Low-tech intraocular ophthalmic microsurgery simulation: A low-cost model for home use

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In order to maintain manual dexterity and surgical skills, trainees are encouraged to partake in regular simulation. Current options for intraocular surgical simulation require specialist microscopic equipment which is expensive and requires access to simulation facilities. A set of core simulation exercises and basic surgical skills of performing the corneal incisions, capsulorhexis, improving the manual dexterity, and suturing were identified, discussed, and agreed among authors before designing this simulation exercise. In this paper, we propose a smartphone-based, low-cost, low-tech model with corresponding exercises for intraocular simulation that can be used at home for the above-mentioned surgical skill set. This model provides an easy, portable, and reproducible method of simulation and can serve as an adjunct to patient-facing surgical training, especially in the current pandemic, where the excess to the simulation facilities or setup of these facilities may be difficult.

Key words: Capsulorhexis, COVID-19, iris surgery, penetrating keratoplasty, simulation, surgical training

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Microsurgical simulation techniques are valuable to the development of ophthalmic surgical trainees and mandated by many training institutions such as the Royal College of Ophthalmologists training curriculum[1] for multiple subspecialties. Currently, simulation practice is made possible either by attending designated Dry or Wetlab courses or by obtaining access to facilities housing simulation equipment. Microsurgical simulation is normally reliant on using specialist equipment with an operating or portable microscope or alternatively by utilizing virtual-reality simulators such as EyeSi.[2] These simulation options are thus not only location specific, but also time and resource intensive associated with high costs. In a recent survey, up to 53.1% of ophthalmology residents and 34.4% of fellows admitted being unable to perform cataract surgery during the pandemic due to a lack of simulation-training facilities in their hospitals.[3] Such factors form barriers to accessing regular, effective simulation practice.

Moreover, ophthalmic surgical training has been gravely affected by the Coronavirus (COVID-19) disease pandemic. Ongoing social distancing measures and reduction in clinical activity has had a knock-on effect on face-to-face surgical training sessions, and significantly reduced elective surgery has minimized training opportunities in routine surgery.[4]

In a world governed by increasing social distancing, limited financial resources, and significant cultural shifts toward education and training, we propose regular use of this simulation model as an adjunct to surgical training. In this paper, we propose a low-tech, smartphone-based simulation setup that allows low-cost, reproducible, and realistic intraocular microsurgical simulation at home.

Surgical Technique

In place of a microscope, we used a smartphone (iPhone X with iOS 13.5.1, Apple, USA) balanced on a stand of books (height 10.5 cm) such that the smartphone camera was overhanging the books and looking down at a work surface [Fig. 1]. The smartphone camera was used in Video mode with × 2 zoom and phone torch illumination as required dependent on room lighting. A set of core simulation exercises necessary for a junior trainee were discussed and agreed among

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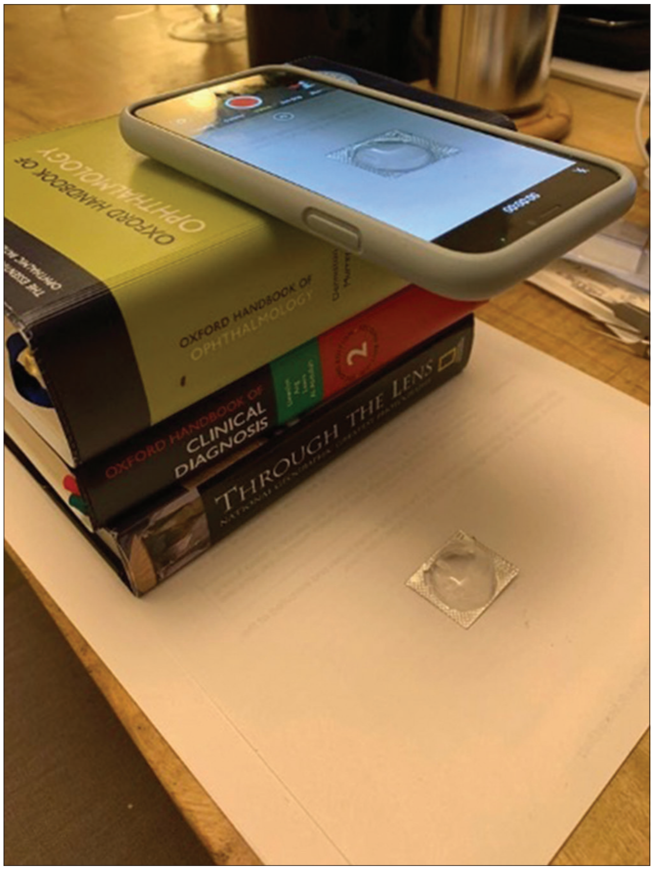

Figure 1: Low-tech intraocular ophthalmic microsurgery simulation (LTIOMS) setup—iPhone is stacked on 3 books (10.5 cm) and balanced over the edge. This ensures the camera is facing vertically down at the simulated surgical field. Access windows are made in the side of lozenge packet which is secured using BlueTac®. Camera is used on video mode and viewing is done on the phone screen interface

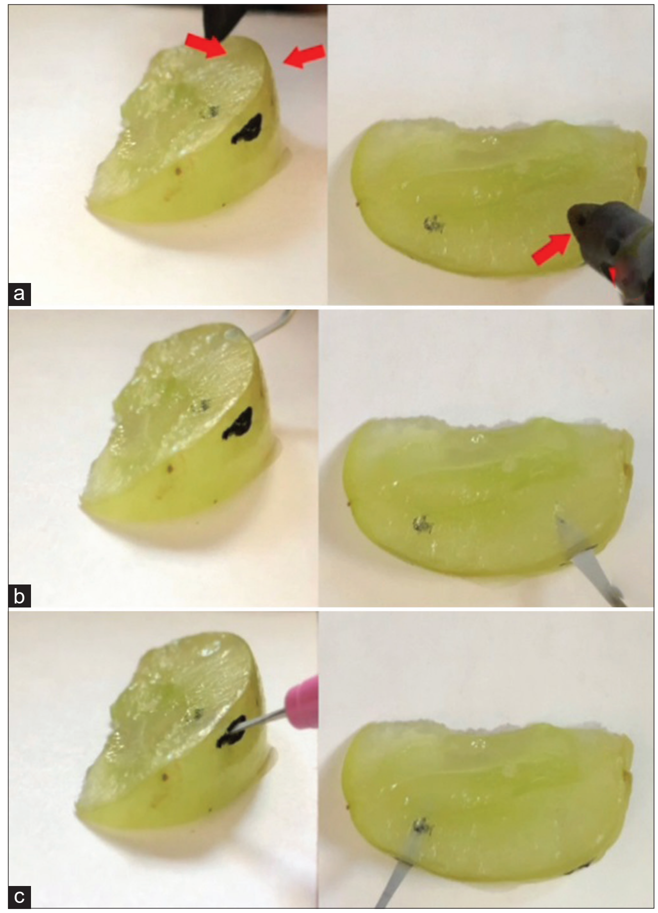

Figure 2: Profile view is shown on the left-hand side showing the skin of the grape and surgeon's co-axial view from the smartphone is shown on the right-hand side focusing on the stroma of the grape. (a) Incision marking on the skin of the grape to left and marking in the stroma of the grape to the right. (b) Keratome incision being made. (c) Incision being made with 15-degree blade

authors before the start of this study. Four important and basic skills of performing the corneal incisions, capsulorhexis, improving manual dexterity, and suturing were identified. For each of these skills, a set of home equipment needed, setup, and the exercise were developed using validated techniques[5] and discussed and agreed among all authors. Core simulation exercises, with corresponding equipment and setup, are described individually below.

Corneal incisions

Equipment needed: Grape, Super glue (Cyanoacrylate, Loctite®, Ohio, USA), cardboard/disposable work surface, marker pen, keratome (2.4 mm), 15° incision blade.

Setup and simulation: 1) Cut a wedge of grape and secure to flat work surface such that the curved side is facing toward the surgeon [Video 1 and Fig. 2a-c]. 2) Draw markings for entry/exit points at proposed paracentesis and main incision sites [Video 1 and Fig. 2a]. 3) Use the keratome to make your main incision as guided by the markings [Video 1 and Fig. 2b]. 4) Use the 15° blade to make your paracentesis as guided by the markings [Video 1 and Fig. 2c].

Capsulorhexis simulation exercise

Equipment needed: Thin slice of boiled potato ~2 cm wide, small piece of cardboard work surface, ruler, marker pen, lozenge packets, small blade, Blu Tack® (putty like pressure sensitive adhesive, Bostik Ltd, Leicester, UK), cystotome on a 1 ml syringe, capsulorhexis forceps.

Setup and simulation: 1) Secure the thin slice of boiled potato to a flat work surface [Video 2 and Fig. 3a]. 2) Mark a 7–10 mm diameter circle [Video 2 and Fig. 3a]. 3) Using a blade, prepare a lozenge packet with incision ports; a main incision port 5 mm wide and full depth of the packet, and a paracentesis port 5 mm × 2 mm in size [Video 2]. 4) Secure the lozenge packet over the potato using Blu Tack® [Video 2 and Fig. 3b]. 5) Using a cystotome, create a simulated "capsular flap" [Video 2 and Fig. 3c]. 6) Using rhexis forceps, complete the simulated rhexis as guided by the circular markings [Video 2 and Fig. 3d].

Dexterity: Loop the hoops

Equipment needed: Paper drinking straw, suture, scissors, small piece of cardboard work surface, lozenge packets, small blade, Blu Tack®, forceps.

Setup and simulation: 1) Using a small blade, prepare your lozenge packet incision ports; two ports 90°–120° apart measuring 5 mm wide × full height of lozenge packet [Video 3]. 2) Secure this lozenge packet to a flat work surface, such that the ports are aligned to your regular operating hand positioning.

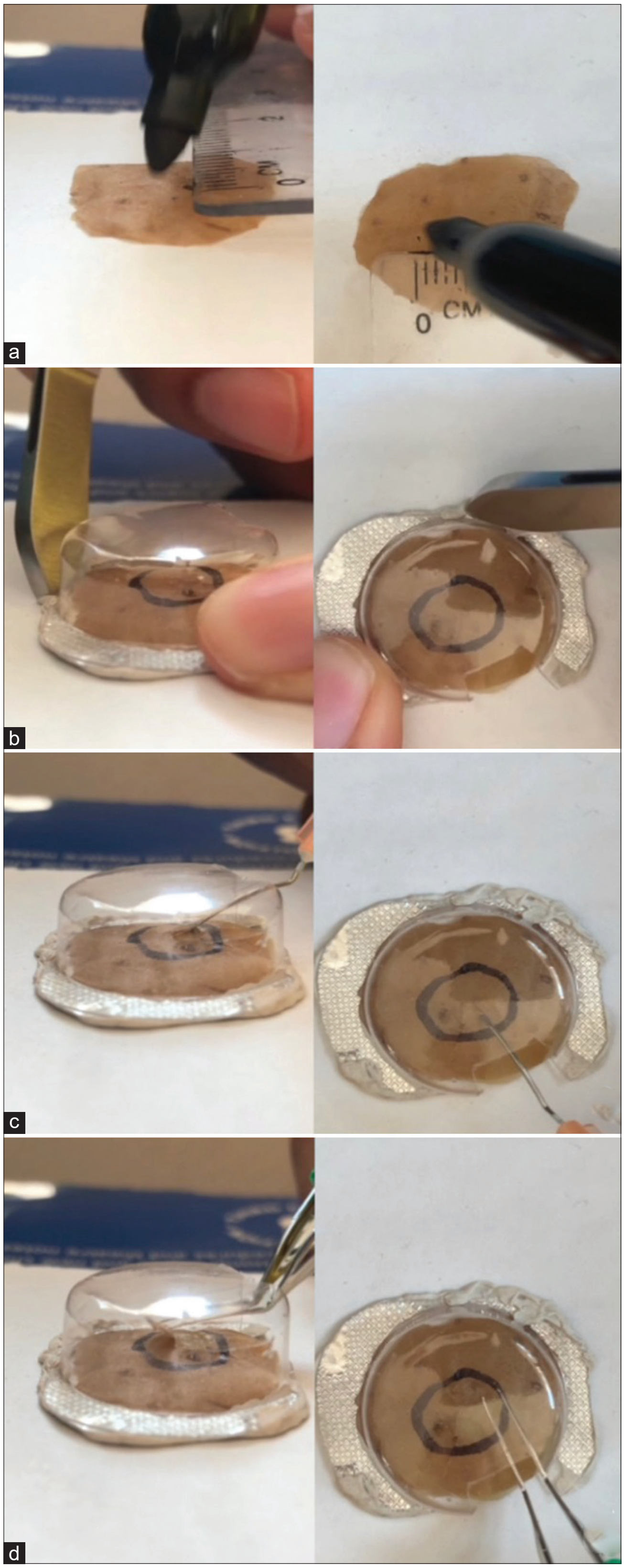

Figure 3: Profile view is shown on the left-hand side and surgeon's co-axial view from the smartphone is shown on the right-hand side. (a) Secure the thin slice of boiled potato to a flat work surface and mark a 7–10 mm diameter circle. (b) Secure the lozenge packet over the potato using Blu Tack®. (c) Using a cystotome, create a simulated "capsular flap." (d) Using rhexis forceps, complete the simulated rhexis as guided by the circular markings

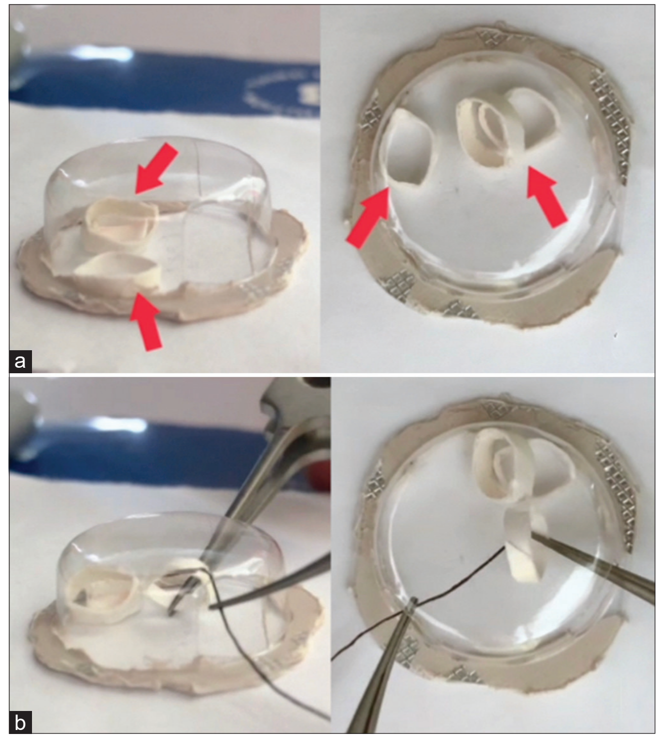

Figure 4: Profile view is shown on the left-hand side and surgeon's co-axial view from the smartphone is shown on the right-hand side. (a) Three cross-sections "hoops" of a drinking straw placed inside the chamber. (b) Threading the hoops onto the thread using forceps and a suture

This is your simulated anterior chamber [Video 3]. 3) Using scissors, cut three cross-sections "hoops" of a drinking straw and place inside chamber [Video 3 and Fig. 4a]. 4) Using forceps and a suture, thread the hoops onto the thread. Repeat as required with both dominant and non-dominant hand [Video 3 and Fig. 4b].

Dexterity: Dot the cross

Equipment needed: Poppy seeds, marker pen, small piece of cardboard work surface, lozenge packets, small blade, Blu Tack®, forceps.

Setup and simulation: 1) Using a small blade, prepare your lozenge packet with a 5 mm wide × 10 mm height incision port on your non-dominant side [Video 4]. 2) Draw a 2 cm × 2 cm cross on a work surface [Video 4 and Fig. 5a, b]. 3) Secure the lozenge packet over the drawn cross. This is your simulated anterior chamber [Video 4 and Fig. 5a, b]. 4) Place 5 poppy seeds inside the chamber [Video 4 and Fig. 5a, b]. 5) Using your non-dominant hand and forceps, place the seeds on the edges of the cross. Repeat as required [Video 4 and Fig. 5a, b].

Suturing: Orange graft suturing

Equipment needed: Orange peel, marker pen, small blade, Blu Tack®, suture of choice, needle holders, forceps.

Setup and simulation: 1) Cut a 1 cm disc out of thin orange peel. This is the simulation corneal "graft." Retain the remaining peel as the "host" tissue [Video 5 and Fig. 6a]. 2) Flatten the remaining peel and secure to a flat work surface using Blu Tack® [Video 5 and Fig. 6a]. 3) Using your suture of choice, needle holders, and forceps, suture the "graft" to the

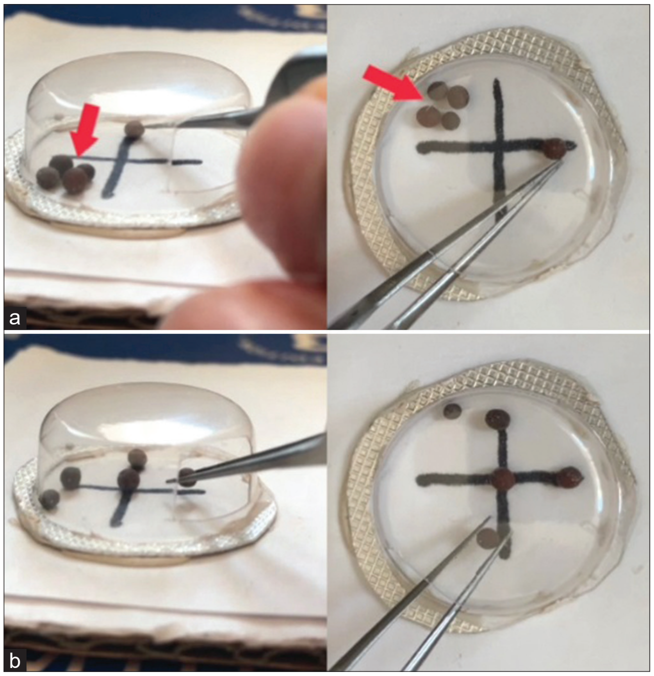

Figure 5: Profile view is shown on the left-hand side and surgeon's co-axial view from the smartphone is shown on the right-hand side. (a) Lift each poppy seed with a forceps in non-dominant hand. (b) Using your non-dominant hand and forceps, place the seeds on the edges of the cross

"host" in various clock hour directions [Video 5 and Fig. 6b]. Repeat with non-dominant hand for practice.

Discussion

Conventional surgical simulation training encompasses virtual reality, wet and dry lab as well as web-based modalities carried out primarily in a structured environment with trainer supervision that is often mandatory as part of a curriculum. Often, there is little or no follow on from these training sessions thus leading trainees to perceive simulation training as part of a "tick box" exercise in their competency attainment.[6] This leads to trainees having high expectations on acquiring hands-on surgical training experience by assuming it is superior to simulation training which is partly implicated in situations where there is a lack of a simulation training culture. Furthermore, the barriers to formal simulation training such as high cost of equipment and other resources, constraints on protected time, ease of access to simulation models, and trainee motivation also play a contributing role.[7] There are low-cost simulation models involving access to theaters and microscope[5] but there is a paucity of literature on low-cost simulation models which do not require access to theaters. Our study describes this low-cost intraocular simulation model which can be set up in any household without access to theater facilities and microscope.

Smartphones are increasingly being incorporated into clinical practice and notably in the field of Ophthalmology to perform a range of functions such as visual acuity assessment, imaging of anterior and posterior segment, and analysis of investigation results such as visual fields to name a few.[8] Techniques for viewing and learning from surgical videos in three-dimension (3D) have also been described; however, there is a lack of intraocular microsurgical skills' simulation

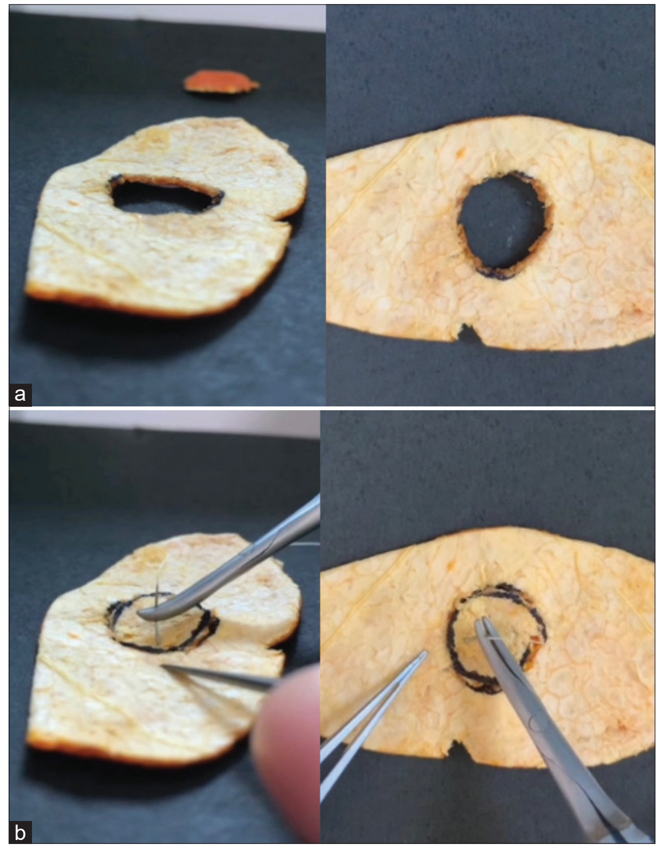

Figure 6: Profile view is shown on the left-hand side and surgeon's co-axial view from the smartphone is shown on the right-hand side. (a) Orange peel with 1 cm diameter hole secured on a flat surface. (b) Suturing of 1 mm diameter disc of orange peel inside the 1 mm hole in the orange peel

solutions for Ophthalmology training, especially for take-home practice.[9,10] The potential for using a smartphone for microsurgery training, albeit not in Ophthalmology, was first described in 2015 and since then several others have been published in the literature.[11] Two basic low-cost models with the former using a coffee cup and smartphone (CCS) and the latter using just a smartphone secured onto a table with an adaptor were able to demonstrate that not only did microsurgical skills improve using the smartphone simulation exercises but this was also translated to performance under the microscope.[12,13] Other smartphone microsurgery simulation models have utilized an additional gadget such as reflective prism glasses[14] and a laptop computer to facilitate the practice.[15] While these methods were able to improve visualization of the training exercises, they did require extra equipment which presents a barrier in setting up the home simulation in the first place. The disadvantages of smartphone use for home microsurgical training include the two-dimensional (2D) visualization and lack of magnification compared to a standard operating microscope. Nonetheless, a randomized controlled trial found that home microsurgical training using an iPad or jeweller's microscope produced similar outcomes in time for suture placement, anastomosis formation, and anastomosis leak rate compared with the use of a laboratory microscope.[16] Another study in minimal-access surgical simulation sought to determine the differences between unstructured (unsupervised and in a home environment) and structured learning among surgical residents. The data revealed that there was no significant difference between the two groups in skill acquisition and technical proficiency.[17]

We acknowledge that our model cannot replace simulation training models using microscopes, vegetables, and animal tissue with real instruments in a theater setting. Nonetheless, this model is designed to help surgeons who cannot access the above due to various reasons. There are a few limitations of our model. First, the hand-foot-eye coordination cannot be replicated in our model. However, we do feel it is an effective way to practice manual dexterity and hand/eye coordination, especially in a cost-effective manner using a smartphone and household materials. Second, our model cannot be directly compared with models using animal or human cadaveric tissue. There are many constraints of using animal and human cadaveric tissue. In the UK, animal and human cadaveric tissues have to be specifically requested, handled, stored, and discarded requiring special permission and licenses. The advantages of our model over animal/human cadaver eye training models include significantly easier setup thereby allowing frequent access and practice, low maintenance, and no requirement of formal approvals/licenses and the setup can be safely recreated in the home environment. Lastly, we acknowledge that the exercises in our model are not mimicking ophthalmic surgery steps. But the aim of our model is to provide a low-fidelity form of practicing manual dexterity for use in ophthalmic surgery when the access to well set surgical simulation suites is limited. We detail the 5 exercises and their correlation to ophthalmic surgery below.

1. Corneal incisions on grapes: Useful for cataract surgery incisions, and for access to anterior chamber for any anterior surgery
2. Capsulorhexis on potatoes: Directly correlates with capsulorhexis step of cataract surgery
3. "Loop the hoops": Emulates manipulation in a confined space, particularly passing sutures hand-to-hand, thereby testing manual dexterity
4. "Dot the cross": As above, emulates detailed manipulation in a confined space much like the anterior chamber
5. Suturing on orange peel: Suturing is naturally required for a variety of ophthalmic surgeries, and therefore this skill is a useful one to practice.

Conclusion

We believe by simplifying simulation training methods and enabling trainees to undertake it in the comforts of their own home or at the workplace office space, our intraocular microsurgery simulation model provides an easy, feasible, realistic, and practical option. Assuming most trainees have access to a smartphone that they already own, and basic disposable surgical instruments as described in our technique, our model does not require any additional expense, thereby minimizing cost and resource barriers. In addition, the smartphone use will enable the practice to be recorded and discussed with a trainer for feedback.

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Conflicts of interest

There are no conflicts of interest.

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