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Evaluation of Two-Dimensional (2D) versus Three-Dimensional (3D) Video Tutorials in Cataract Surgery for New Trainees

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Abstract

Purpose Microscopic ophthalmic surgery requires an understanding of three-dimensional (3D) spaces within the eye. Recently, there has been an increase in 3D video training tools in health care. Studies have evaluated the efficacy of 3D tutorials in general surgery, but little has been published within ophthalmology. We present a randomized study evaluating differences in surgically naïve trainees after watching either a 2D or 3D phacoemulsification tutorial.

Design This was a double-blind, randomized study. A group of third and fourth year medical students at our institution were randomized with stratified randomization based on prior surgical courses to control for differences in baseline surgical skill. The two study arms were watching 2D or 3D instructional videos on phacoemulsification (Richard Mackool).

Methods Participants received a preliminary survey and participated in an hour-long microscopic surgery session. During the session, participants performed tasks evaluating baseline microscopic spatial awareness and surgical skill. The students were then instructed to watch either a 2D or 3D video on phacoemulsification based on their randomized study arm. During the postintervention session, participants performed the biplanar incision and capsulorhexis steps of cataract surgery discussed in the video on model eyes. Students were evaluated on speed and overall capsulorhexis quality.

Results Thirty-one students qualified for the study and completed the microscopic surgery session. Students in both groups had similar baseline speed and quality of preintervention microscopic tasks ($p > 0.05$ for all tasks). Postintervention, students randomized to the 3D video performed significantly faster than the 2D group for biplanar incision (11.1 ± 5.5 s vs. 20.7 ± 10.5 s, $p = 0.001$). There were no statistically

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significant differences found between the groups in capsulorhexis timing ($p = 0.12$) or quality score ($p = 0.60$).
Conclusions 3D video surgical training tutorials may improve speed of certain steps of cataract surgery for surgically naïve ophthalmology trainees. Given the limited sample size of this study, further investigation of their effectiveness is warranted.

Learning cataract surgery is among the most fundamental yet challenging aspects of ophthalmology residency training. Over the past two decades, there has been a paradigm shift in resident surgical training from a sole focus on surgical volume to a more holistic, competency-based evaluation system with an emphasis on outcomes.[1,2] This change prompted investigation into how technology could be incorporated into resident surgical education.[3] To supplement traditional training in the operating room, a variety of educational technologies have been studied in ophthalmology programs, including videos, surgical simulations, microscopic recordings, wet labs, and even virtual reality (VR).[3–7] Given the difficulty of observing microscopic ophthalmic surgery in two-dimensional (2D) videos, three-dimensional (3D) video training has also been proposed.

The role and efficacy of 3D intraoperative technology has been widely reviewed and accepted, especially in urologic and gastrointestinal laparoscopic surgeries, where it has been shown to be to improve surgery performance.[8] More recently, it has been implemented in ophthalmic surgeries.[9] Microsurgery education has been traditionally limited by the necessity for teaching microscopes to provide adequate conceptualization of the procedure. An added benefit of the 3D technology in cataract surgeries has been the enhanced view for those watching the 3D screen in the operating room. Educational 3D videos of surgery can also be delivered outside the operating room via portable 3D headsets. Studies have shown that such 3D videos have value in teaching ophthalmic surgical concepts to medical students.[8,10] As a result, some have advocated for the use of 3D videos for resident surgical training, but the efficacy of 3D versus 2D video in teaching surgical techniques remains unclear.

Novel educational technology is often quite expensive for ophthalmology residency programs, and 3D headsets are no exception. In light of cost and limited relevant evidence, formal investigation into its efficacy is needed. The purpose of this study is to determine the value of 3D video tutorials in residency education with a randomized study evaluating the differences in performance of surgically naïve trainees after watching either a 2D or 3D phacoemulsification tutorial.

Methods

Medical students at our institution interested in pursuing a surgical specialty were randomized to watch specific steps of phacoemulsification and evaluated pre- and posttutorial on various microscopic surgical tasks. This study was approved by our institution's Institutional Review Board, and informed consent was obtained. All data collection was in conformity with county, federal, and state laws, and this study adhered to the tenets of the Declaration of Helsinki.

Participant Selection

A recruitment email was sent to all post-clerkship students (third and fourth year students) of the School of Medicine with inclusion criteria of students who were surgically naïve in microscopic surgery and specifically interested in surgical specialties. Each interested student completed a presurvey indicating the following: (1) time spent watching surgery under a microscope within the last 6 months, (2) time spent performing surgery under a microscope within the last 6 months, (3) self-perceived comfort with knot tying (scaled from 1 to 100), and (4) specific surgical courses taken in medical school. Participants were excluded if they had performed more than 5 minutes of microscopic surgery in the last 6 months.

Randomization

This study was a double-blind study. Participants were grouped based on a stratified randomization scheme with each stratification randomized based on a permuted block with block size of 2. Participants were stratified into two groups based upon surgical experience excluding the mandatory 2-month surgical clerkship. Those with 0 or 1 month of additional surgical courses were considered "beginners," and those with more than 1 month of additional surgical courses were considered "experienced." The 1-month cutoff was determined based on the lesser variability in surgical knot-tying confidence of those with more than 1 month of surgical experience. All participants were randomized prior to participation in the in-person surgical session.[11]

Surgical Session

The hour-long surgical session was divided into three sections, the preintervention, intervention, and postintervention sections. Surgical tasks were video-recorded to assist with evaluation.

Preintervention

The preintervention session was conducted to identify any baseline difference in surgical skill between the two groups. The session consisted of general tasks performed under ophthalmic microscopes (Carl Zeiss AG, Jena, Germany): sprinkle placement, grape suturing, uniplanar corneal incision on a model eye (Kitaro Dry Lab, Kitaro Eye, Nishinomiya, Japan), and touching anterior chamber landmarks on a model eye. These tasks were chosen to evaluate baseline levels of spatial awareness, hand coordination, and ability to complete simple tasks under the microscope. For sprinkle placement, students were asked to use their dominant hand to pick up the sprinkles from a small cup and put them in four locations marked on a foam platform at various elevations. They were evaluated on timing and number of dropped sprinkles. For grape suturing, students were asked to pass a suture between two marked dots and tie a single knot. They were graded on timing. For the model eye uniplanar corneal incision, students were asked to make a uniplanar incision using their dominant hand with a sideport blade as shown in a diagram provided to them. The incisions were evaluated on timing. For anterior chamber landmarks, students were asked to use a spatula to enter the anterior chamber through the previously made incision and touch four locations within the anterior chamber, removing the instrument after each location. They were evaluated on timing and accuracy.

Intervention

2D and 3D versions of a video (clipped between 1:40 to 5:12) from “Mackool Online Fundamentals Episode 1: Phaco Fundamentals” were set up in individual rooms located separately from the ophthalmic microscopes.[12] In the video, a cataract surgeon demonstrates a biplanar incision and a capsulorhexis. The 2D and 3D versions of the video only differed in their dimensional format and were otherwise identical. The 3D headsets used in the study were the Cinemizer 3D Glasses manufactured by a medical company (Carl Zeiss AG, Jena, Germany). Students were guided to specific rooms based upon their randomized group (2D or 3D phacoemulsification tutorial). The participants were not made aware that there was an alternative video tutorial that was different from their assigned format. Each participant was given two opportunities to watch the 3.5-minute clip of the video.

Postintervention

After watching the video, participants performed the same preintervention tasks followed by two additional postintervention tasks specific to the video: a biplanar incision and a complete capsulorhexis. The biplanar incision and the capsulorhexis were evaluated for timing. In addition, the quality of the capsulorhexis was evaluated by subjective grading by three individual ophthalmologists using a scoring system modified from a published grading model, which included instrument handling, flow of maneuver, setup for re-grasp, control of rhexis flap, and capsulorhexis size and position.[2] The time required to create the biplanar incision along with the time to create, and the overall quality of, the capsulorhexis were the primary outcomes of the study as these were the tasks that were covered in the video intervention.

Statistical Analysis

Nonparametric testing (Wilcoxon ranked sum or Pearson chi-squared testing) was performed using Stata software to determine statistical significance with alpha of 0.05 (StataCorp, College Station, TX). Nonparametric testing was used due to the small sample size and inability to assume normal distribution.

Results

Of 47 students who filled out the presurvey, 5 students were excluded for having spent more than 5 minutes performing surgery under the microscope. Of those remaining, 31 were available and participated in an in-person surgical session. Fifteen students were assigned to the 2D group, and 16 students were assigned to the 3D group. Among all study participants, the average number of elective surgical courses completed was 1.3 months, and the mean self-perceived confidence in knot tying (scaled from 0 to 100) was 59.8. There was no observed statistically significant difference in either months of additional surgical courses or knot-tying confidence between the 2D and 3D groups.

In the preintervention evaluation, there were no significant differences between the 2D and 3D groups on any of the six metrics evaluated: time of sprinkle placement, suture tying, uniplanar incision creation, and anterior chamber landmarks touched, as well as accuracy of sprinkle placement and anterior chamber landmarks (►**Table 1**).

In the postintervention evaluation, there was a significant difference in the average time to complete the biplanar incision between the 2D and 3D groups ($p = 0.0014$), as shown in ►**Table 2**. There was no significant difference in the average time to complete the capsulorhexis between the groups ($p = 0.12$). Finally, there was no significant difference in the cumulative ophthalmologist grading score of capsulorhexis quality, which was 12.1 ± 3.4 for the 2D group and 12.5 ± 3.6 for the 3D group ($p = 0.60$). ►**Fig. 1** shows boxplots of the three primary outcomes.

Table 1 Preintervention tasks

	2D group	3D group	*p*-Value
Sprinkle placement (s)	58.9 ± 26.2	61.2 ± 20.5	0.51
% of participants who dropped sprinkles	42.9%	53.3%	0.57
Microscopic suture tying (s)	30.6 ± 21.5	28.4 ± 16.7	0.99
Uniplanar incision creation (s)	12.0 ± 4.8	13.6 ± 10.1	0.91
Anterior chamber landmarks (s)	59.4 ± 24.4	47.1 ± 20.8	0.78
Degrees inaccurate in anterior chamber landmarks	16.2 ± 11.4	23.2 ± 25.1	0.34

Table 2 Postintervention tasks

	2D group	3D group	*p*-Value
Biplanar incision (s)	20.7 ± 10.5	11.1 ± 5.5	0.0014[a]
Capsulorhexis (s)	292.3 ± 113.2	228.9 ± 105.8	0.12
Cumulative capsulorhexis quality score (7–25)	12.1 ± 3.4	12.5 ± 3.6	0.60

[a]Statistically significant.

Discussion

In this study, we found that 3D video tutorials resulted in statistically significant reductions in time to complete the simple surgical task of biplanar incision in surgically naïve trainees compared to 2D video tutorials. There were no statistically significant differences in time to complete capsulorhexis or quality of capsulorhexis between the groups with this sample size.

Modern cataract surgery is an inherently 3D procedure that can be difficult to appreciate in 2D. As such, ophthalmic educators have been exploring ways to use novel technology to better educate ophthalmology trainees. Surgical simulation has been extensively investigated as a means to supplement training. Staropoli et al[13] found that the Eyesi surgical simulator (Haag-Streit Group, Koeniz, Switzerland) significantly reduced the cataract surgery complication rate of third-year residents. VR training has also been studied with promising results. Saleh et al[14] found that VR video training significantly improved resident skills in all parameters of cataract surgery, including capsulorhexis and antitremor training. Recently, technology enabling 3D educational videos such as 3D headsets has emerged, providing another potential way to deliver ophthalmic surgical education. However, research on 3D instruction in ophthalmology has been limited. Prinz et al[10] found 3D videos to be helpful for medical students in learning of cataract surgery concepts, but they did not study outcomes of surgical techniques. The only major study investigating 3D videos for ophthalmic surgical training was done by Chhaya et al[8] in their study investigating 3D versus 2D videos for teaching vitreoretinal surgery. The authors found that 3D videos may have value in teaching certain vitreoretinal surgeries such as tractional retinal detachment and four-point scleral fixation of an intraocular lens. Still, the literature lacks any previous formal investigation into the utility of 3D videos in cataract surgery.

In this study, the only primary outcome that was significantly different between the two groups was time to complete the biplanar incision. We hypothesize that the 3D video may have had a greater effect on that task than on the capsulorhexis since it occurs in different physical planes. Although we did not find statistically significant differences in capsulorhexis quality or timing, it is possible that a larger sample size would have led to different results for these more complex tasks, as the 3D group did do better on both of those outcomes. Therefore, this study is primarily limited by its small sample size of 31 trainees. In addition, though we measured the timing of the biplanar incisions, we were not able to grade their quality. It is possible that some of the incisions which were completed faster could have been lower quality. Furthermore, the participants in this study were medical students, many of whom were likely less familiar with ocular anatomy than ophthalmology residents learning cataract surgery. It is possible that differences between 2D and 3D interventions would be less significant for trainees more familiar with the 3D features of the eye. Finally, the study is limited by the abbreviated degree of the video intervention, which totaled just 7 minutes. A more comprehensive 3D intervention would result in a more robust study.

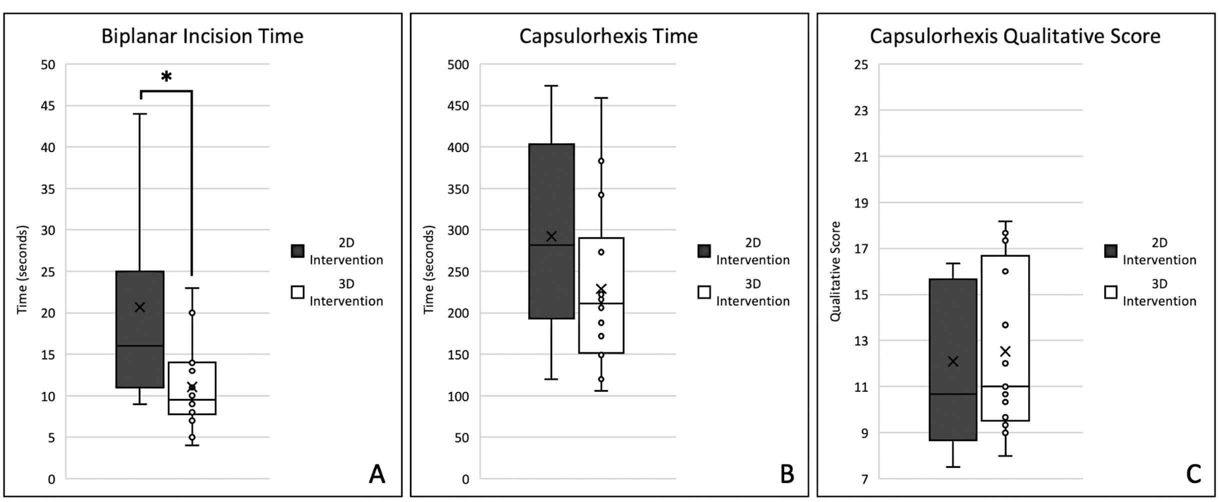

Fig. 1 Boxplots of postintervention primary outcomes. **(A)** Biplanar incision time. **(B)** Capsulorhexis time. **(C)** Capsulorhexis qualitative scores. $^{*}p < 0.05$.

Based on our results, future investigation is warranted into the utility of 3D technology in ophthalmic surgical training. In particular, future studies with a larger sample size and a more prolonged intervention would help clarify the possible advantages of 3D training. In addition, comparing the 3D headsets used in this study, which retail for $789, with other, more expensive 3D options such as the Eyesi simulator (Haag-Streit Group, Koeniz, Switzerland), which costs $100,000 to $200,000, could help guide ophthalmic educators in choosing the best options for their program.[15–18]

In conclusion, 3D technology shows promise as an educational tool in the setting of microsurgery in surgically naïve trainees. It may have a future role in cataract surgery training in formal residency education.

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Conflict of Interest
None declared.

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