Self-made Vitreoretinal Surgical Simulator Using Silicone Mold

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Abstract

There is no consensus on an appropriate and sustainable practice method in vitreoretinal surgery. We found a self-made vitreoretinal surgical simulator using a silicone mold that can offer various operative maneuvers and can become a solution for such a problem. We obtained a spherical silicone mold, a mannequin head, and spray material on the net market and combined them with expired surgical instruments to complete the simulator. Simulated vitrectomy was performed by vitreoretinal experts, and the practicality was verified. They reviewed that the simulated eyeball had size and rigidity very similar to the eyeball and that the intraocular practice swing seemed to be useful for the prevention of complications. The silicone material's semitransparency and open-sky structure offered them plenty of visibility. The membrane simulated by spray glue provided them with an excellent peeling sensation. These findings suggested that this simulator is suitable for practicing the basic procedures of vitreoretinal surgery. The simple shape seems to have many possibilities, and further verification at many facilities is desirable.

Introduction

Eliminating complications in intraocular surgery is one of the dreams for ophthalmic surgeons. “Practice makes perfect” is an age-old idiom¹, and wet lab training using pig eyes is a common method for practicing cataract surgery. However, in vitreoretinal surgery, there is no consensus on an appropriate and sustainable surgical practice method in Japan². It is speculated that there are many countries under similar circumstances. Furthermore, the COVID-19 pandemic worldwide has restricted the use of numerous wet lab facilities, and thus, vitreoretinal surgery training has become more difficult³. As a result, such a complicated situation has emerged, which may cause some complications arising from unskilled surgeons to occur.

Practice methods for vitreoretinal surgery have been reported previously^{2, 4–12}. Virtual reality (VR) machines that enable various training surgical techniques are attractive simulators^{4–7}. Other surgical simulators that offer direct feelings using real surgical instruments also seemed useful^{2, 8–12}. However, as the demand for more sustainable simulated eye models surfaced, we explored simpler and more inexpensive surgical simulators.

The purpose of this report is to describe a self-made vitreoretinal surgical simulator that anyone can obtain anywhere, that is cost-effective and that has size and rigidity very similar to those of a real eyeball.

Results

Three surgeons were classified as vitreoretinal experts in our hospital, and their reviews of this surgical simulator using silicone molds were summarized as follows for each procedure. *Video 1* (Supplementary information 1) demonstrates the instance of how to use this simulator.

Sclerotomies (Fig. 1a)

First, along with a surgical procedure, they made 3 ports 3–4 mm from the simulated corneal limbs. Because they felt the rigidity of this material closely resembles that of a real eyeball, this practice could develop the sensation of inserting trocars toward the center of the eyeball and allow practice of the angled incision technique.

Core and peripheral vitrectomy (Fig. 1b)

They performed the movement of core vitrectomy, inducing posterior vitreous detachment and peripheral vitrectomy while being conscious not to unknowingly move or distort the simulated eyeball. Its open-sky structure made the experts feel the visibility was excellent. They felt a better surgical field with a combination of the wide viewing system. However, with only a surgical microscope, even with the naked eye, they could obtain enough visibility. There were some differences between this simulator and a real eyeball due to the lack of refractivity of the former, but it was sufficient and useful for practice. It is important for the prevention of intraoperative complications that moving a cutter and lighting up the intended part be performed via dexterous bimanual operations, while an appropriate distance from the retina is maintained. This simulator could contribute to such practice, which is essential for vitrectomy. This stroke training seems to facilitate the actual approach of all directions in the vitreous cavity while maintaining a good surgical field.

Vitreous base shaving and indentation (Fig. 1c)

They moved a cutter probe while indenting each quadrant of this spherical silicone mold using a chandelier lighting system (25G Vivid Chandelier, Synergetics Inc. St Charles, Missouri, USA). The material, which features semitransparency and moderate rigidity, was expected to help inexperienced surgeons learn a sense of coordinated movement of a cutter probe and a scleral depressor.

Membrane peeling (Fig. 1d)

Furthermore, the membrane made of spray material (Scotch Spray Glue 55, 3 M Japan Limited, Shinagawa-ku, Tokyo, Japan) was peeled off. This imitated biomembrane adapted to the silicone material's characteristics of being difficult to adhere to. They could use this spray by drying it for approximately 10–20 minutes and felt that it resembled the sticky epiretinal membrane (ERM) based on touch. This feeling was considered to bring about excitement and sense of the peeling maneuver to trainees who had not experienced vitreous surgery.

Wound closure (Fig. 1e)

Finally, they removed the cannulas and closed the wounds with surplus surgical sutures. The skill of smooth sutures should be practiced well since the self-seal of the wound may not be obtained even in minimally invasive vitreous surgery. Vitreoretinal experts judged that this practice would contribute to acquiring such skill, although the frictional resistance increased slightly compared with usual eyeballs.

Although *video 1* did not demonstrate this, if a lens (HHV DISPO, Hoya, Shinjuku-ku, Tokyo, Japan) was fitted into the simulated cornea to create a closed space and a gel-like substance was poured, a cutter probe and infusion system could be driven. This vitreous body resection using a foot pedal allowed them to feel more actual condition, but the use of the disposable pack appeared not sustainable due to its cost and effort.

Discussion

It can be said that ophthalmic surgical exercise using pig eyes is common but not casual enough, so such training may not be a sustainable practice. As a result, inexperienced trainees sometimes have to perform surgery on patients before their skills are well developed¹. Our simulator, using a spherical silicone mold, can become the solution to the abovementioned problem. This silicone material has not only a size similar to an eyeball but also moderate flexibility that closely resembles the sclera, and it can realize an ideal training environment. Moreover, its semitransparency and open-sky structure are suitable for observation from the intraocular side or from outside of the eye globe. Currently, most surgical instruments have become disposable and are discarded after a single use. However, in this simulator, the use of these instruments can help to create a surgical environment similar to that in such facilities. These characteristics allow for simulated surgery without having to travel to special facilities that offer plenty of pig eyes and vitreous surgical machines. Therefore, effective and sustainable surgical training in a distorted environment, such as the COVID-19 pandemic, may be realized.

Recently, the progress of surgical training appliances using VR, for example, EyeSi as a representative, has been remarkable^{1, 4–7, 13, 14}. However, EyeSi is extremely expensive and not generally used yet¹⁵. Other simulators from previous reports^{2, 8–12} have been fascinating for perceiving direct feedback. Some of them simulated surgery using eyeball models from marketing products^{8, 10}. These were high quality but also relatively expensive¹¹, while spherical silicone molds were able to obtain for approximately 2 dollars in the Japanese net market at the time of this experiment. In addition, these silicone molds seemed to be available for less than 10 dollars in the net market written in English, which suggests that anyone can casually purchase them in many countries. Rice et al. also reported a similar low-cost simulator that had an open-sky structure and that was crafted by a table tennis ball¹¹. This eye model had a 40-mm diameter, which seemed to differ in terms of size and rigidity compared to a real eyeball, while our spherical silicone mold had an approximately 25-mm inside diameter and moderate flexibility.

A challenging problem was how to reproduce extremely thin biomembranes, such as an inner limiting membrane of approximately 1–5 μm ¹⁶. We tried numerous kinds of tapes and paint materials. Unfortunately, silicone prevented them from adhering well, suggesting that they were not recommended for peeling. Nail polishing and adhesive for silicone material were thought to be sufficiently effective, but several hours were needed for drying. To overcome these disadvantages, several spray materials were verified, referring to past reports^{10, 11}. Consequently, Scotch Spray Glue 55 was chosen due to the

advantages that it was easy to make it thin and that its drying time took only approximately 10–20 minutes. The touch to peel this material was like sticky ERM. Other unknown ingredients with the potential to produce an excellent membrane have not been sufficiently examined; thus, further studies on membrane materials are necessary.

This simple shape may bring about further creative uses. For instance, we made the original assessment scale using our device in reference to previous reports^{17, 18} (Fig. 2). We intend to launch this evaluation for trainees, and safer vitreoretinal surgery would be expected. If enthusiastic surgeons do not have surgical instruments or mannequins, they can perform borderless self-training by substituting wires and a plastic bottle cap (Fig. 3). It may be used for surgical discussions in academia. Many other possibilities are expected depending on the user's objective and individual intellectual contributions.

This simulator has obvious limitations, such as the absence of cornea, lens, and vitreous body. In fact, it does not correspond to all vitreoretinal surgical maneuvers. However, almost all of our hospital's vitreous experts and ophthalmological residents were impressed by its quality. Overall, it may be said that this is a novel self-made vitreoretinal surgical simulator due to the abovementioned reputation and usefulness. Further investigation in many other facilities will be needed, but we hope that this report will help young vitreous surgeons and patients worldwide.

Methods

One of the most important structures in this simulator is the spherical silicone mold (found through searching for it using the terms "Sphere" and "Silicone Mold" in various net markets), making it an ocular substitute. It is generally used as a tool to make accessories by pouring resin into the mold. The size and shape of this material vary, and the material we used had an 8-mm hole on the top and a semitransparent spherical form, with inner and outer diameters of 25 mm and 27 mm, respectively (Fig. 4). The thickness is approximately 1 mm close to the posterior pole of the sclera. The silicone mold is a flexible material that can be easily cut with scissors; we enlarged the hole by several mm and brought it close to the corneal diameter.

We added sterilized or expired disposable vitreous surgical instruments that were used in the facility to this substitute eyeball. In our hospital, we used vitreous forceps (25G Grieshaber Advanced DSP Tips ILM Forceps, Alcon Laboratories Inc., Fort Worth, TX, USA), cutter and light guide probes (25G Constellation Vision System, Alcon Laboratories Inc., Fort Worth, TX, USA), and so on. Furthermore, after pinning the spherical silicone mold on the optic nerve of the mannequin head, whose orbit was already dug, a very precise human eye model could be constructed (Fig. 5).

The intraocular membrane was mimicked by Scotch Spray Glue 55 as our very thin material. The spherical silicone mold was reversed and lightly sprayed on the bottom.

In terms of the observation system, we used a combination of a surgical microscope (OPMI Lumera 700, Carl Zeiss Meditec, Oberkochen, Germany) and a wide viewing system (Resight, Carl Zeiss Meditec,

Oberkochen, Germany).

Vitreoretinal experts reviewed the usability of this simulator. Surgeons who had performed a minimum of 30 vitrectomies for rhegmatogenous retinal detachment and 30 scleral buckling and who subsequently had continuous surgical practice as vitreoretinal consultants were classified as vitreoretinal experts¹⁹.

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: All authors read and approved for publication of this manuscript.

Availability of data and materials: The data that support the findings of this study are available from the corresponding author, T.N., upon reasonable request.

Competing interests: The authors have no conflicts of interest to declare that they are relevant to the content of this article.

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Authors' contributions: T.N. conceptualized and drafted the manuscript as a major contributor. H.K. was involved in reviewing this simulator and revised the paper for intellectual content. M.K. and K.S. supervised this report and were involved in reviewing this simulator. All authors read and approved the final manuscript.

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Figures

Figure 1

Simulated vitreoretinal surgery using our simulator. a Sclerotomies. b Vitrectomy. c Vitreous base shaving under indentation. d Membrane peeling. e Wound closure.

Assessment scale for operative maneuver

1. Sclerotomies and Infusion line placement					
	1	2	3	4	5
2. Core and Peripheral vitrectomy					
	1	2	3	4	5
3. Vitreous base shaving and indentation					
	1	2	3	4	5
4. Membrane peeling					
	1	2	3	4	5
5. Wound closure					
	1	2	3	4	5

<Point to be noted>

Evaluate the 1-5 score based on the following point.

Respect for tissues

- ✓ Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments: 0
- ✓ Consistently handled tissues appropriately with minimal damage: 1

Keeping surgeon's view

- ✓ Often performed the surgery in inappropriate microscope driving or with too close or far lighting system: 0
- ✓ Always keeping areas of surgery in good focus and illumination: 1

Accurate instrument handling

- ✓ Many unnecessary or repetitive movements: 0
- ✓ Exact movements of instruments with no and repeated motion.: 1

Smooth instrument handling

- ✓ Frequently stopped operating or performed awkward moves: 0
- ✓ Fluent moves of instruments with no awkwardness: 1

Knowledge of procedure

- ✓ Deficient knowledge. Did not know what to do at the steps: 0
- ✓ Demonstrated familiarity with all aspects of the operation: 1

Figure 2

The draft of assessment scale. We intend to evaluate each maneuver carried out by the residents with this assessment scale before vitreous surgical introduction.

Figure 3

Our simulator without surgical instruments. Our simulator enables enthusiastic surgeons to perform borderless self-training without any surgical instruments.

Figure 4

The spherical silicone mold. We used a spherical silicone mold that had an 8-mm hole at the top and a semitransparent spherical form with inner and outer diameters of 25 mm and 27 mm, respectively.

Figure 5

Overviews of our simulator. a Photo while using the simulator. b Side view. c Front view.

Supplementary Files

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