Globe-fixation system for animal eye practice

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We designed a globe-fixation system for use with animal eyes for surgical skills training. The system core is a cup with an adjustable aperture. Vacuum is exerted through the cup to capture the globe at the preequatorial region. The cup rides over a hollow base, sliding on its opening spurs. A ballast is screwed to the end of the thread of the cup to create tactile feedback and create a tendency to return to the primary position. The system provides optimum versatility for the practice of anterior segment procedures, namely stability, rotation, a tendency to return to the primary position, globe pressure adjustability, and a modifiable orbit size.

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Online Video

The American Board of Ophthalmology has added surgical proficiency in the 6 core competencies mandated by the Accreditation Council for Graduate Medical Education for residency training and evaluation.[1,2] Laboratory training is indispensable to building and assessing surgical skills. This training includes a variety of approaches: animal practice eye models,[3–9] virtual reality simulators,[10–12] artificial practice eye models,[13,14] and computer-based learning.[15] Despite recent advances in virtual reality simulation and its prospects in facilitating surgical training and circumventing the need for wet labs, surgical skills acquisition and innovation are still highly dependent on animal practice with eye models as the closest approximation to real surgery.[16]

Animal eyes cannot be used in their own cranium for surgical skills training in wet labs, and when they are enucleated, they lose the required stability. Gross and primitive methods of fixation are too rigid or not stable enough to simulate real surgical experience. A variety of platforms with different terminologies have been introduced to impart stability: globe fixation system, artificial eye/ocular socket, hollowed-out eye socket, artificial orbit, dummy orbit, eye-support device, and eye-model container.[17–22] Several features, namely, stability, maneuverability, and pressure adjustability, have been variably incorporated into these systems. A transilluminated artificial orbit has also been devised for vitreoretinal ophthalmic procedures.[18] We present an artificial orbit with maneuverability and adjustability features.

SYSTEM DESIGN

The conventional scientific literature was searched through Medline and Google Scholar using the key words mentioned above (globe fixation system, artificial eye/ocular socket, hollowed-out eye socket, artificial orbit, dummy orbit, eye-support device, and eye-model container). The patent source, www.google.com/patents, was also searched.

Sheep eyes, as the readily available and optimal choice in this setting, were biometrically studied for

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Additional financial disclosure: The authors patented their invention in Patent and Company Registration Administration of Iran (#63896; March 2010) and are considering the transfer of its right to a third party.

Omid Bafkar provided input in the industrial design.

Video was presented at the XXVIII Congress of the European Society of Cataract and Refractive Surgeons, Paris, France, September 2010.

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gross estimation of the required dimensions (data reported elsewhere).

A list of needed features for a globe-fixation system was determined through in-depth observation during representative surgical procedures by 2 experienced ophthalmologists. The features were stability, maneuverability (moving or rotating), tendency to return to the primary position (and its adjustability), pressure adjustability, orbit size adjustability.

Dry Test

Based on the design, the primary prototype was developed and its performance was observed and evaluated (without the use of animal eyes).

Wet Test

The second prototype was used for 8 representative anterior segment procedures: microkeratome-assisted keratectomy (as in laser in situ keratomileusis), epithelial debridement (as in photorefractive keratectomy), intrastromal corneal ring segment implantation, capsulorhexis, phacoemulsification, anterior lamellar keratoplasty, posterior lamellar keratoplasty, and trabeculectomy.

Results

The system and its elements are illustrated in Figures 1 to 4. The fixation system worked well in the 8 procedures noted above performed by 2 ophthalmologists (M.J., S.F.M.) in 20 sheep eyes (supplied from the slaughterhouse). Minor refinements were incorporated into the final prototype.

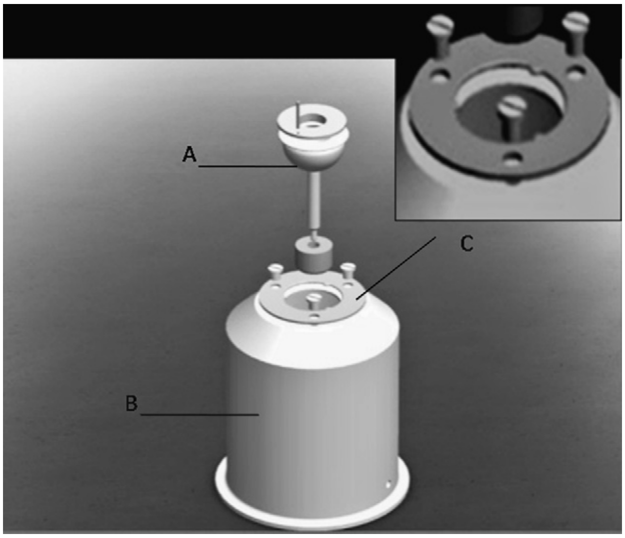

Figure 1. The globe-fixation system for ophthalmic surgery training. The device comprises a rustproof cup (*A*) mounted over a hollow base (*B*) constructed from powder-coated rustproof steel to play the role of the human skull. The inset shows details of the base opening, which has 3 trapezoid dentil-like projections inside (*C*) over which the cup slides or rotates.

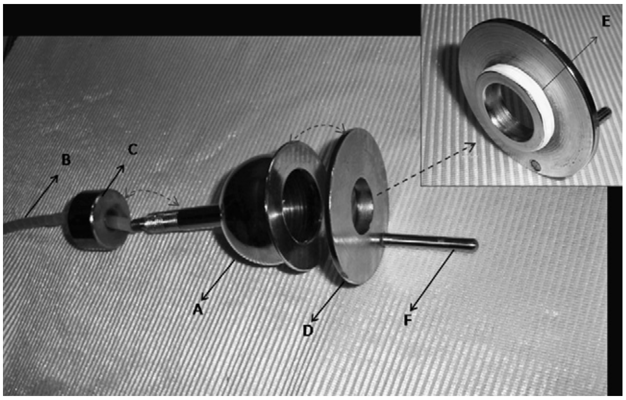

Figure 2. An expanded view of the animal eye-holder assembly. It shows the cup (*A*) and the thread for connection to a suction tube (*B*). Heavy ballast (*C*) is screwed to the thread so the cup tends to return to the primary position once slid away, mimicking real surgical experience. (The weight of the ballast is adjustable.) A size-adjustable aperture (*D*) is screwed into the cup, with a lining (*E*) to control air leakage. A small metal handle (*F*) is screwed into the aperture edge to enhance maneuverability. Available aperture diameters are 20, 23, and 25 mm, which are suitable for sheep, pig, and human eyes of different ages.

The video (available at http://jcrsjournal.org) shows the components and application of the final prototype for anterior segment procedures.

DISCUSSION

Globe fixation systems have different features.[23–25] Styrofoam heads are easy to use and not costly, but they do not provide sufficient stability. The Mandell eye mount[22] is a user-friendly low-cost system with no hand-positioning skill training. Otto's device[17] offers better stability and intraocular pressure adjustability and also features hand-positioning skills training. The Porrello et al. device[20] is complex and has multiple components: Plexiglass bulb holder, red reflector plate, and polyvinyl chloride base support. It also needs a long setup time. A dummy orbit[19] has been designed with the primary elements of an adjustable eye support for intraocular pressure regulation, a cylinder, and a removable ring for didactic purposes for training in direct and indirect ophthalmoscopy, laser applications, ultrasonography, and tonometry.

Stability is the crucial requirement for any globe-fixation system, but this creates a dilemma as it is normally associated with stiffness of the field of ophthalmic surgery, ie, the globe, which is not desirable. In our system, stability is achieved in 2 ways: background stability, which is provided by the heavy base, and static stability on the cup, which is achieved by the negative pressure exerted through the cup to the posterior pole of the globe by the vacuum pump. The cup rides over

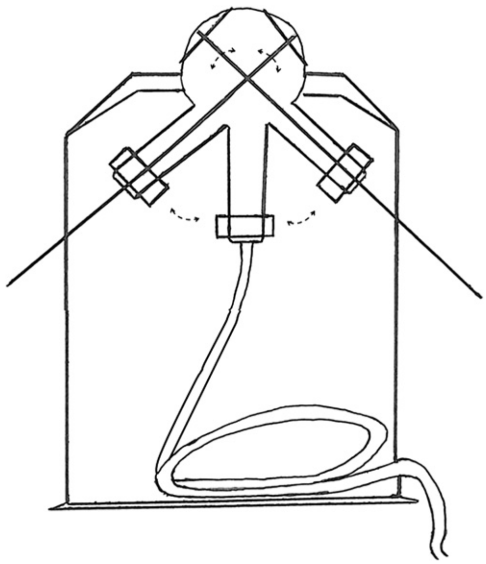

Figure 3. A schematic view that shows the maneuverability of the eye holder and the connection inside.

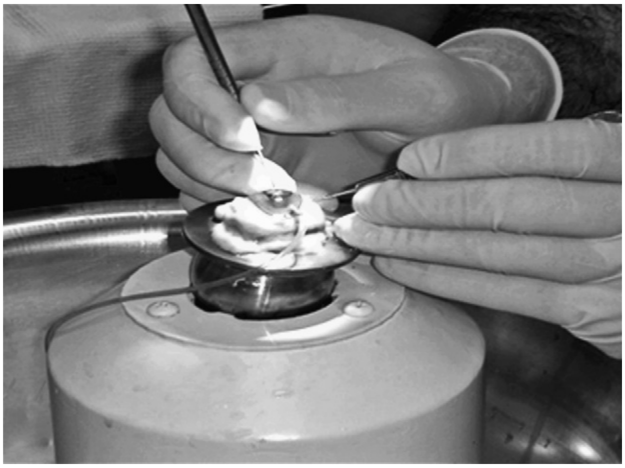

Figure 4. Surgical performance of the globe-fixation system on a mounted sheep eye. The upper portion of the base is designed to provide a convenient rest position for the surgeon's hands.

the cavity top, sliding on the dentil-like projections of the opening. This makes the eye maneuverable in 3-dimensional space and flexible to leave the primary position for another position, as is the case in real surgery. The heavy ballast creates a tendency to return to the primary position, which provides natural tactile feedback and a very reversal move; the automatic reversal to the primary position prepares the eye for the next surgical step. This is the ultimate state in simulating actual surgical experience and what we call "dynamic stability." Few systems combine these features.

Pressure adjustability has already been introduced[17] and is a feature of our system. This offers the ability to adjust the globe pressure for different procedures or different steps of a single procedure. It is achieved through the use of an automated vacuum that has pressure gradient valves and achieves a gross tactile range of 10 mm Hg to 50 mm Hg. A microkeratome pass, for instance, requires relatively high globe tension.

The adjustability feature was further enhanced: Through the installation of different weights to the thread of the cup, the tendency to return to the primary position can be modified. The other adjustability dimension is that different-sized globes can be mounted on the system from a variety of sources, for example, human cadaver or animal eyes of different ages and species, through variable-sized apertures. This is in contrast to current devices, which are mainly designed to accommodate human cadaver or pig eyes. Our system can also fixate sheep globes, which are the most readily available eyes in Central Asia and the Middle East. (There is no access to pig eyes on religious grounds.) The metal handle screwed onto the aperture edge increases maneuverability, similar to the action of traction or bridle sutures during ophthalmic procedures.

Because of things we learned during the design and development of the globe-fixation system, we made several major revisions. In the earlier designs, we intended to fixate the globe in the cup rather than over it. This meant the eye had to be fully inserted into the cup to leave only the anterior segment out of the cup. This had 2 limitations: It was not flexible for accommodating different globe sizes, and, more important, the vacuum hole was often obstructed by the periglobal tissue (Tenon capsule, optic nerve). Removing these elements from the globe is not practical; however, such tissue may act as a space filler and sealer in these settings, which is desirable. We resorted to mounting over rather than in the cup. This means the globe is captured at its preequatorial region around the aperture. This leaves a free space behind the globe and transforms the mechanism of negative pressure application from a focal one to a diffuse one and prevents the vacuum hole from being stuffed by the periglobal tissue. It also makes the system compliant to a wide range of globe sizes.

In the earlier designs, we used an O-ring around the aperture of the base for sliding the cup. In these versions, the vacuum was exerted diffusely in the hollow base and while it was being applied, it also pulled the cup down and adversely increased the friction around the O-ring. Later, we used 3 trapezoid spurs to facilitate sliding the cup over the base instead and directed the vacuum specifically through the thread of the cup.

Our system lacks a face form, which has a decorative value but, more important, has a role in mimicking other aspects of the ophthalmic surgical field; ie, natural obstacles of nose or (prominent) brow. This must be considered in future versions. The wrist-rest feature should also be considered and optimally should be designed along with the face form. The accompanying vacuum system of the platform is voluminous; a compact vacuum system might fit in the hollow cavity of the base. The current system may need enhancement and modification to enable it to simulate posterior segment procedures.

In conclusion, we recommend the use of this globe-fixation system as it provides the trainee or surgeon with the dynamism and versatility needed to practice anterior segment procedures; namely, stability, rotation, an adjustable tendency to return to the primary position, globe pressure adjustability, and a modifiable orbit size for various animal and human eyes of different ages.

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