Corneal Transplant Education in a Clinical Setting

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Corneal Transplant Education in a Clinical Setting

by

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Abstract

Keratoplasty, or corneal transplant, is available as a solution for patients suffering from corneal pathology. There are various types of keratoplasty available to prospective patients depending on the severity and the histological layer affected. Surgeries such as keratoplasty have been observed to cause distress among prospective patients, which may impede recovery. Patient education in a timely and appropriate delivery can help alleviate preoperative anxiety. Creating patient education materials for keratoplasty can help prepare for surgery and subsequent recovery. These materials utilize both 2D and 3D design tailored to the unique needs of low-vision patients to teach them about their options for keratoplasty. One part is visual information cards illustrating each operation offered that incorporate visually-accessible design. Another part is an interactive 3D-printed resin model of the cornea highlighting the layers to be removed and replaced. Both are to be used within a consultation to supplement the ophthalmologists’ explanation to alleviate preoperative anxiety and provide useful information on the surgical and recovery process.
**INTRODUCTION**

*Project Concept*

The cornea has a major presence in our psyche. Seeing anything disturbing its thin surface evokes a visceral sense of dread in the average person. This fear would apply to those patients needing keratoplasty, or corneal transplantation. These patients have to give eye surgery serious consideration when presented with options, leading to stress for some. Preoperative stress has been correlated with poor postoperative recovery and is observed with elective surgeries (Ali, et al., 2013). It has also been shown that patient education can be integral in reducing preoperative anxiety (Ng, et al., 2004). Keratoplasty education involves a compound understanding of corneal anatomy, pathophysiology, surgical techniques, and recovery. This provides a challenge for ophthalmologists to properly convey surgical approaches in a way that their patients can be confident in their decision to undergo surgery.

The purpose of this project is to demystify the various types of corneal transplantation procedures for prospective patients. The creation of this project will rely on carefully considered design choices to better communicate to those with low vision during a patient consultation. This is based on the needs of the Flaum Eye Institute in Rochester, NY, and will include both 2D and 3D materials to be integrated into their practice. The approach will be that of a client-to-artist project and it will define my workflow as well as conversations with the Flaum Eye Institute.
**Audience**

The primary audience for this project is middle-aged to older adults with profound vision loss, as that is the population most in need of corneal transplantation. The secondary audience includes ophthalmologists that perform corneal transplants as well as any loved ones that may accompany the patient upon their consultation. The hospital-based clinic of Dr. Rachel Wozniak, MD, Ph.D., a cornea specialist and corneal transplant surgeon, will serve as the basis for collecting audience feedback.

**Goals and Objectives**

The goals of this project are to provide comprehensive patient education materials that can be seamlessly integrated into a keratoplasty consultation and that connect with the audience. When a patient uses these materials, their preoperative anxiety will lessen. Accessibility will be carefully considered throughout the design process for a keratoplasty patient’s unique needs. Dr. Rachel A. F. Wozniak, M.D, Ph.D. will implement these materials in her practice and they will ideally be shared amongst colleagues and others in her field. Biomedical art has long been a vehicle for patient education. This approach to ophthalmologic illustration will also highlight art’s role in overall patient well-being. Successful execution of this project can then create opportunities for the expanded use of biomedical art in the clinical setting.
SECTION 1: SCIENTIFIC BACKGROUND

The cornea is a transparent, ovoid, avascular tissue covering the anterior surface of the eye. It measures 11–12 mm in horizontal diameter and it is only 640 μ even at its thickest. Despite its size, the cornea is integral to vision and eye health (Sridhar, 2018). It provides 70% of the total refractive power in the eye and is integral in protecting the internal surfaces of the eye from infection (Sridhar, 2018). Within the tissue are 5 histologically distinct layers that are clinically significant in corneal transplantation (Donaghy et al., 2015). From anterior to posterior, these layers are the epithelium, bowman’s membrane, stroma, Descemet’s membrane, and endothelium.

All or some of these layers may become compromised through many corneal pathologies. These produce scarring of the cornea and prevent the refractive surface from working properly, causing blurry vision, astigmatism, and even blindness (Tidke & Tidake, 2022). Some corneal pathologies are straightforward such as physical injury, chemical injury, or infection (Tidke & Tidake, 2022). Others are due to progressive ectatic, or corneal thinning, disorders or congenital dystrophies. Keratoconus, an ectatic disorder that produces a forward bowing of the cornea, and Fuchs’ dystrophy, a disease in which the corneal endothelium fails to function properly, are now some of the most common indications for keratoplasting (Koulouri, 2020). Previous graft failure is another indication, often employing a different method of transplant to the previously failed method (Lisa et al., 2022).

The oldest and most common corneal transplantation technique worldwide is penetrating keratoplasty or PKP. This is when all five layers of the cornea are trephined, removed, and
replaced (Donaghy et al., 2015). PKP is particularly suitable for diseases that affect the entire thickness of the cornea. While this surgical approach has a high success rate, this method also has a lengthy recovery, a high rejection rate, and results in high astigmatism, which can all affect a patient’s final visual outcome (Koulouri, 2020). Thus, for some disease states that only involve part of the cornea as opposed to the entire thickness, PKP would be considered drastic. Therefore, various other partial-thickness keratoplasty techniques have been and continue to be developed and used alongside PKP. The goal of these partial methods is to retain as much healthy tissue as possible to ease wound healing, reduce complications, reduce transplant rejection rates, and improve overall vision (Donaghy et al., 2015).

Descemet’s Membrane Endothelial Keratoplasty (DMEK) focuses on removing and replacing the corneal endothelium and Descemet’s Membrane for disease local to these anatomic layers. A similar surgical approach, Descemet’s Stripping Automated Endothelial Keratoplasty (DSAEK) has also been widely used in which the corneal endothelium, Descemet’s membrane, and a small amount of posterior stromal tissue are transplanted (Tourtas et al., 2012). A Sinskey hook is used to scrape off the damaged cornea underneath the anterior layers and the donor tissue is then injected into the anterior chamber. To force the tissue to form on the posterior surface of the cornea, the surgeon injects a bubble of air into the anterior chamber (Donaghy et al., 2015) (Tourtas et al., 2012).

Deep Anterior Lamellar Keratoplasty would be employed for cornea scarring or defect affecting the epithelium, bowman’s membrane, and part of the stroma (Khoulouri & Hellwinkel, 2020). A trephine is also used, but the cornea is only cut part of the way through (Donaghy et al, 2015). It is removed and sutured as a PKP would be. There have been recent developments in artificial keratoplasty through keratoprosthesis. This is a prosthetic cornea made of two parts:
one polymethyl methacrylate piece and one titanium plate with a carrier donor tissue in between. This and other artificial methods are still in development and are most commonly used in severe scarring or repeat graft failure.

Cornea transplant is a precarious process, starting from securing the tissue. As of now, the most common means is through an eye bank from a human donor. As of 2020, there are only 742 eye banks to serve a global need of 12.7 million keratoplasty patients (Khoulouri & Hellwinkel, 2020). With this small supply of grafts, many still fail. Preoperative stress has been correlated with poor postoperative recovery and is frequently observed in patients undergoing elective surgeries (Ali, et al., 2013). However, it has also been shown that patient education can be integral in reducing preoperative anxiety (Ng, et al., 2004). When it comes to avoiding graft failure, early recognition, and prompt treatment have been cited as the most important (Donaghy et al., 2015). With all of these factors, there is a need for patient education materials to cater to the specific needs of these patients within Dr. Wozniak’s clinic and the clinics of other ophthalmologists.
SECTION 2: BODY OF WORK

Early Development

*Surgical Illustration*

During early development, I created a step-by-step illustration of DALK (Figure 1). This used a combination of drawings in Adobe Photoshop and diagrams in Adobe Illustrator. The design style and language are typical in ophthalmological surgical illustrations. However, the level of detail along with the font and color choice also made the illustration difficult for someone with low vision to easily discern. These drawings are often created for resident education and may be utilized for patient education as well. However, this mode of delivery is inappropriate for my project. It was important to create both visual and written language appropriate for a lay audience. Dr. Wozniak advised me on language decisions best used for their patients. One early objection from the clinic was the use of tools. As a result, I had to reduce the circular trephine, Sinskey hook, and sutures while still communicating their use.

*Figure 1: DALK Surgical Illustration*
Some aspects of the illustration were kept and adapted. The schematic diagrams were an early exploration into depicting the cornea’s cell layers. The eye was kept in the same position, although much more stylized.

**Accessibility**

Working in a client-artist framework requires an in-depth understanding of how this project will be implemented with the target audience. Because these materials are created for those with visual impairments, I needed to consider their level of ability. This required researching guidelines around creating printed materials for low vision.

There is ample literature on typeface choices for low-vision reading. Tight spacing and letters with indistinct strokes cause visual crowding in text. When presented to people with low vision, the crowded text causes a decrease in both reading speed and reading acuity (Beirer et al., 2021). A sans-serif or clear-serif font is often recommended. Arial, Helvetica, Futura, and Courier Fonts are examples of typefaces with measured contrast and enough distance between characters to be distinct (Action for Blind People, 2004). Double spacing between lines has produced the best results with acuity (Balecmore-Wright et al., 2013). For font size, measurements between size and leading may be different between typefaces, and any necessary modifications would need to be undertaken to best suit the chosen type.

Color choice is a useful communication tool. But along with text, there are color guidelines for low-vision design as well. High contrast is frequently emphasized in print and web design (Wake, 2019; Action for Blind People, 2004). Upon review, Dr. Wozniak also brought up
the issue of designing for colorblindness. This was not a prior concern, as they were not my primary audience, but it’s a concern for ophthalmologists – the secondary audience. I would need to determine appropriate hues for that population while keeping to my design.

For low-vision patients, print media has limitations. Despite the visual solutions, if the patient still cannot discern the information then it will be lost. I decided to create supplementary materials to incorporate touch as well as sight. I made plans to print a 3D histological model of the cornea using the available facilities at the Rochester Institute of Technology. As the patient interacts with the model, the physical texture conveys the cells of each layer. During a consultation, patients will be able to better understand the structure of the cornea and the sections that need transplantation.
Design Process – Patient Education Cards

Assets

I incorporated my earlier research into accessibility guidelines into developing a visual style for the patient education cards. This was plotted out in Adobe Photoshop and rendered in Adobe Illustrator. The first set of drawings was a series of black, white, and red figures (Figure 2). These plans evolved into something less harsh and with less visual noise. I focused on solid, discernable shapes. Tools were replaced with simple arrows and lines delegating the process of incision, removal, and suturing.

The color scheme grew with different hues denoting various sections of the cornea. It was especially important to point out Bowman’s and Descemet’s membranes which stayed green and violet respectively. For the damaged tissue, I decided to avoid a strong red to avoid any feelings
of danger. Avoiding red tones also became useful when modifying the pages for colorblindness. To determine the hue edits, I used the online tool Coblis to simulate various forms of colorblindness. Through this, I adjusted the red and green tones of the piece (Figure 3).

I created icons for various keratoplasty indications, PK/DALK sutures, the recovery process, and general eye health (Figure 4). The icons are placed throughout the card and will signify important post-operative directions. For example, Dr. Wozniak requested an image of a person lying supine to recover from DSEK and DMEK. I included a simple rendering of a head for that specific procedure, placing it at the appropriate stage.
Page Layout and Printing

For each sheet, I assembled the illustrations and the text in an 8.5x11-inch print layout. I included various fonts that were appealing yet appropriate for accessibility purposes. The printouts have Optima for the text, HP simplified for the headers, and Franklin Gothic Demi for the subheaders. All text is at 14 point or larger while retaining a level of information satisfactory to the Flaum Eye Institute.

A consistent layout maintains readability. The information is sectioned into an introduction, surgical steps, and recovery (Figures 7.1-7.5). Each section of the text, barring the surgical steps, has the same alignment. For the surgical steps, the illustrations are ordered in a logical succession with text captions to supplement them. Important steps are emphasized in the illustration and the goal is to draw attention while not taking away from flow and readability.

Each keratoplasty method has 6 copies of each type printed for patient use with one laminated copy to be in permanent use within the clinic. The paper will be matte to reduce glare.
and improve visibility. The weight will be heavier than the average computer paper to prevent wear as well as to provide a quality print so the patient sees it as a higher priority and will refer to it more. Future prints will be at the discretion of Dr. Wozniak and the Flaum Eye Institute. My initial print runs required some minor changes in leading and color choice. I ran each test print until my advisors and I determined them satisfactory in their final design.

**Design Process – 3D model**

*Modeling*

For the 3D model, I needed to have the thickness of each layer as close to scale as possible. Measuring the actual ratio of the cell layers gave me an estimation of my final dimensions. Three pieces at a ratio of 2:4:1 (Epithelium & Bowmans: Stroma: Descemet’s & Endothelium) was the best choice when it came to accuracy and producing a structurally sound model. Three layers would correlate to each partial thickness procedure. The final size would need to be large enough for a patient to differentiate layers on texture alone, but not so big it would be cumbersome to use.

I used Maya to create a schematic model of each layer and I sketched out a plan of the cell pattern in Adobe Illustrator (Figure 5). The cell patterns were refined in Mudbox until I discovered that modeling each cell right in Maya would result in a clean final print (Figure 6). The cells are kept true to their basic patterns and their distinct texture.
Printing

I printed two iterations of the model in resin using stereolithography. The final dimensions are 4x2x2 inches. At the size I am working in, resin would retain the most detail. I printed a test model with a low polygon count and a final model with a high polygon count. Minor manual adjustments were made to improve the peg and cavity mechanism. This resulted in a model that interlocks well, fits nicely in the hand, and is easy to handle. To better highlight the layers, I painted the outside two pieces opaque while keeping the stroma clear (Figure 8.1). This is similar to how the stroma functions in the body as it gives the cornea its transparent quality. Upon further review, I printed two more outside pieces and colored them the same orange used in the card to signify an unhealthy cornea (Figure 8.2). The “healthy” and “unhealthy” pieces would be swapped out during a demonstration.
SECTION 3: USABILITY TESTING

Experimental Process

Experimental Group

The intended audience of this work is patients undergoing corneal transplantation. I had the help of ophthalmic technician Kenzie Herron to fulfill the requirements of the patient survey within Flaum Eye Institute. This includes submitting an Institutional Review Board form as well as a consent form for patients. The 5 question survey will evaluate a patient’s understanding of the procedure and level of confidence in their operation. 50 patients aged 18+ will be selected from the clinic of Dr. Rachel Wozniak. 25 patients will be given verbal instructions as well as the cards and model demonstration. The remaining 25 patients will only receive verbal instruction. This data will be aggregated over time and used to evaluate the effectiveness of the materials. Over time this data will prove to be quantifiable proof of the effectiveness of the materials.

Initial Feedback

Reception of the patient education materials has been overwhelmingly positive between both physicians and patients. Dr. Rachel Wozniak is utilizing the sheets as well as the model within her clinic to prepare for the approval of the IRB. From this, patients have expressed gratitude and appreciation for this new method. It has also been reported to help them better understand their surgery. Physicians within Flaum Eye Institute have also expressed interest in utilizing the materials, specifically commenting on the 3D model. Physicians have requested printed copies for their use.
CONCLUSION

The patient education materials for Flaum Eye Institute went through rigorous revision and review. This was to ensure the best possible product for the audience in terms of design and accessibility. Both the sheets and the 3D model were very well-received by patients and physicians. As a result, I am overall pleased with the final artwork. Biomedical illustration continues to be a reliable source of patient education as well as a vehicle to ease patient anxiety.

Further work would involve the production of the 3D model and the cards as well as the continued distribution of the materials within the Flaum Eye Institute, University of Rochester, as well as ophthalmology clinics outside of Rochester. It would also be beneficial to monitor participating patient recovery rates. I would like to continue designing within ophthalmology to create biomedical visuals for a low-vision population as well as to improve their outcomes.
Illustrations of the surgical steps for penetrating keratoplasty along with the length of the operation as well as the length of visual and physical recovery.
Figure 7.2: DALK Front Page

Illustrations of the surgical steps for deep anterior lamellar keratoplasty along with the length of the operation as well as the length of visual and physical recovery.
Recovery

Immediately after
You may go home after the surgery
There may be some discomfort, tearing, or itching
All medication and an eye shield will be provided to you at the time of surgery with detailed instructions on how to care for your eye

1-3 weeks
Wear an eye shield as directed by your doctor
Avoid heavy lifting (over 10lbs) and strenuous exercise as directed by your doctor
Avoid touching or rubbing your eye

1 month - 2 years
After 3 months your doctor will begin to remove your sutures
It may take up to 1 year to achieve your final vision
Continue to use your eye drops as prescribed

IF YOU ARE EXPERIENCING:
Redness Discharge
Pain Change or Loss of
Swelling Vision
CALL YOUR DOCTOR IMMEDIATELY

The back pages are focused on the specific steps of recovering after the operation. There is also a list of symptoms of graft rejection in case the graft may fail.
Descemet's Membrane/Stripping Endothelial Keratoplasty (DMEK/DSEK)

Descemet's Membrane or Descemet's Stripping Endothelial Keratoplasty is a partial-thickness transplant. The inner 2-3 layers of the cornea are replaced by a graft.

Why DMEK/DSEK?
DMEK/DSEK is necessary when the inner layers of the cornea are damaged but the rest of the cornea is healthy.

Steps

1. Your cornea will be measured and marked and the donor graft will be prepared and cut.

2. The damaged cornea will be removed via a small incision. The donor graft will be inserted through another incision.

3. An air bubble will be placed in your eye to help the graft conform to the shape of the cornea.

Eye Heals: 2-4 WEEKS
Regain Vision: 3-6 WEEKS

Figure 7.4: DSEK/DMEK Front Page

Illustrations of the surgical steps for descemet’s membrane/descemet’s stripping endothelial keratoplasty along with the length of the operation as well as the length of visual and physical recovery.
Recovery

Immediately after
You must lie on your back for 5-7 days after surgery
You may go home after the surgery
There may be some discomfort, tearing or itching
All medication and an eye shield will be provided to you at the time of surgery with detailed instructions on how to care for your eye

1-3 weeks
Wear an eye shield as directed by your doctor
Avoid heavy lifting (over 10lbs) and strenuous exercise as directed by your doctor
Avoid touching or rubbing your eye

1 month - 2 years
After 3 months your doctor will begin to remove your sutures
Your final vision will take up to 1-2 years to achieve
Continue to use your eye drops as prescribed

IF YOU ARE EXPERIENCING:
Redness  Discharge
Pain     Change or Loss of Vision
Swelling

CALL YOUR DOCTOR IMMEDIATELY

Figure 7.5: DSEK/DMEK Back Page
The information on this page is similar to DALK and PK except for the extra step of lying supine after the operation.
Figure 8.1: 3D printed cornea model

The final cornea model painted to highlight the separate pieces: the epithelium and bowman’s membrane, the stroma, and descemet’s membrane and the endothelium
Figure 8.2: 3D printed cornea model with disease layers

The final cornea model with the unhealthy layers interlocking, demonstrating how each piece would signify where transplantation is needed.
REFERENCES


