



Effect of paired radial incision orientation relative to DMEK scroll axis on the likelihood of triple scroll formation in young donor tissue

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INTRODUCTION

Descemet's Membrane Endothelial Keratoplasty (DMEK) is the preferred surgical treatment for endothelial diseases such as Fuchs' dystrophy and bullous keratopathy. However, intraocular unscrolling of DMEK grafts can be challenging, particularly with younger donor tissue (age <50).¹ Paired radial incisions, placed 120° apart, have been used to ease unscrolling in young donor tissue by encouraging grafts to adopt an open triple scroll conformation rather than a natural double or single scroll (Fig 1).²

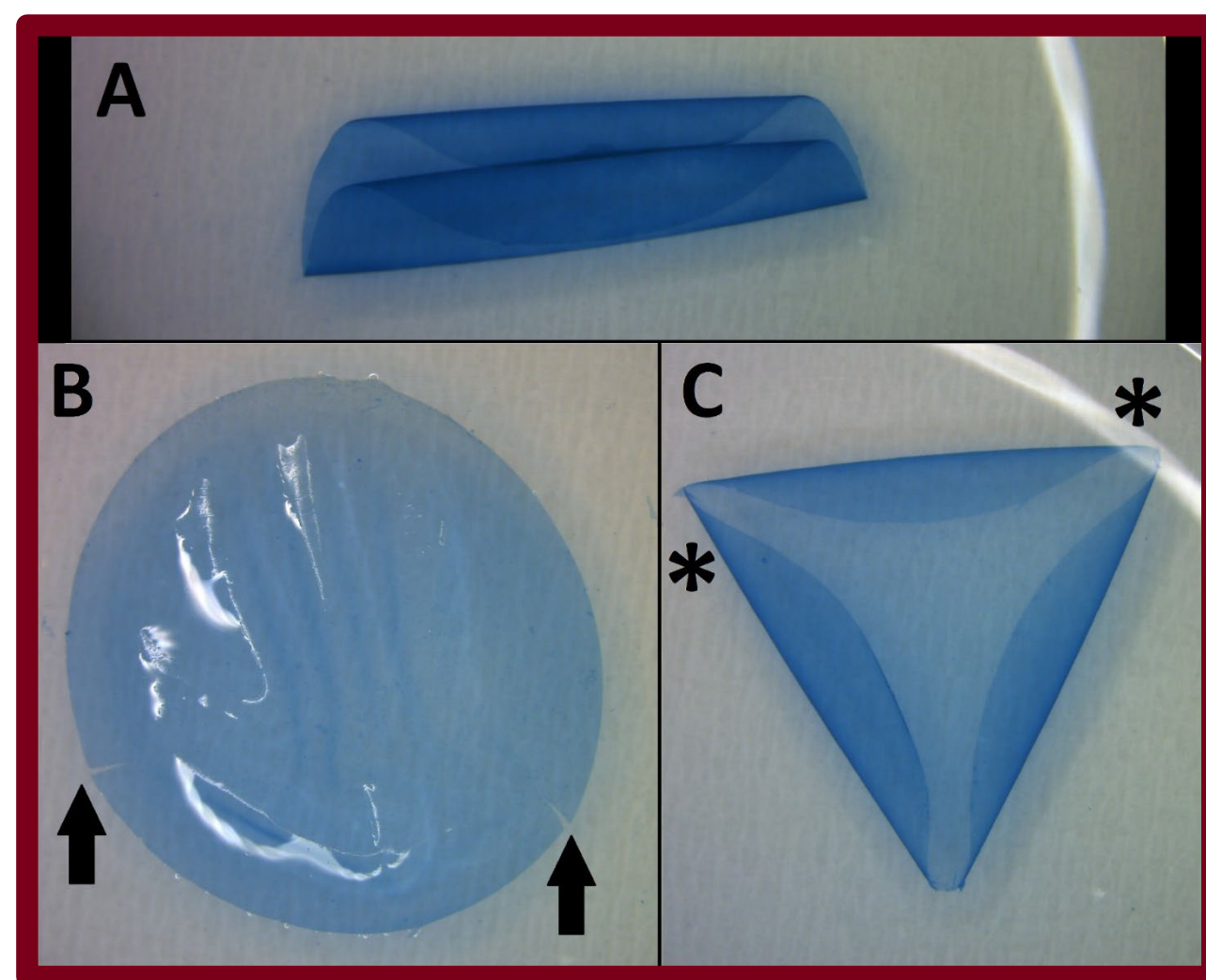


Fig 1. Typical DMEK double scroll (A). Two small (<1mm) radial incisions added 4 clock hours apart from each other (B). Radial incisions brace the DMEK tissue open into a triple scroll conformation (C).

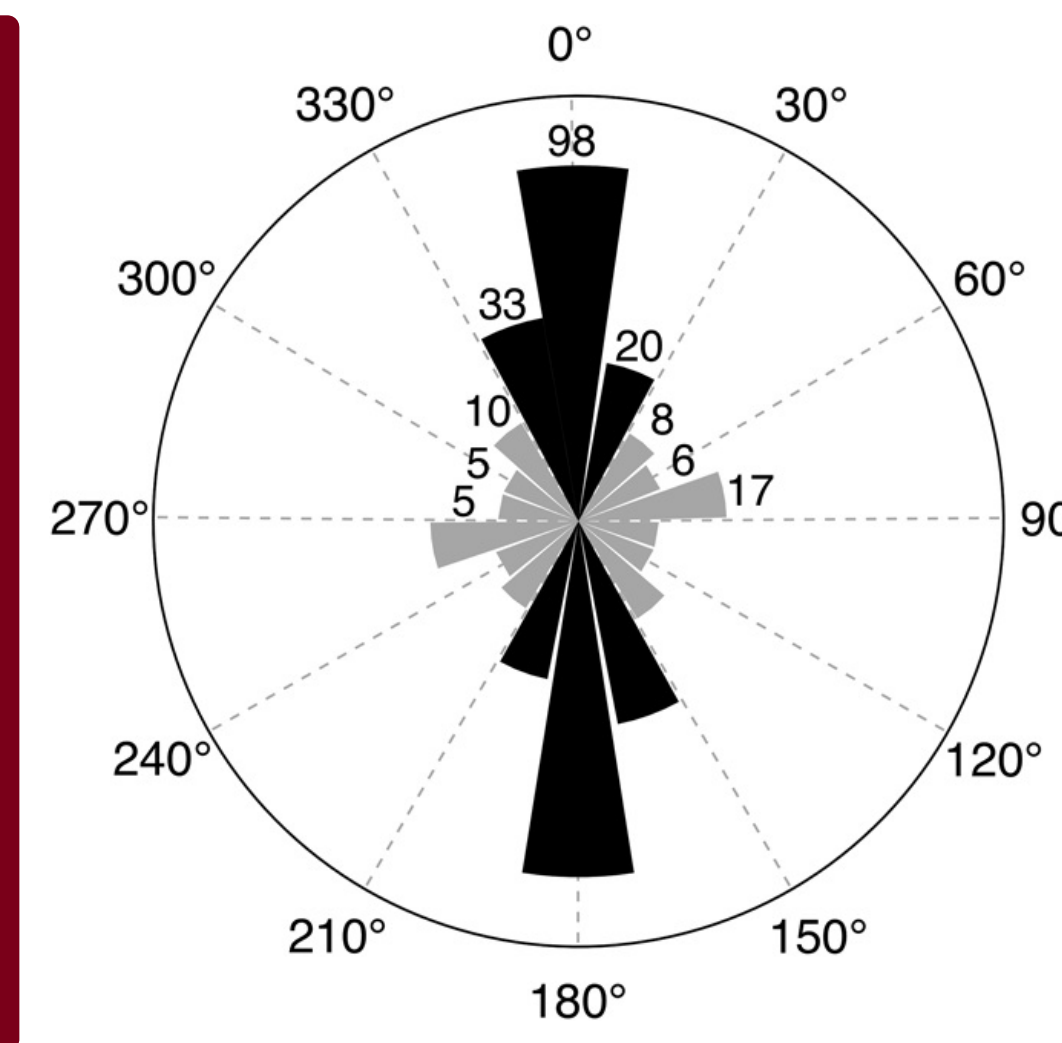


Fig 2. Distribution of DMEK scroll axis preference. Corneas predominately scroll around the vertical axis (black bars represent 75% of the distribution). Image credit: Katrin Wacker, MD

For tissue from donors <65 years old, 75% of grafts with incisions form a stable triple scroll. No study has examined why all grafts do not form a triple scroll. Recent studies found that DMEK grafts preferentially scroll around the superior-inferior (S-I) axis (Fig 2), suggesting that graft scrolling behavior can be predicted by eye orientation³. The purpose of this study was to evaluate whether placement of paired incisions relative to the preferential graft scrolling axis affects the ability of the graft to form a triple scroll.

METHODS

- Human corneas with research consent from donors < 65 years old were obtained from the Lions Gift of Sight.
- Donor characteristics, including age, gender, death to preservation time, and diabetes status were recorded.
- For *in vitro* testing, pairs of 1mm long radial incisions spaced 120° apart were made with "Deep Well Trifold Cover" (Moria SA, Antony, France) after SCUBA peeling and trephination. Incisions were placed on opposing sides of the S-I axis (at 60° & 300° or 120° & 240°) or the N-T axis (at 30° & 150° or 210° & 330°) for mated pairs with donor age ≤65.
- Triple scroll formation was compared between S-I and N-T groups after grafts were submerged in saline and encouraged to triple scroll.
- Paired radial incisions location relative to donor eye orientation was recorded for *in vivo* testing of young (age <50) preloaded transplant DMEK tissues.
- Surgical videos from young donor tissue DMEK cases were reviewed. Triple scroll formation and unscrolling times were compared for grafts with S-I incisions vs. N-T incisions.

RESULTS

In Vitro DMEK scroll testing

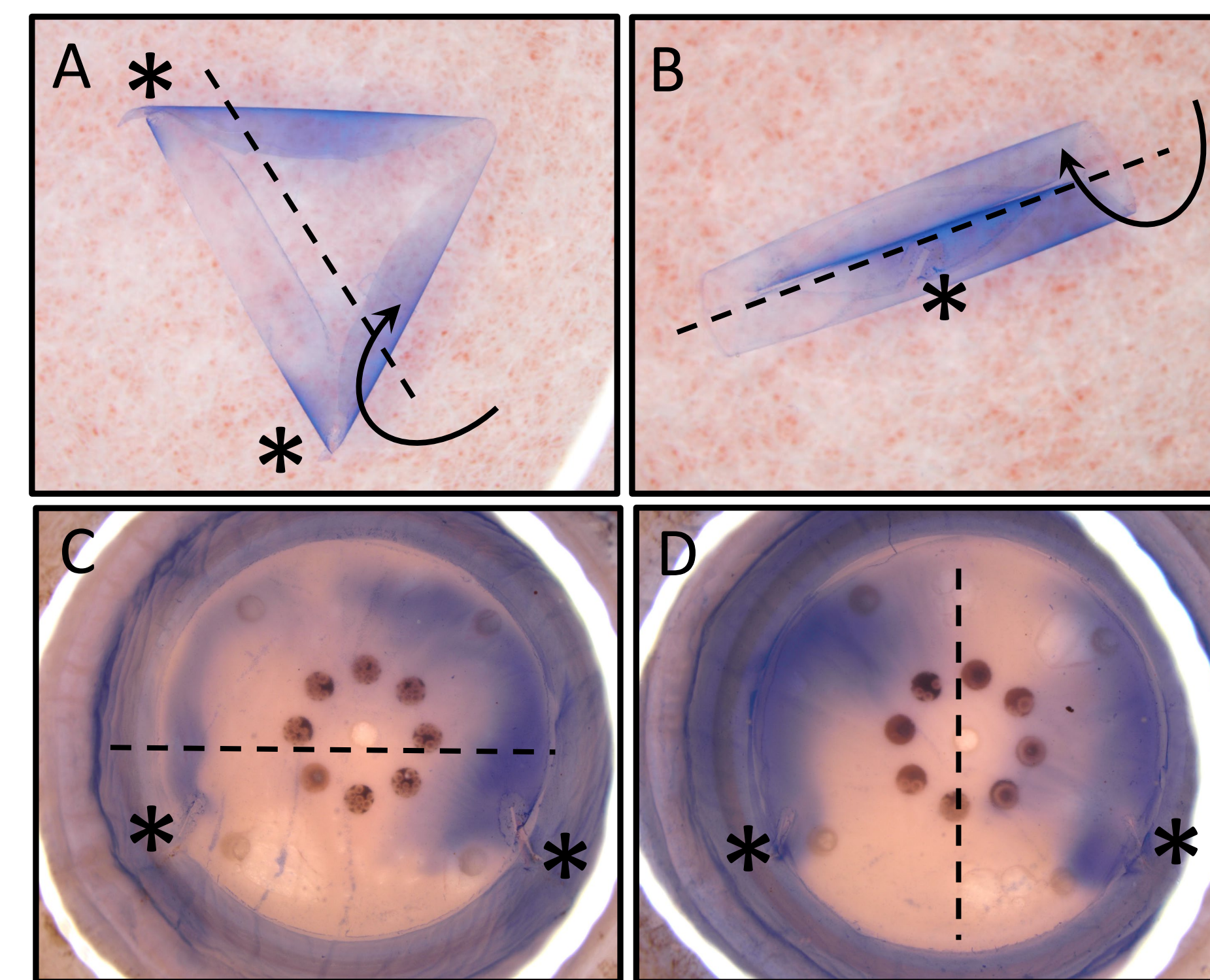


Fig 3. Representative scrolling patterns of mated DMEK tissues with paired radial incisions placed along horizontal axis (A) and vertical axis (B) demonstrating triple scroll and double scroll formations, respectively. The vertical eye (S-I) axis is represented by a dotted black line, and radial incisions are marked with asterisks. The triple scroll shown in A was prepared with horizontally aligned (N-T) incisions (C). The double scroll in B was prepared with vertically aligned (S-I) incisions (D).

In Vivo surgical video review

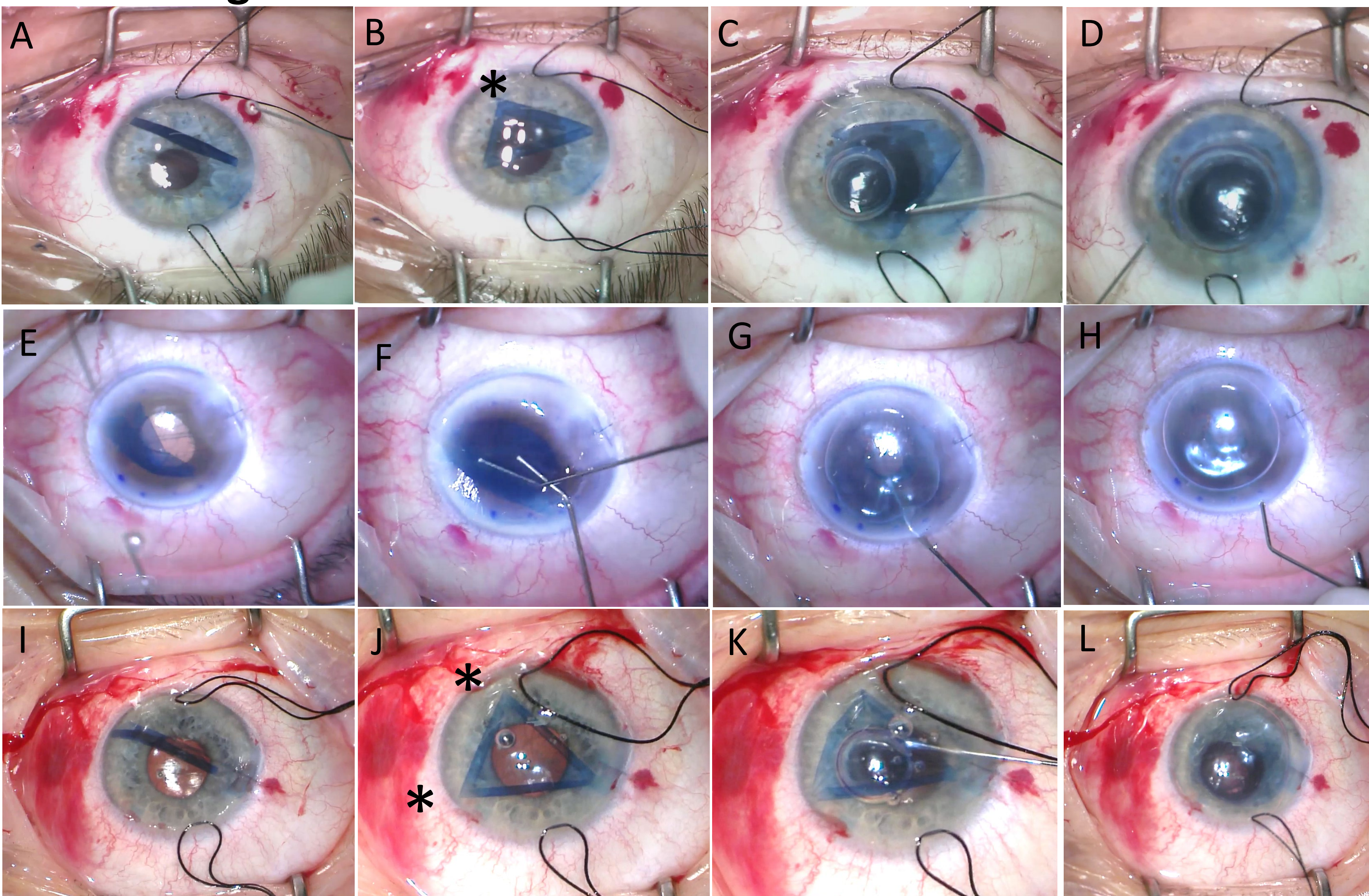


Fig 7. DMEK surgery video stills of sub-50 year old donor eyes prepared with horizontal axis aligned incisions (A-D, I-L) and vertical axis incisions (E-H). Tight scrolls are injected (A,E,I), and tissue is opened when paired incisions (asterisks) brace the graft open in stable triple scroll (B,J), or graft is pinned to the iris (F). Air bubble is placed under graft (C,G,K) to unroll graft edges. Bubble is then enlarged for graft dehiscence (D,H, L). Mated eyes from a 40 year old donor (1st and 2nd row) demonstrate triple scroll formation with horizontal (B) but not vertical axis (F) incisions.

Fig 4. In vitro testing: Triple scroll formation by scroll axis

Scroll Axis	Triple scroll	No triple scroll	% Triple scroll
Vertical	3	5	37.5%
Horizontal	6	2	75.0%
Total	9	7	56.3%

Fig 5. In vitro testing: Triple scroll formation by incision location

Paired Incision location	Triple scroll	No triple scroll	% Triple scroll
Superior	1	3	25%
Inferior	2	2	50%
Nasal	4	0	100%
Temporal	2	2	50%

Fig 6. In vivo testing: Triple scroll formation and unscrolling time by scroll axis alignment

Scroll Axis	Triple Scroll formation	Elapsed time (mm:ss)	Age (yr)
Vertical	2/3 (67%)	04:26	45
Horizontal	3/3 (100%)	05:10	41.7
Overall	5/6 (83%)	04:50	43.3

DISCUSSION

- DMEK grafts strongly prefer to scroll around the vertical (S-I) axis.
- Stable triple scroll conformation is more likely to form when small paired incisions are aligned with horizontal (N-T) axis vs. vertical axis (S-I) from *in vitro* scroll submersion testing. Difference is not statistically significant (75% vs. 36%, Fisher exact test, p=0.314)
- The most likely triple scroll formation came from placing the incision in the nasal quadrant (4/4). The least likely was superior quadrant (1/4)
- The trend for a stable triple scrolls to form more easily with horizontal vs. vertically aligned paired incisions was reflected *in vivo* (100% vs 67%, respectively) based of review of DMEK surgical videos.
- Paired incisions assisted in holding the graft open in a triple scroll conformation 83% of the time in surgery.
- Surgical unrolling times were similar between horizontal and vertically aligned paired incision groups (5m:10s vs. 4m:26s, respectively)
- The DMEK scroll axis may vary slightly by donor, but eye orientation is a fixed visual cue that can be referenced for incision placement prior to scrolling of the free-floating DMEK graft.
- Placement of incisions on the horizontal axis is a simple intervention that could increase ease of using younger donor tissue.
- All attempted sub-50 yr old DMEK tissues were unscrolling in under 8 minutes, demonstrating it is feasible to use younger donor tissue. Adding 41-50 year olds would increase eligible donor pool by 15% (54,315 vs. 47,230).⁴
- DMEK tissues from young donors can be prepared by eye banks with good success. In a larger unpublished case study of <50 donor DMEK transplant tissue preparations (which this study was part of) the source eye bank had 1 failure in 14 attempts, and the failure was with diabetic tissue, a known cause of tissue prep failure.

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DISCLOSURE

Peter Bedard, David Hardten, Mark Hansen and Joshua Hou are patent holders at University of Minnesota, licensed by Moria SA