Brief Communication

Versatile, low-cost ophthalmic wet lab device to improve diagnostic and surgical eye training

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ABSTRACT

Ophthalmologists rely on wet lab training for both diagnostic procedures and surgical techniques. Existing wet lab devices are limited to surgical training and lack functionality for performing required perioperative diagnostic examinations. This study aimed to develop an affordable, easily manufactured eye holder to enhance ophthalmology training for wet lab simulations. A three-dimensional (3D)-printed animal eye holder was designed in 3D with a funnel-shaped structure resembling an orbital eye socket. The design was optimized for optimal wet lab activities. The animal eye holder device demonstrated potential use for ultrasound biometry, handheld keratometry, tonometry, and ophthalmological surgical training. These activities can be performed effectively after the animals' eyes are stabilized inside the holder in flat and inclined positions. This innovative animal eye holder is the first designed to provide flexible diagnostic practice and surgical training, especially during wet lab activities.

KEYWORDS 3D printing, cataract, device, glaucoma, ophthalmologic surgical procedures

Cataracts are the leading cause of blindness worldwide, accounting for approximately 50% of all cases. Age-related cataracts, the most common type, typically develop over decades, with traumatic cataracts contributing to 12–46% of cases.[1–3] In Indonesia, the prevalence of blindness is 3.0%, with the highest rates observed in East Java (4.4%), West Nusa Tenggara (4.0%), and South Sumatra (3.4%).[4]

Training in examination procedures and the use of diagnostic tools is essential for medical and veterinary specializing in ophthalmology, especially ophthalmology residents who complete rotation in cataract and glaucoma divisions. The learning curve for diagnostic examinations and surgery, including the use of medical devices in wet laboratories, is steep.[5,6] However, ethical concerns restrict direct training on the human eyes, and existing multifunctional tools in the lab are limited to surgical practice in the horizontal position.[7,8] Versatile lab devices can accommodate both diagnostic and surgical training in various positions. This study aimed to develop and evaluate a cost-effective, three-dimensional (3D)-printed eye wet laboratory animal eye holder that securely holds animal eyes, particularly those of goats, whose ocular dimensions approximate those of humans.

METHODS

Study design and device development

This device development study involved the iterative design of a 3D-printed animal eye holder suitable for adult goat eyes. The device features a funnel shape holder designed as a truncated cone with different superior and inferior diameters, specifically dimensioned to accommodate adult goat eye. The holder was designed to remain stable in both horizontal and inclined positions.

The initial prototype was fabricated from the top of a plastic bottle, cut to approximately 4–5 cm from the opening. This transparent prototype allowed visualization of the upper and lower borders of the eyeballs during external length measurement. Following initial testing, a refined 3D design was created using AutoCAD software (Autodesk, Inc., USA). The final device was manufactured via 3D printing using polylactic acid filament with modifications to optimize its functionality for wet laboratory activities.

The eye holder has been used in primary research conducted in Indonesia entitled "Prediction model of eyeball length calculation in hypotony condition: measurement study using ultrasound biometry immersion technique and morphometry in goat eyes." The study was approved by the Ethics Committee of the Faculty of Medicine, Universitas Indonesia – Cipto Mangunkusumo Hospital (No: KET-358/UN2.F1/ETIK/PPM.00.02/2023). In addition, the device has been registered for intellectual property protection by the Ministry of Law and Human Rights of the Republic of Indonesia, with the intellectual property rights held by Mardianto, et al.

Animal tissue source

Goat eyes were obtained from animals slaughtered for commercial consumption and not specifically for experimental purposes, ensuring compliance with the 3R principles (replacement, reduction, and refinement) for the use of animals or animal-derived tissues in research. Following institutional guidelines, the eyes were protected with plastic covers during transportation to the research site.

Device components and specifications

The animal eye holder has four main parts: funnel, standing section, buffer, and base (Figure 1a–f). The funnel serves as the placement area and is designed to accommodate eyeballs similar to human eyes. A slot was incorporated to visualize the lower border of the eye during measurement. Additionally, a small hole allowed the insertion of strings to prevent eyeball displacement. The bottom of the funnel contains thread to allow rotation for microscope observation or height adjustment (Figure 1c).

The standing section consists of top and bottom parts with hexagonal sides featuring threaded holes for attaching funnel sections. The buffer allows for adjustment of height and angle. The base is a rectangular board with tooth-like slots on both sides for support. The tilt angle can be adjusted by positioning the buffer in different slots (Figure 1d–f).

Iterative design process

The initial plastic prototype was used to measure eyeball external length and intraocular pressure (IOP) using a Dino-Lite Digital AF3113T microscope (Dunwell Tech., Inc., USA) and I-Care PRO TA03 Tonometer (Icare USA, Inc., USA), maintaining a probe–cornea distance of 8 mm according to the manufacturer's guidelines. However, this prototype was prone to structural damage, and manual slope adjustment resulted in instability and inconsistent measurement angles.

The first 3D-printed prototype eliminated instability issues but had limitations: the funnel was too large, and the eyeball was not securely positioned. Observation slots and access holes were initially insufficient in size, limiting accurate identification of eyeball borders and restricting the insertion of needles for anterior chamber manipulation during IOP adjustment.

Subsequent modifications reduced the funnel diameter, enlarged the observation slots, and expanded access openings to improve visualization and procedural access. During ultrasound biometry, downward pressure applied to the device in a horizontal position caused forward tilting of the standing section (Figure 1d–f). To address this imbalance, additional mass was incorporated into the

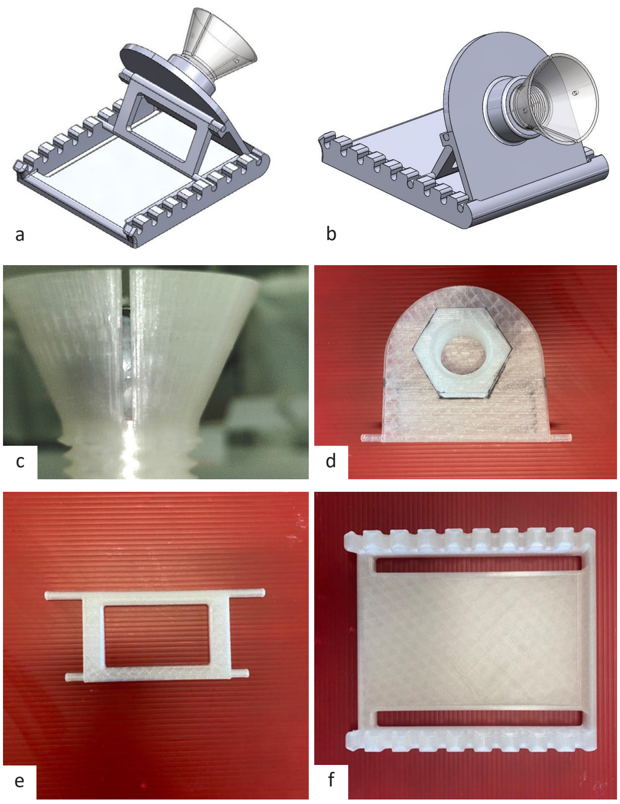

Figure 1. Initial design of the animal eye holder using three-dimensional (3D) printing. Assembled view of the animal eye holder, rear view (a) and front view (b); side view of the funnel (c); top view of the standing (d), buffer (e), and base part (f)

anterior portion of the standing section, improving stability during biometric and tonometric procedures. The final design demonstrated improved stability, visualization, and usability for wet laboratory training and measurement applications.

RESULTS

Final device development

A 3D-printed animal eye holder was successfully developed following iterative design modifications to improve stability, anatomical compatibility, and functional performance. The initial prototype made from the top of a plastic bottle helped position the eye, but had many limitations. It lacked durability, was unstable during procedures, and did not securely hold the eyeball in place, particularly when pressure was applied during the measurements. Therefore, we developed a 3D-printed animal eye holder to support ocular procedures using goat eyes in a wet laboratory setting. This device was specifically designed to replicate the contour of the orbital socket, allowing for secure positioning of the globe during various experimental manipulations.

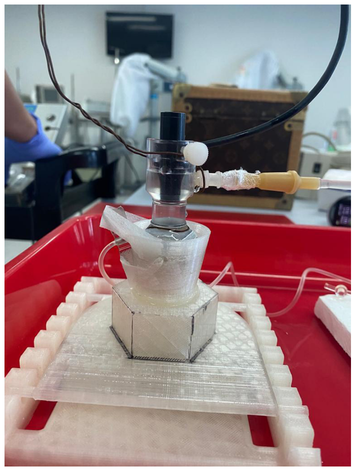

Figure 2. Ultrasound biometry measurement using an animal eye holder. It places the eyes accurately to get the appropriate biometry results

Compared with the initial plastic prototype, the improved design provided better eye stabilization, enhanced visibility of anatomical landmarks, and greater measurement consistency during IOP and ocular biometric assessments. Key design modifications included reducing the funnel diameter to better fit the globe, enlarging the lateral observation slots to facilitate procedural access and anatomical assessment, and reinforcing the base to improve balance during the procedures. These improvements have led to the development of reliable and practical tools for experimental and ophthalmic surgical training.

The applicability of the device was tested at two primary positions: horizontal and inclined. In the horizontal position, it has been successfully used for diagnostic examinations, such as ultrasound biometry (Figure 2) and handheld keratometry. When positioned at an incline of approximately 45–60°, the device facilitated accurate IOP measurements using an I-Care tonometer (Figure 3). Moreover, the eye holder proved valuable in supporting a range of surgical techniques including intracameral and intravitreal injections, corneal incisions for instrument access, corneal suturing, capsulorhexis training, and intraocular lens implantation (Figure 4). These results demonstrate the versatility and effectiveness of the device for both diagnostic and surgical training applications.

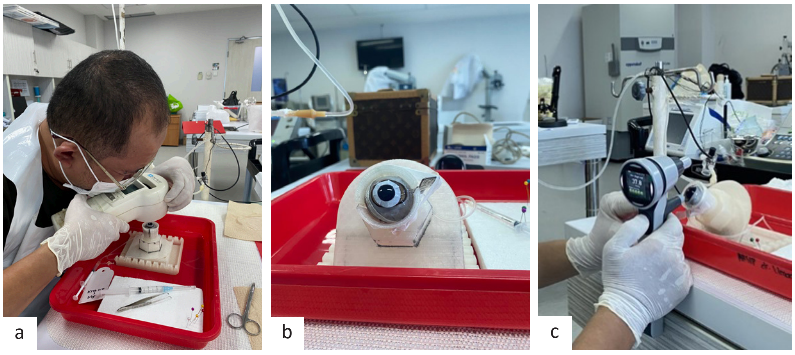

Figure 3. Keratometry and tonometry measurement using animal eye holder. (a) Application keratometry; (b) sclera imitation is made from paper and formed like a doughnut, the eye is stable inside the funnel with the help of a flat elastic band for sewing which is fixated at the outer surface of the funnel using 3M tape; (c) the eye position when we used I-Care tonometry was to mimic the semi-fowler position of the patient's eye

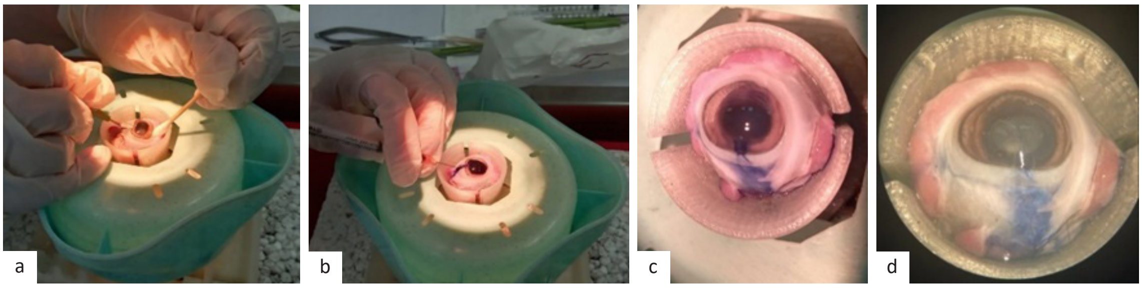

Figure 4. Surgical training using an animal eye holder. (a) The action of making the corneal main incision; (b) injecting the trypan blue stain; (c) anterior chamber filled with trypan blue; (d) complete capsulorhexis of the lens

DISCUSSION

The 3D printed animal eye holder has potential applications in diagnostic training, including portable tonometry (I-Care),[9] handheld keratometry,[10] ultrasound biometry (immersion),[11] and surgical training.[12] Its anatomical compatibility with goat eyes, which are similar in size and structure to the human eye, provides a realistic and stable simulation environment in both horizontal and inclined positions. This device offers several advantages, particularly for goat eyes, which provide a realistic surgical environment and are stable in both horizontal and oblique positions.[12] To ensure stability in the oblique position, a flat elastic band was placed on the scleral surface near the limbus and secured through two holes on both sides of the funnel. The band was affixed to the funnel wall using a 3M white tape, which is commonly used in medical settings.

During IOP measurement using I-Care, the holder must be tilted beyond 45° to prevent the probe from falling. Additionally, handheld keratometry examination was assisted using an imitation sclera made from doughnut-shaped material, with an inner diameter of 11 mm and paper thickness of 3 mm. The imitation sclera was made because keratometry measurements could not be performed directly on goat eyeballs because their non-spherical shape of the limbal structure differs from that of the human cornea, thereby preventing accurate keratometry measurements. This independent animal eye holder is suitable for eye surgery training,[11] including cataract surgery (creating corneal tunnels or anterior lens phacoemulsification),[13] corneal suturing,[10] and glaucoma surgery (creating scleral flaps and scleral tunnels).[14] To facilitate hand positioning during surgical training, an additional plastic doom was added around the eye holder, which was made using a commercial toilet tissue holder.

Various wet lab holding devices have been utilized over time. Conventional devices, such as the styrofoam head, are used for animal eye stabilization, but are less stable, especially during manipulation. A device named the i-STAND PLUS Eyeball Stand with Fixation Head (Madhu Instruments Pvt. Ltd., India) was developed for use in animal eye fixation. However, this device can only hold the eye horizontally.[15]

Our novel wet lab device demonstrates originality and potential impact. This device enhances the functionality of existing devices by training physicians to perform diagnostic examinations required prior to cataract surgery. The adjustable tilt position provides additional versatility. The device is designed to accommodate multiple orientations, with the oblique position suited for procedures such as tonometry and keratometry and the horizontal position optimized for biometry and surgical training. Its multifunctional design offers a distinct advantage by supporting the use of various ophthalmic diagnostic instruments, including I-care tonometers, handheld keratometers, and immersion-based ultrasound biometers.

Despite these advantages, the device requires further validation regarding its accuracy and reliability for use in live animals and in post-enucleation conditions. Additional studies are needed to assess its applicability to other commonly used animal models such as pigs and sheep. However, further research is required to confirm the validity and reliability of this method in different animal models.

This versatile animal eye holder was designed to support both diagnostic practice and surgical training, addressing the common challenges encountered in wet lab activities. It provides a comprehensive perspective for students to perform diagnostic evaluations and practice cataract surgery in a controlled wet lab setting. This device has great potential for use by veterinary students specializing in ophthalmology and general practitioners who undergo training to become ophthalmologists.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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