# K-RIM (Corneal Rim) Angle Surgery Training Model

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**Purpose:** To develop an angle surgery training model for training an array of microincisional glaucoma surgery (MIGS) procedures.

**Methods:** We describe a method for preparing an angle surgery training model using human cadaveric corneoscleral rims. The model provides realistic tactile tissue simulation and excellent angle visualization requiring bimanual technique. Corneoscleral rims may be used multiple times and are prepared at low cost, allowing for a high volume of practice surgeries.

**Results:** This model allows for practice in bimanual surgical training using the gonioscopy lens for visualize alongside surgical tools. The in vivo surgical conditions and limited tactile feedback are recreated using human cadaveric eyes which nonhuman models fail to provide. Our model is prepared at low cost, with relative ease and also provides appropriate positioning of Schlemm canal and for high volume of practice as the canal can be used in 90-degree segments.

**Conclusions:** Few angle surgery training models currently exist and none provide these necessary features. The model presented here aims to meet the growing demand for adequate training models required for technically advanced MIGS techniques.

**Key Words:** glaucoma, training model, minimally invasive glaucoma surgery, bimanual technique, corneoscleral rims

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Glaucoma surgery is rapidly advancing as many new microincisional glaucoma surgery (MIGS) devices are being developed including the FDA approved iStent Trabecular Micro-bypass stent (Glaukos Corporation), Trabectome (NeoMedix Corporation),[1] Cypass Micro-stent (Novartis), and the Xen Gel Stent (Allergan). Investigational devices include the Hydrus Micro-stent (Ivantis), and MicroShunt implant (InnFocus).[2] Other novel trabecular bypass procedures include ab interno trabeculotomy using a Kahook Dual Blade, a catheter, or a 5-0 polypropylene suture. Most of these techniques fall under the category of ab interno angle surgery and are bimanual ab interno procedures—one hand holds the gonio prism lens (such as a Swan Jacobs lens) while the other holds the device or inserter suspended in the anterior chamber. Compared with traditional incisional glaucoma surgery, MIGS techniques hope to offer a safe risk profile while maintaining acceptable efficacy.[3,4] However, the difference in approach from traditional filtering surgery combined with the large variety of emerging techniques makes surgical training and education difficult.[5] Furthermore, the steep learning curve may lead to an increased risk of complication during the initial use of the device in patients. A realistic angle surgery training model is needed to facilitate education of current surgeons and glaucoma specialists in these new techniques, and to train our surgeons of the future. Current categories of training models include virtual-reality, cadaveric, animal, and inanimate with an abundance of literature on virtual-reality training models.[5]

Ab interno trabecular bypass MIGS involves a different skill set compared with traditional glaucoma surgery in that intraoperative gonioscopy is required. A fair degree of bimanual coordination is necessary and visualization is key. If the lens is held at a suboptimal angle in relation to the microscope the view will be inadequate, and excess pressure by the gonio prism lens creates corneal striae which can further impede the view. Angle surgery also requires much higher magnification compared with phacoemulsification and excellent depth perception. Proper identification of Schlemm canal and the delicate nature of the tissue provides additional challenges. Because of the characteristics of the tissue within the iridocorneal angle region, most of the MIGS techniques have minimal tactile feedback especially upon engaging the trabecular meshwork. Instead, the surgical procedures must be almost entirely guided by visual feedback.

The ideal angle surgery model would use have realistic tissue characteristics, employ bimanual technique, be efficient to set up, and applicable to a multitude of MIGS procedures. Some wetlabs for training in iStents have used donor corneal rims which are inverted to expose Schlemm canal for iStent insertion. The model is relatively simple to prepare and utilizes human cadaveric tissue, teaching trainees the variety in appearance of angles structures and tactile characteristics of Schlemm canal. However, this model lacks bimanual training aspect as a gonio lens is not required. Furthermore, as the rim is inverted, Schlemm canal is presented in a convex configuration which is opposite to the positioning from the surgeon's point of view in the operating room.

The challenge with using human cadaver eyes is that corneal edema sets in soon after harvesting, impeding the

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view during gonioscopy. Hypertonic gels can be injected into the anterior chamber to improve clarity, though this is not always successful. Porcine eyes can be used with excellent corneal clarity yet lack a single continuous Schlemm canal instead having segmental canal-like structures termed the angular aqueous plexus.[6–8] The porcine trabecular meshwork is thicker compared with human eyes yielding differences in tactile feedback in vivo.[8] Nonetheless, impressive models including porcine eyes with quantitative canalography, bovine, and sheep eyes training models have been developed due to ease of access and similarity of human eyes as substitutes.[9–12]

We describe a novel bimanual angle surgery training model using human cadaveric corneoscleral rims that provides excellent visualization of angle structures, and tactile feedback/bimanual approach similar to the real-life experience. The model is relatively simple to set up and the required materials are accessible to any surgeon with access to an eye bank.

## METHODS

Corneoscleral rims from human cadaveric eyes not suitable for transplantation or already used for corneal procedures such as DSEK are acquired from the eye bank and set up as follows (and illustrated in Fig. 1): The rims are trephinated with a 9 mm diameter trephine centered on the corneal rim. A Styrofoam base is placed on a 30-degree angled surface using a binder. The rim is placed on the base and the borders are secured with pins placed adjacent to the rim but not penetrating the rim. To provide realistic training, we ensure that Schlemm canal is not buckled during this process. Pins are arranged in a semicircular concave pattern open to the surgeon, allowing access for surgical instruments. The pins generate a concave semicircular perimeter in the Styrofoam that seals the tissue against the Styrofoam floor to contain the medical lubricant (Fig. 2).

Medical lubricant (Muko gel) is used to fill the inside of the anterior chamber and the area contained within the semicircular barrier. Ophthalmic Viscosurgical Devices (OVDs) are also an option though usually more expensive than medical lubricant. A gonio lens (disposable or non-disposable) is then held with the bottom immersed in medical lubricant with one hand, and then the other hand is free to implant the trabecular bypass device (iStent or Hydrus) or manipulate the trabecular meshwork (perform a trabeculotomy using a Kahook Dual Blade or a gonioscopy assisted transluminal trabeculotomy). Video supplementation showing preparation of the training model as well as iStent insertion can be found in the Supplemental Digital Content (http://links.lww.com/IJG/A223). The optical media between the surgeon and the angle only includes medical lubricant and gonio lens. After surgery has been performed in one quadrant the rim can be rotated 90 degrees in situ, which allows for 4 separate training sessions are one rim. The surgical simulation was compared with perform MIGS using an artificial eye SimulEYE KDB model (SimulEye, California). The surgeons' feedback was qualitatively assessed with a questionnaire.

## RESULTS

We have successively completed various angle surgeries with the presented training model and find the surgical conditions to simulate real life. These angle surgeries include Trabecular Microbypass (iStent, Glaukos, California), and needle and dual-blade goniotomy (Kahook Dual Blade, New World Medical, California), and segmental gonioscopy-assisted transluminal trabeculotomy. The angled positioning of the rim and use of medical lubricant provides an excellent viewing field. The model uses bimanual approach for effective and realistic utilization of the gonio prism lens alongside surgical devices. Tissue used in the model is ideal because it recreates the subtle tactile feedback that nonhuman models fail to provide and requires gonio prism lens visualization, mimicking in vivo conditions. Furthermore, the corneoscleral rim provides the realistic curvature of Schlemm canal. The ability to rotate the corneoscleral rim also allows for 4 separate training sessions for increased training efficiency. The model is prepared with relative ease and low cost.

MIGS angle surgery was also successfully performed with the artificial eye (SimulEYE KDB, California).

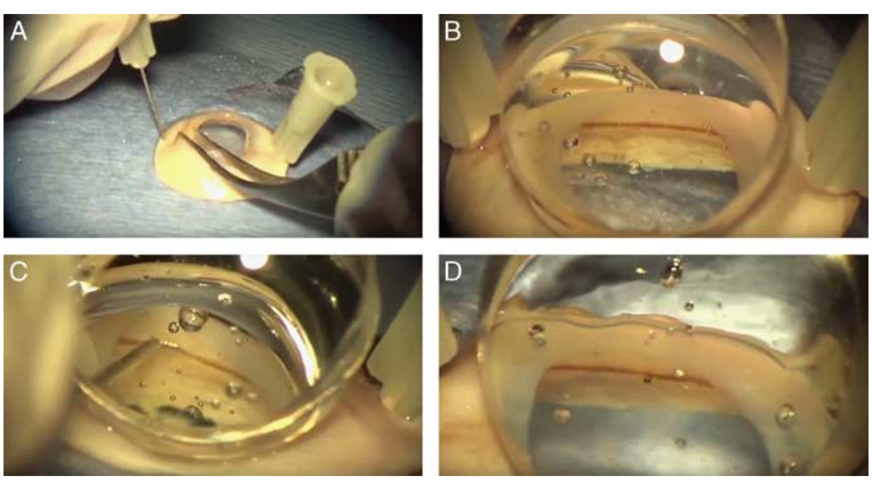


**FIGURE 1.** K-RIM model with iStent insertion. A, Two pins are placed opposing each other on the scleral portion of the cadaveric tissue with enough space to allow insertion of surgical tools and goniolens. B, Gonioscopy view using goniolens to visualize the trabecular meshwork (brown line) superficial to Schlemm Canal. C, Gonioscopy view with surgeon in progress of inserting iStent into the trabecular meshwork. D, Gonioscopy view after insertion of iStent into the trabecular meshwork. Figure 1 can be viewed in color online at www.glaucomajournal.com.

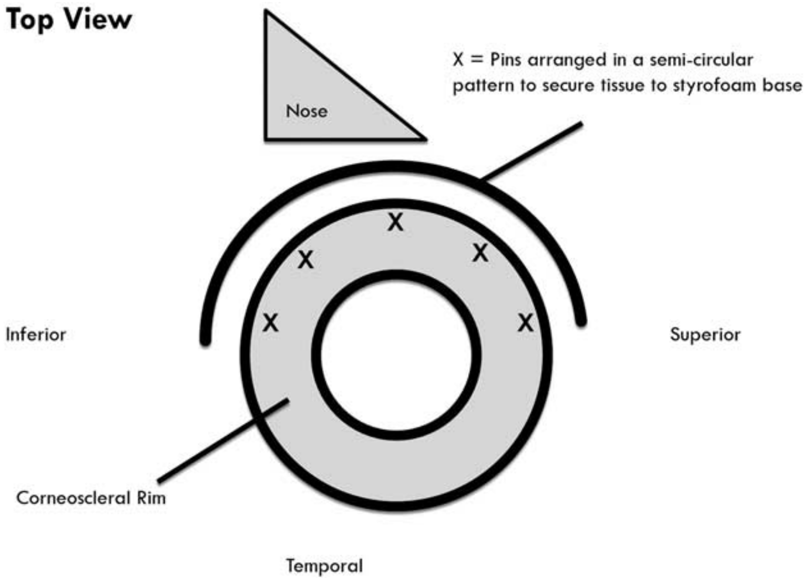


**FIGURE 2.** Schematic of K-RIM model set-up. Five pins are arranged in a semicircular perimeter along the nasal aspect. Pins are inserted perpendicular to the tissue into the perimeter of the corneoscleral rim to ensure tissue is secured to the Styrofoam base.

Qualitative data from the surgeons comparing the K-RIM model to the artificial eye is in Table 1.

## DISCUSSION

The technically demanding nature of MIGS and steep learning curve requires advancements in the quality of currently available angle surgery training models. Accurate tissue simulation is critical for developing skills necessary to perform these surgeries. The corneoscleral rim provides an effective and accurate simulation for angle surgery training. The tissue characteristics of the model replicates tactile feedback provided under surgical conditions and will provide a way for surgeons to gain proficiency in utilizing intraoperative gonioscopy. Further benefits to our model are ease of preparation and excellent visualization of angle anatomy with additional advantage of allowing training via bimanual technique. Low-cost rims may be used multiple times providing an efficient cost-effective model for practicing angle surgery in high volume with excellent clarity allowing exercise of various angle surgeries.

One group has previously described an angle surgery model for trabectome that involves trephinating whole cadaver eyes and gluing on rigid gas permeable (RGP) contact lenses.[13] The approach merits the bimanual technique requiring a gonio lens and a clear optical interface to visualize angle structures, and similarly uses cadaver eyes which offer the most realistic tactile feedback.[14] The disadvantages are time required to glue RGP lens on the globe and securing a supply of RGP lenses.

Other MIGS simulation models that have been reported in literature include virtual reality, inanimate, and animals. Interestingly, virtual reality models are among the most extensively studied albeit the lack of tactile feedback and questionable validity of nonphysical conditions. A proposed method of evaluation had assessed 118 eligible studies for validity of training models.[5] Interestingly, none of the trials fit their model of validity; a thought echoed in other studies.[5,10,14] Attempts have been made to enhance current training models including the recent porcine eye quantitative canalography and EyeSi models.[9,15] Developing a standardized quantifiable evidence-based medicine validity assessment tool for training models is highly favored and an innovative avenue of further investigation. Multiple noncadaveric model variations stress tactile feedback similarities, angle visualization, and resource availability as potential advantages, but only human eye preparations can truly mimic in vivo conditions with high accuracy.

There are limitations with our model. Because of the open sky technique with the OVD lens, one does not experience corneal striae, which happens in vivo from excessive pressure from the gonioprism. It is important to mentally remind trainees to use as little pressure on the gonioprism as possible when using this model. Furthermore, as all

**TABLE 1.** Qualitative Survey Response by Surgeons Comparing K-RIM and SimulEYE KDB Training Models

| | K-RIM | SimulEYE KDB |
|---|---|---|
| Ease of preparation | Good | Excellent |
| Angle visualization | Excellent | Good |
| Bimanual ergonomics | Good | Excellent |
| Surgical ergonomics | Fair | Excellent |
| Tissue feedback | Excellent | Good |
| Cost | Potentially very cost effective if tissue is readily available | Moderate cost |

Measures include ease of preparation, angle visualization, bimanual ergonomics, surgical ergonomics, tissue feedback, and cost.

instruments access the angle via the open-sky and not through true incision, our model does not replicate aspects of surgical egonomics such as oar-locking the instruments in the wounds or the management of wound burping issues. In comparison, the artificial eye evaluated has a closed system with a cornea that produces striae with excessive gonioprism pressure and is thus more useful as a training aid for intraoperative gonioscopy. Furthermore, the trainee makes incisions in the artificial eye model that better replicate the subtleties of surgical ergonomics such as instrument oar-locking.

The emergence of a large variety of developing MIGS techniques and investigational devices has created the challenge of providing surgeons with realistic training models. The novel bimanual angle surgery training model presented here uses human cadaveric corneoscleral rims providing excellent visualization of angle structures and realistic surgical conditions. Despite a growing need for adequate angle surgery training models, there are few currently available which are sufficient for training in MIGS techniques. There is a need for a standardized quantifiable evidence-based medicine validity assessment tool for training models, and this will be an important area of future research.

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