Glasses-Assisted 3D Display System–Guided Descemet Membrane Endothelial Keratoplasty Tissue Preparation

Davide Borroni, MD, PhD,† Carlos Rocha-de-Lossada, MD, FEBO,‡§¶ Paola Bonci, MD,‖ Miguel Rechichi, MD,** Marina Rodríguez-Calvo-de-Mora, MD,‡†† Rahul Rachwani-Anil, MD,‡‡ Jose' Maria Sánchez González, MD,§§ Facundo Urbinati, MD,†† María García Lorente,†† Luca Vigo, MD,† and Francesco Carones, MD†*

Purpose: The aim of this study was to evaluate the feasibility of Descemet membrane endothelial keratoplasty (DMEK) tissue prep- aration using a glasses-assisted 3-dimensional (3D) display system and to compare it with a conventional surgical microscope.

Methods: Healthy pairs of human corneas suitable for penetrating keratoplasty surgery were selected for this study. The tissues were randomly divided into 2 groups. Each pair of corneas had 1 cornea (group 1) prepared with NGENUITY (Alcon) with a 5-second staining time with vision blue, and the fellow cornea (group 2) was prepared using a OPMI Lumera 700 surgical microscope (Carl Zeiss Meditec, Jena, Germany) with a 30-second staining time. DMEK graft preparation time, speed of stripping, graft width, and endothe- lial cell loss were evaluated.

Results: Twenty-eight pairs of corneas were included in this study. The graft preparation time was significantly higher in the 3D group than in the conventional group (498 ± 147 vs. 418 ± 85 seconds, *P* value = 0.031). The mean speed of stripping was 0.59 ± 0.081 mm/s in group 1 and 0.089 ± 0.005 mm/s in group 2 (*P* value = 0.024). The mean endothelial cell density in group 1 and group 2 before tissue preparation was 2162 ± 115.21 and 2153 ± 122.45, respectively (*P* value > 0.1). After tissue preparation, the endothelial cell density reduced to 1911 ± 150.72 in group 1 and 1998 ± 90.72 in group 2 (*P* value = *P* value > 0.05). The graft width was 5.05 ± 0.71 mm in group 1 and 4.92 ± 0.23 mm in group 2 (*P* value > 0.05).

Conclusions: DMEK tissue preparation with 3D display system NGENUITY is feasible with a slightly increased preparation time. The improved visualization allows a reduced staining time that could

Descemet membrane endothelial keratoplasty (DMEK) surgery with its selective replacement of corneal endothelium is becoming the preferred surgical solution for endothelium dysfunctions.[1–3] The preparation is still one of the main obstacles why many surgeons do not adopt it as their preferred surgical endothelial keratoplasty technique.[4,5] Owing to its complex tissue preparation, staining the corneal tissue before the stripping is recommended to avoid damage.[6,7] Many surgical techniques have been proposed to avoid or reduce the use of vital dyes, sometimes used multiple times, and to improve the following surgical procedure outcomes.[8,9] Exposure to vital dyes has a negative influence on the elastic modulus of DM and may decrease endothelial cell density (ECD).[10,11] Reduced exposure of DM to vital dyes is associated with better results; hence, it is highly recommended.[12–14] Recently, heads-up 3-dimensional (3D) surgical visualization systems have replaced the eyepieces of conventional surgical microscopes with high-resolution dual- camera systems that retransmit an image on a screen in front of the surgeon.[15,16] The NGENUITY 3D digitally assisted visual- ization system (Alcon Vision LLC, Fort Worth, TX) displays real-time images from a camera mounted on the microscope using a high-definition digital 3D display. In addition, the NGENUITY system uses a smaller camera aperture while keeping the eye illumination the same, enhancing the depth of field. Based on theoretical calculations, depth of field with NGENUITY when the camera aperture is reduced to 30% can be 2–3 times greater than that of a standard operating microscope with a focal length of 200 mm and 10· oculars.[17] This change to an all-digital technology represents a major breakthrough in eye surgery, enabling greater resolu- tion with higher magnification and panoramic viewing with a wider visual field.[18,19] Nevertheless, little is known regarding the use of heads-up 3D surgical visualization systems in DMEK procedure, and the literature on this topic is scarce.[20–22] Galvis et al[21] were the first to describe this approach. Recently, Del Turco et al[22] reported that heads-up 3D DMEK surgery proved good outcomes regarding visibility, image quality, and teaching potential surpassing 2D technology. In the same line, Panthier et al[20] also agreed revealing that this method is a feasible option, with a higher quality of surgical details,

and suitable to instruct novice surgeons. However, they found that graft preparation and total surgical time were significantly higher than conventional surgery. The aim of this study was to evaluate the feasibility of heads-up 3D DMEK stripping and to compare it with DMEK stripping using a conventional microscope.

MATERIAL AND METHODS

Tissue Selection

Twenty-eight pairs of healthy human corneas suitable for penetrating keratoplasty were included in this study. ECD was over 2000 cells/mm in all tissues. ECD was evaluated before and after tissue preparation. Tissues were selected from nondiabetic patients. Corneas suitable for research purposes were provided by Bologna Eye Bank, Bologna, Italy. The tenets of the Declaration of Helsinki were followed in all the procedures for the involvement of human subjects in bio-medical research. After retrieval, the corneal tissues were immerged in a vial with 100 mL of organ culture medium (Cornea Max; Eurobio, les Ulis, France). The vials were stored at 31°C with a dry incubator. Routine methods were used to check endothelial quality. An in-built eyepiece reticule (10 · 10) for inverted microscope (Axiovert; Zeiss, Oberko- chen, Germany) was used to record ECD. To reduce the risk of manual errors, 5 readings were taken from different sites.

Tissue Preparation

Each pair of corneas had 1 cornea (group 1) prepared with a glasses-assisted 3D display system (NGENUITY by Alcon) with a 5-second staining time, and the fellow cornea (group 2) was prepared using a OPMI Lumera 700 surgical microscope (Carl Zeiss Meditec, Jena, Germany) with a 30-second staining time. The surgical steps were the same in both groups. A single trephine technique was used as previously described.[6] Sub- sequently, the endothelium was stained with trypan blue 0.06% (Vision Blue; DORC, Zuidland, the Netherlands) for 5 seconds in

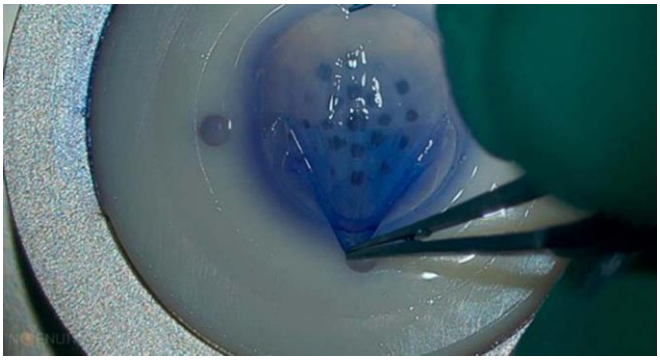

FIGURE 1. DMEK stripping with glasses-assisted 3D display system. (The full color version of this figure is available at www.corneajrnl.com.)

FIGURE 2. DMEK tissue showing a decreased staining than usual grafts. (The full color version of this figure is available at www.corneajrnl.com.)

group 1 and 30 seconds in group 2. Later, the peel was initiated from the corneal periphery at the junction of the cornea and trabecular meshwork. A pediatric crescent 2.3-mm angled knife (Alcon Laboratories, Inc, Fort Worth, TX) with the bevel up (Alcon Laboratories, Inc) was used to strip DM from its periphery toward the center. After stripping 2 mm of the peripheral DM, a Moria 8.5-mm punch was then used in both groups to cut the graft. The corneo-scleral rim was then spared. The totally peeled DM graft was grasped with a pair of forceps and placed in a petri dish with BSS. Later, the graft was measured, examined by microscopy, and the ECD was calculated. To reduce bias, a single surgeon performed all the stripping procedures. The time of tissue preparation was recorded and analyzed. Statistical analysis was performed using the 1-tailed Student *t* test.

RESULTS

Twenty-eight pairs of corneal grafts were included in this study. The time to perform the graft preparation was significantly higher in the 3D group than in the conventional group (498 6 147 vs. 418 6 85 seconds, *P* value = 0.031). The mean speed of stripping was 0.59 6 0.081 mm/s in group 1 and 0.089 6 0.005 mm/s in group 2 (*P* value = 0.024). The mean ECD in group 1 and group 2 before tissue preparation was 2162 6 115.21 and 2153 6 122.45, respectively (*P* value - 0.1). After tissue preparation, the ECD reduced to 1911 6 150.72 in group 1 and 1998 6 90.72 in group 2 (*P* value . 0.05). The graft width was 5.05 6 0.71 mm in group 1 and 4.92 6 0.23 mm in group 2 (*P* value - 0.05).

DISCUSSION

Glasses-assisted 3D display systems are gaining popularity in ophthalmic surgery. Higher detail visualization and depth of perception of anatomical structures are changing surgical approaches.

Lately, the DMEK procedure has gained popularity. The need to clearly discriminate the shape and position of the graft in the anterior chamber is attracting corneal surgeons to new visualization systems. Glasses-assisted 3D display systems have reported their potential in DMEK surgery because tissue preparation is a critical step before this procedure (Fig. 1).

In DMEK tissue preparation, the influence of the staining time in the final outcome of the procedure and in the long-lasting viability of endothelial cells has always been a topic of discussion.[23] Multiple studies have tried to reduce the exposure to colorants.[24] In this study, we compared pairs of corneas aiming to reduce the differences in the results.[25,26] The improved visualization of the glasses-assisted 3D display system enabled a good quality stripping of the DMEK tissues while reducing the staining time to 5 seconds. As a result, we were able to obtain a suitable tissue for DMEK surgery, with a less toxic effect, in the 3D group (Fig. 2).

The speed of stripping has an influence on the final shape of the graft.[9] In our study, the speed of stripping and the final shape of the graft did not show significant differences among both arms. This might suggest that despite less experience in glasses-assisted 3D display system surgery compared with the conventional surgery using a microscope, a similar performance with a greater visualization is achievable. Moreover, all-digital visualization systems may detect earlier possible areas of tearing or ruptures.

Endothelial cell loss was similar in both groups with a minimal higher loss in the 3D group, although the differences were not statistically significant. Probably, this could be explained due to less experience with the 3D visualization system, and it could improve with more practice.

This study has multiple limitations. It was the first time that the surgeon used a 3D visualization system. Moreover, the prior experience and training with the conventional microscope could have influenced the outcomes.

Other limitations include the low number of corneal tissues studied because of unavailability influenced by the COVID-19 pandemic and the different staining time among both techniques. Additional studies could be beneficial in improving the knowledge on the potential of all-digital visualization systems.

CONCLUSION

DMEK tissue preparation with 3D display system NGENUITY is feasible with a slightly increased preparation time. The improved visualization allows for a reduced staining time that could be beneficial because it may reduce the toxic effect of staining colorants.

REFERENCES

1. Peraza-Nieves J, Sánchez-González JM, Rocha-de-Lossada C, et al. Corneal densitometry patterns in Descemet membrane endothelial keratoplasty and Descemet stripping automated keratoplasty. *Int Oph- thalmol*. 2021.
2. Trouvain AM, Szurman P, Bocqué C, et al. Liquid bubble dissection technique assures rapid and safe DMEK lamella preparation. *Graefes Arch Clin Exp Ophthalmol*. 2021;259:3519–3520.
3. Heslinga FG, Lucassen RT, van den Berg MA, et al. Corneal pachymetry by AS-OCT after Descemet's membrane endothelial keratoplasty. *Sci Rep*. 2021;11:13976.
4. Gadhvi K, Pagano L, Menassa N, et al. DSAEK centration and interface folds: surgical management. *Cornea*. 2020;39:1457–1459.
5. Price MO, Feng MT, Price FW Jr. Endothelial keratoplasty update 2020. *Cornea*. 2021;40:541–547.

6. Parekh M, Borroni D, Ruzza A, et al. A comparative study on different Descemet membrane endothelial keratoplasty graft preparation tech- niques. *Acta Ophthalmol*. 2018;96:e718–e26.
7. Parekh M, Leon P, Ruzza A, et al. Graft detachment and rebubbling rate in Descemet membrane endothelial keratoplasty. *Surv Ophthalmol*. 2018; 63:245–250.
8. Tzamalis A, Vinciguerra R, Romano V, et al. The "yogurt" technique for Descemet membrane endothelial keratoplasty graft preparation: a novel quick and safe method for both inexperienced and senior surgeons. *Cornea*. 2020;39:1190–1195.
9. Borroni D, Gadhvi K, Wojcik G, et al. The influence of speed during stripping in Descemet membrane endothelial keratoplasty tissue prepa- ration. *Cornea*. 2020;39:1086–1090.
10. Majmudar PA, Johnson L. Enhancing DMEK success by identifying optimal levels of trypan blue dye application to donor corneal tissue. *Cornea*. 2017;36:217–221.
11. Weber IP, Rana M, Thomas PBM, et al. Effect of vital dyes on human corneal endothelium and elasticity of Descemet's membrane. *PLoS One*. 2017;12:e0184375.
12. Ho WT, Chang JS, Chen TC, et al. Evaluation of patent blue as the vital dye in an animal model of Descemet membrane endothelial keratoplasty. *Cornea*. 2019;38:360–363.
13. Chen SY, Tran KD, Wehrer S, et al. Patent blue V as an alternative stain for DMEK grafts: safety, stain retention, and feasibility. *Cornea*. 2019; 38:1322–1327.
14. Chamani T, Javadi MA, Kanavi MR. Trephine- and dye-free technique for eye bank preparation of pre-stripped Descemet membrane endothelial keratoplasty tissue. *Cell Tissue Bank*. 2019;20:321–326.
15. Kantor P, Matonti F, Varenne F, et al. Use of the heads-up NGENUITY 3D Visualization System for vitreoretinal surgery: a retrospective evaluation of outcomes in a French tertiary center. *Sci Rep*. 2021;11: 10031.
16. Vélasque L, Arbousoff N, Rigaudier F, et al. Lux study: contribution of a three-dimensional, high dynamic range, ultra-high-definition heads-up visualization system to a significant delivered light intensity decrease during different types of ocular surgeries. *J Fr Ophtalmol*. 2021;44: 1129–1141.
17. Rizzo S, Abbruzzese G, Savastano A, et al. 3D surgical viewing system IN ophthalmology: perceptions of the surgical team. *Retina*. 2018;38: 857–861.
18. Bin Helayel H, Al-Mazidi S, AlAkeely A. Can the three-dimensional heads-up display improve ergonomics, surgical performance, and ophthalmology training compared to conventional microscopy?. *Clin Ophthalmol*. 2021;15:679–686.
19. Palácios RM, Kayat KV, Farah ME, et al. Heads-up digitally assisted surgical viewing with intraoperative optical coherence tomography for myopic schisis repair. *J Ophthalmic Vis Res*. 2021;16:127–130.
20. Panthier C, Courtin R, Moran S, et al. Heads-up Descemet membrane endothelial keratoplasty surgery: feasibility, surgical duration, complica- tion rates, and comparison with a conventional microscope. *Cornea*. 2021;40:415–419.
21. Galvis V, Berrospi RD, Arias JD, et al. Heads up Descemet membrane endothelial keratoplasty performed using a 3D visualization system. *J Surg Case Rep*. 2017;2017:rjx231.
22. Del Turco C, D'Amico Ricci G, Dal Vecchio M, et al. Heads-up 3D eye surgery: safety outcomes and technological review after 2 years of day -to- dayuse. *Eur J Ophthalmol*. 2021;11206721211012856.
23. Chen C, Solar SJ, Lohmeier J, et al. Viability of preloaded Descemet membrane endothelial keratoplasty grafts with 96-hour shipment. *BMJ Open Ophthalmol*. 2021;6:e000679.
24. Weisenthal RW, Yin HY, Jarstad AR, et al. Long term outcomes in fellow eyes comparing DSAEK and DMEK for treatment of Fuchs Corneal Dystrophy. *Am J Ophthalmol*. 2022;233:216–226.
25. Marchand M, El-Khoury J, Harissi-Dagher M, et al. Outcomes of first cases of Descemet membrane endothelial keratoplasty (DMEK) at a Canadian university hospital centre. *Can J Ophthalmol*. 2021.
26. Cervantes LJ, Tallo CA, Lopes CA, et al. A novel virtual wet lab-using a smartphone camera adapter and a video conference platform to provide real-time surgical instruction. *Cornea*. 2021;40:1639–1643.