experienced DSAEK surgeons.

Ex-vivo human models of DMEK training have been described, wherein human graft tissue is implanted into cadaveric human globes. However, tissue availability, cost, and poor visibility due to corneal edema are limiting factors for surgeons who wish to undertake training for DMEK surgery.[7] The ideal model needs to be easily available, cheap, and reproducible. It should also closely mimic human DMEK surgery for surgeons who are beginning to adopt to DMEK surgery.

Here we describe an ex-vivo non-human model (goat model) for DMEK training that closely matches the experience of human DMEK surgery.

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Instruments and materials

A wet lab facility and the following surgical instruments are required [Table 1].

A pair of fresh goat eyes, obtained from an abattoir, was immobilized on an i-SAND PLUS Eyeball Stand with Fixation Head (Madhu Instruments Pvt Ltd, New Delhi, India). Cotton gauze was used to stabilize the goat's eye on the stand. One goat eye was used to harvest the anterior lens capsule, which is used to create a pseudo-DMEK donor graft. The second goat eye was used as the recipient of the donor graft.

Preparation of pseudo-DMEK graft

[see Video 1], A large limbal paracentesis is created, and the anterior chamber, which has shallowed post-mortem, is

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re-inflated with HPMC. The paracentesis is extended using corneal scissors, and the incision is extended for 360 degrees, removing the entire cornea. The side port blade was used to enter the root of the iris, and then, using sharp scissors, the iris tissue was dissected 360 degrees. The intact lens was subsequently separated from the surrounding and underlying vitreous phase by injecting saline between the lens equator and the root of the ciliary body. A small and careful entry was made with a sharp 15° blade at the lens equator superiorly. The incision is extended for 360°, freeing the anterior capsule from the lens, taking care to avoid tearing [Fig. 1]. Typically, a 16–18-mm-diameter piece of anterior capsule can be harvested from each eye. This can be divided in half to allow preparation of two pseudo-DMEK graft per lens capsules.

Table 1: Surgical instruments and materials required

Balanced salt solution
5% formalin solution (obtained diluting commercially available formalin with normal saline solution)
Corneal scissors
Side port blade 15°
10 ml syringe with 26-gauge needle
Corneal trephine blade 7.5-8 mm
Teflon block
Trypan blue stain (0.4%)
DMEK graft injector

Pseudo-DMEK graft staining and loading

One half of the capsule is spread over the Teflon block with the concave side facing downward and punched with a 7.0–8.0 mm trephine. The harvested capsule is stained using trypan blue (0.4%) for 3 min, which is then wicked away using a cellulose spear. Finally, formalin 5% is applied to the still flat capsule dropwise using a syringe for 30 seconds. The formalin is washed off using saline, and the stained, fixed pseudo-graft is transferred to a galipot containing saline with nontoothed forceps. The scrolled graft is loaded into a glass injector (Geuder AC, Heidelberg, Germany) mounted on a 3cc syringe [Fig. 2] [see Video 2].

Preparation of pseudo-DMEK graft injection

To allow graft injection and handling, the anterior chamber of the second goat eye is deepened by performing a vitreous tap using a 10cc syringe with a large-bore needle inserted 6 mm posterior to the limbus.

The anterior chamber is reformed using saline injected from a side port made at the limbus. A 3–3.2 mm main incision is made using a keratome through which injector can passed without resistance.

Once the graft was injected into the anterior chamber [Fig. 2], the main incision is closed using 10-0 nylon. The scroll is

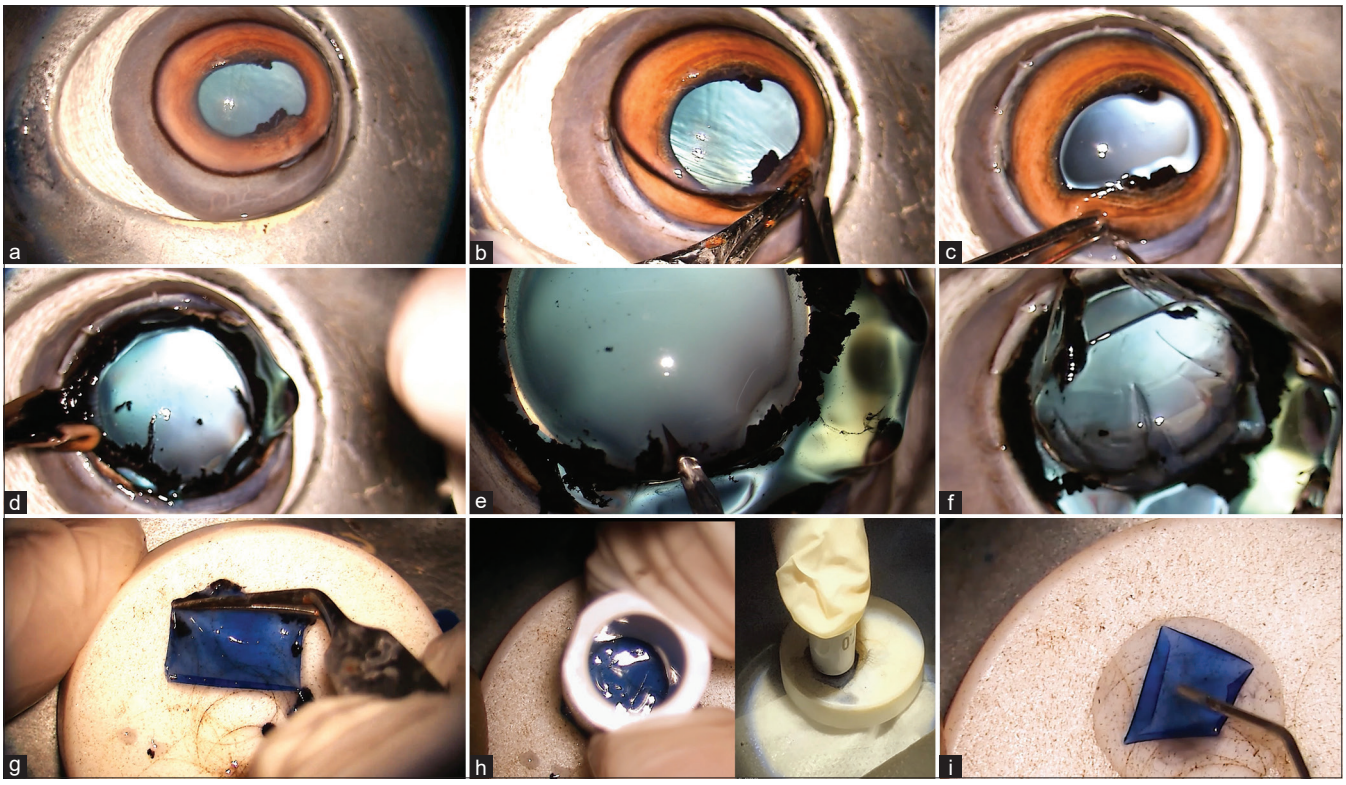

Figure 1: Illustration of the preparation and staining phases of pseudo-DMEK graft; (a-b) a limbal paracentesis is created and extended using corneal scissors for 360 degrees, removing the entire cornea. (c) The side port blade was used to enter the root of the iris, and then the iris tissue was dissected 360 degrees. (d) The intact lens was subsequently separated from the surrounding and underlying vitreous phase by injecting saline between the lens equator and the root of the ciliary body. (e) A small entry was made at the lens equator superiorly. (f) The incision is extended for 360°, freeing the anterior capsule from the lens. (g) One half of the capsule is spread over the Teflon block with the concave side facing downward and (h) punched with a 7.0–8.0 mm trephine. The harvested capsule is stained using trypan blue (0.4%) for 3 min. (i) Formalin 5% is applied to the still flat capsule dropwise using a syringe for 30 seconds

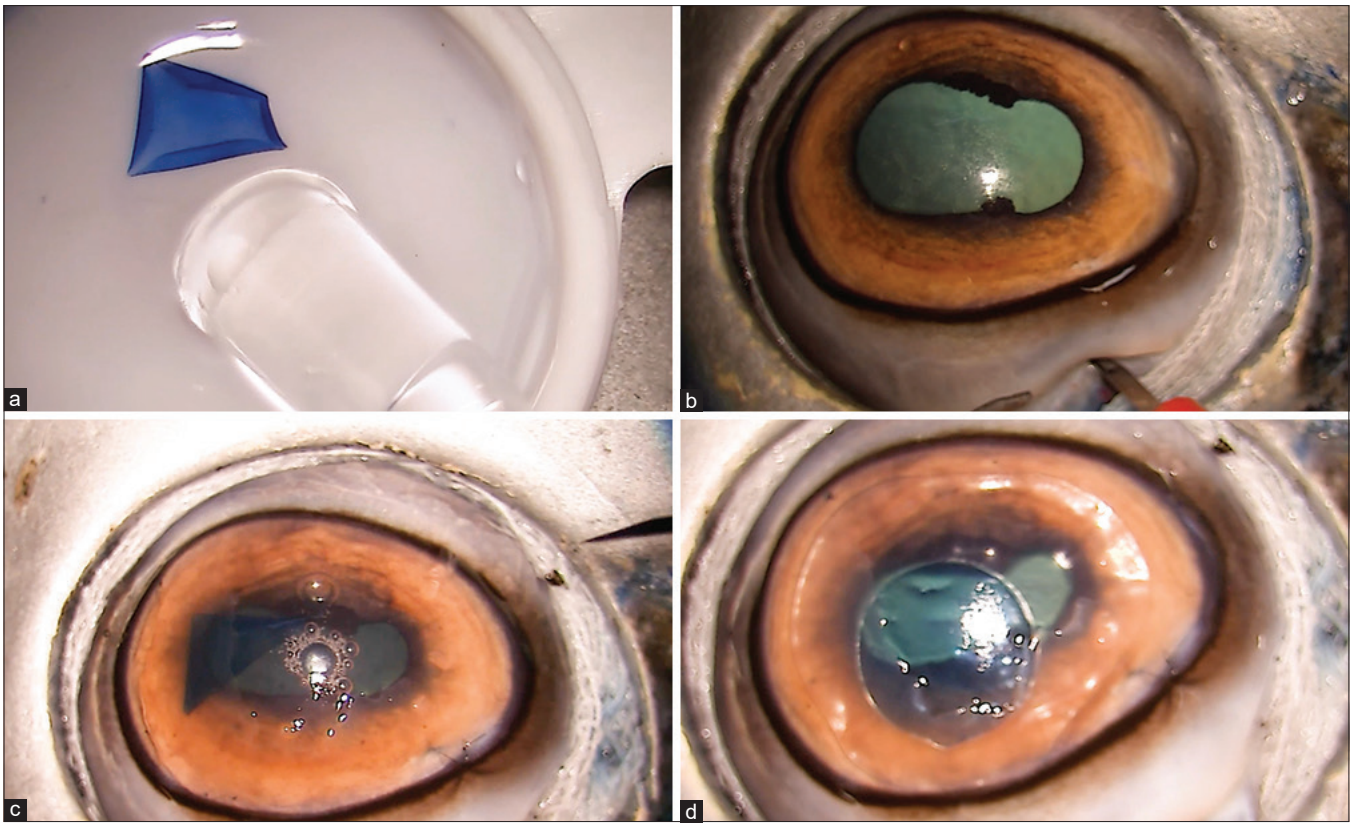

Figure 2: Illustration of the loading and injection phases of pseudo-DMEK graft; (a) the scrolled graft is loaded into a glass injector mounted on a 3cc syringe. (b) The anterior chamber of the second goat eye is deepened by performing a vitreous tap using a 10cc syringe inserted 6 mm posterior to the limbus. (c) Once the graft was injected into the anterior chamber, (d) the scroll is unfolded and held in place with an air bubble

Table 2: Summarizing the existing simulation models (wet models)

Wet lab model	Features
Human cornea model	
Human corneas not suitable for transplantation[13-16]	Require one human corneal scleral rim (it is used before for DMEK graft preparation, then mounted on the artificial chamber and used as recipient)
No human cornea model	
Porcine model[11]	Require two porcine globes: anterior lens capsule of one porcine eye is used to create a pseudo-graft and then implanted it into an intact porcine globe.
Goat eye model	Require two goat globes: anterior lens capsule of one goat eye is used to create a pseudo-graft and then implanted it into an intact goat globe.
Onion model[12]	Require one onion and any phacoemulsification practice eye model: The pseudo-graft is created with the inner transparent membrane of the onion (Allium cepa) and then implanted in a simulation phacoemulsification eye model.

unfolded using the classical maneuvers described for human DMEK and held in place with an air bubble.[8]

Discussion

The goat eye model can simulate all the steps of DMEK surgery, except descemetorhexis. It is cost-effective, facilizing repeated practice. The goat eye mimics the human eye in its structure, albeit being significantly larger. Corneal clarity was preserved in fresh goat eyes for 48 hours after collection. In refrigerated eyes that initially cloudy, clarity was restored after a period of warming under the warm light from the surgical microscope. Unlike the porcine model, it is possible to obtain two 8 mm pseudo-graft goat lens capsules. The goat anterior lens capsule pseudo-graft can be dyed and fixed to create scrolls that behave very similarly to the human DMEK grafts from older donors.

This can be explained by nanomechanical similarities between the DM and lens capsule. The epithelial side of anterior lens capsule and endothelial side of the descemet membrane are stiffer than their anterior chamber side and stromal side, respectively.[9] Proteomics and biochemical analysis of anterior lens capsule and descemet membrane showed that anterior lens capsule is softer than descemet membrane, and therefore, anterior lens capsule scrolls are more compared to descemet membrane. To reduce the scrolling of the anterior lens capsule to the level of descemet membrane scrolling, we treated goat anterior lens capsule pseudo-graft with 5% formalin for 30 seconds to make the anterior lens capsule stiffer, so it behaves similar to human DMEK graft. Formalin is a widely used fixative in histology and almost universally available in a

hospital setting. The use of formalin to make the anterior lens capsule less elastic in goat eyes and induce cataract for surgical training[10] has also been reported.

Droutsas *et al.*[11] show how the anterior capsule of enucleated porcine eyes as a substitute of the donor Descemet membrane may be an easy and effective option Table 2. These porcine pseudo-grafts also form scrolls when submerged in fluid (similarly to the human graft) and were tear resistant and easy to prepare. However in much of the world, including the Indian subcontinent, there is limited availability of porcine eyes due to the absence of swine breeding and production farms, as opposed to goat farms which are widespread.

Mittal and colleagues describe their original onion simulation model using inner transparent membrane of the onion as pseudo-graft which can be injected into a phacoemulsification practice eye.[12] It is readily available and cost-effective, but in contrast to human grafts, it curls away from its stroma, and it is more difficult to handle due to its thickness. Therefore, it can provide good training for peeling and loading, but not for unfolding. Limitations of the goat eye model compared with the human DMEK are the differences in graft preparation and the inability to perform a descemetorhexis.

Conclusion

To the best of our knowledge, this is the first description of a goat eye model for DMEK surgery, and the first time fixation to change the scroll tightness has been employed. The model mimics the key steps of DMEK insertion and unfolding well and available in countries where porcine tissue is unavailable. In our experience, this model helps trainees to improve their understanding and handling of the DMEK graft prior to embarking on surgery in patients.

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Conflicts of interest

There are no conflicts of interest.

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