

DATE 8/12/2020

JOB NAME JCRS

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Remote corneal suturing wet lab: microsurgical education during the COVID-19 pandemic



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Purpose: To study the feasibility and efficacy of a new remote wet lab for microsurgical education using a corneal suturing task.

Setting: Department of Ophthalmology, University of California San Francisco, San Francisco, California, USA.

Design: Prospective randomized controlled study.

Methods: Ten ophthalmology residents were stratified by post-graduate year and randomized to perform a corneal suturing task consisting of placing the 4 cardinal sutures for a penetrating keratoplasty in porcine eyes with or without remote ophthalmology attending feedback. Subsequently, both groups repeated the same task without remote feedback to test whether initial remote feedback affected subsequent performance. Finally, the group without feedback was crossed over to repeat the same corneal suturing task with remote feedback. The effectiveness of the remote wet lab was assessed subjectively by survey and objectively by grading each suture pass.

Results: Resident-reported comfort with corneal suturing improved significantly after the remote wet lab for all residents. Residents and attendings rated the remote wet lab as equally or more effective compared with previous in-person wet labs and overall effective in corneal suturing. Attendings rated the remote wet lab as effective in multiple domains of microsurgical education using a modified microsurgical global rating scale. Objective corneal suturing performance was similar for both groups.

Conclusions: The remote wet lab was feasible and effective for training ophthalmology residents in corneal suturing. This represents a new social distancing compliant platform for microsurgical education during the COVID-19 pandemic.

J Cataract Refract Surg 2020; ■:1–8 Copyright © 2020 Published by Wolters Kluwer on behalf of ASCRS and ESCRS

Online Video

The first confirmed case of COVID-19, caused by the new coronavirus SARS-CoV-2, in the United States was reported in Washington State on January 20, 2020. On March 11, the World Health Organization officially declared COVID-19 a pandemic, the first to be caused by a coronavirus.¹ By March 15, the Centers for Disease Control issued a recommendation to cancel community-wide mass gatherings of greater than 250 people and gatherings of greater than 10 people that serve high-risk populations, including physicians.² The next day, on March 16, the city and county of San Francisco, along with 5 other counties comprising the San Francisco Bay Area, became the first region in the United States to issue a shelter-in-place law, banning all nonessential activities and gatherings.

At that time, there were just under 5000 confirmed cases of COVID-19 in the United States. In the ensuing 2 months, the field of ophthalmology changed dramatically. On March 18, the American Academy of Ophthalmology issued a statement urging all ophthalmologists to immediately cease providing any nonurgent treatment.³ There were more than 1.5 million confirmed cases of COVID-19 in the United States as of May 20, 2020.

Because of COVID-19, elective surgeries, including most ophthalmic surgeries, had been cancelled or postponed to minimize potential exposure and to conserve personal protective equipment (PPE). Furthermore, operating room personnel had been limited to essential participants only. These factors led to, and might continue to lead to, a

Submitted: July 13, 2020 | Final revision submitted: July 29, 2020 | Accepted: July 30, 2020

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Supported in part by a Research to Prevent Blindness unrestricted grant to the University of California San Francisco, Department of Ophthalmology.

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significant reduction in ophthalmology resident case volume. In this setting, surgical education through microsurgical wet labs can help address a significant need. These surgical educational programs are present in 98% of ophthalmology residency programs and are known to reduce the rate of intraoperative complications in ophthalmology resident-performed microsurgery.^{4–6} However, because of COVID-19, all in-person academic activities, including structured in-person wet labs, had been cancelled or severely restricted. As such, there was a call for innovative solutions to maintain rigorous education of surgical residents, including ophthalmologists, while ensuring safety.⁷

In this prospective randomized controlled study from a single academic center, we studied the feasibility and efficacy of a low-cost, social distancing–compliant remote wet lab for resident microsurgical education during the COVID-19 pandemic using a corneal suturing task. We surveyed the participating residents and attendings for subjective feedback and investigated the effect of attending remote feedback on objective resident corneal suturing performance. To the authors' knowledge, this is the first report to evaluate a remote wet lab for ophthalmology residents.

METHODS

Subjects

This study was approved by the University of California San Francisco (UCSF) Institutional Review Board and adhered to the tenants of the Declaration of Helsinki. Ten residents and 3 anterior segment attendings were recruited from the UCSF Department of Ophthalmology. Exclusion criteria were used to protect individuals who were at higher risk for severe illness due to COVID-19 based on Centers for Disease Control guidelines.⁸ All residents were required to pass a daily health screen within 4 hours of entering the wet lab and to wear PPE consisting of a face mask and gloves, per UCSF institutional policy. To ensure sufficient social distancing, residents completed the remote wet lab one at a time. Attendings provided remote feedback from the safety of their homes or offices.

Remote Wet Lab Design

F1 Residents were randomized into 2 groups, remote(+) and remote(–), which were stratified by postgraduate year (**Figure 1, A**). This intervention scheme has been reported previously.⁹ The residents participated in a virtual lecture (Zoom Video Communications) reviewing proper corneal suturing technique and

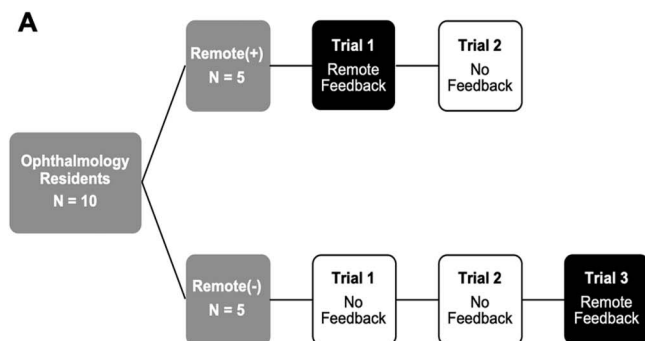
explaining the corneal suturing task, which consisted of passing the 4 cardinal sutures of a penetrating keratoplasty in porcine eyes using 10-0 nylon. Residents were also shown the corneal suturing grading rubric (**Figure 1, B**), which was modified from the Mayo Clinic corneal trauma curriculum to provide a maximum score of 6 per suture pass or 24 per trial.¹⁰ The residents were provided 5 minutes per suture pass and allowed 1 attempt per suture pass; they received a score of 0 of 6 for each broken or pulled through suture. All porcine eyes underwent full-thickness trephination (Barron Suction Trephine, Katena) performed by the same study investigator (Z.H.) immediately prior to each trial to provide consistency.

In the remote feedback trials, attendings provided live feedback using verbal communication, visual gestures, and a virtual whiteboard at any point during the corneal suturing task (Supplemental Digital Content, **Video 1**, available at <http://links.lww.com/JRS/A163>). In the trials without remote feedback, the entire corneal suturing task was performed using only the standard operating microscope (Carl Zeiss Meditec AG). Two or 3 consecutive trials were performed based on the randomization assignment. In trial 1, the remote(+) group had remote feedback, whereas the remote(–) group had no attending feedback. In trial 2, both groups had no feedback to test for persistence of effect from remote feedback in the remote(+) group. In trial 3, the remote(–) group was crossed over and given remote feedback to serve as an internal control to ensure that any observed differences between the groups in trials 1 and 2 were not due to confounding variables, such as innate surgical ability.

Residents completed a prewet- and postwet-lab survey to assess comfort with the various aspects of corneal suturing. In addition, both the residents and attendings completed a postwet-lab survey to assess the effectiveness of the various components of the remote wet lab. The attending survey included a modified global rating scale validated by Reznick et al. from University of Toronto, consisting of 5 generic components of operative performance and anchored by behavioral descriptors.^{11,12} A 5-point Likert scale was used for all appropriate survey questions.

Remote Wet-Lab Setup

The wet-lab setup consisted of a standard operating microscope with a laptop computer (Apple) on the surgical table to provide an external view of the resident's hand and body positioning, a smartphone (iPhone Xs Max, Apple) attached to the assistant ocular using a universal smartphone adapter (Gosky Optics) to provide a microscope view of the porcine eye, and a large external monitor connected to the laptop to provide a virtual whiteboard (**Figure 2, A**). For the attending home office, only a desktop computer was used (**Figure 2, B**). The laptop computer (external view), smartphone (microscope view), and desktop computer (attending view) cameras were video conferenced together using Zoom.



B

CRITERIA	POINTS
Suture Length (Graft) 0.8 – 1.2 mm	+1
Suture Length (Host) 0.8 – 1.2 mm	+1
Suture Depth (Graft) 66–99% depth	+1
Suture Depth (Host) 66–99% depth	+1
Suture Radiality <10 degrees from radial	+1
Suture Tension Taut with no wound mounding	+1

Figure 1. Remote wet-lab experimental design. **A:** Ten ophthalmology residents were stratified by postgraduate year and randomized to either the remote(+) or remote(–) group. The remote(+) group started with attending remote feedback, whereas the remote(–) group had no remote feedback (trial 1). Both groups repeated the same task without remote feedback (trial 2). The remote(–) group crossed over and

repeated the task with remote feedback (trial 3). **B:** Each suture pass was objectively graded using a rubric modified from the Mayo Clinic corneal trauma curriculum.

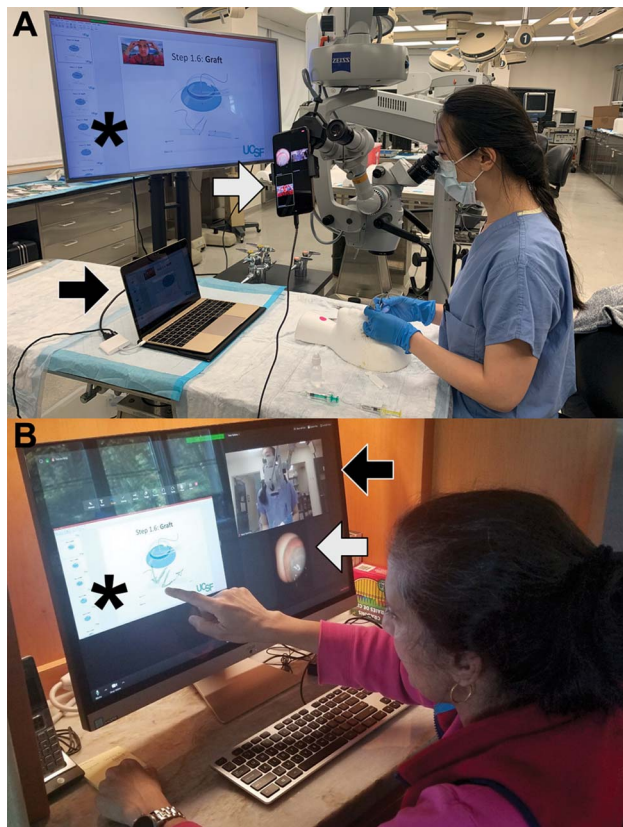


Figure 2. Remote wet-lab experimental setup. *A:* Resident wet-lab setup showing a single resident in full PPE operating at the surgical microscope with a laptop computer (black arrow) on the surgical table to provide an external view of the resident’s hand and body positioning, a smartphone (white arrow) connected to the assistant scope using a universal adapter to provide a microscope view of the porcine eye, and an external monitor (asterisk) to provide a virtual whiteboard. *B:* Attending home office setup showing an attending in front of a desktop computer displaying an external view of the resident (black arrow), microscope view of the porcine eye (white arrow), and interactive virtual whiteboard (asterisk). No PPE is required for the attending at home (PPE = personal protective equipment).

Data Analysis

At the conclusion of the remote wet lab, 2 masked graders scored each pig eye (representing a single trial) by consensus using the modified corneal suturing rubric (Figure 1, B). Suture length was measured to the nearest 0.1 mm using surgical calipers, and radiality was measured to the nearest degree using a protractor. For suture depth and tension, the measurements were based on consensus grader opinion. Depth was assessed by using forceps to evert the corneal tissue and view if the suture was between 66% and 99% thickness. Tension was assessed by placing forceps underneath the suture to determine whether the suture was taut and viewing whether the corneal wound edges were mounded.

F3 Each pig eye received a score out of 24 (Figure 3).

All data are expressed as mean ± standard error. Statistical comparisons within groups were made in paired fashion using Wilcoxon signed-rank tests, whereas statistical comparisons between groups were made in unpaired fashion using Wilcoxon rank-sum tests using R (R Core Team).

RESULTS

T1 Table 1 summarizes baseline resident characteristics for the remote(+) and remote(–) groups. A total of 10 UCSF

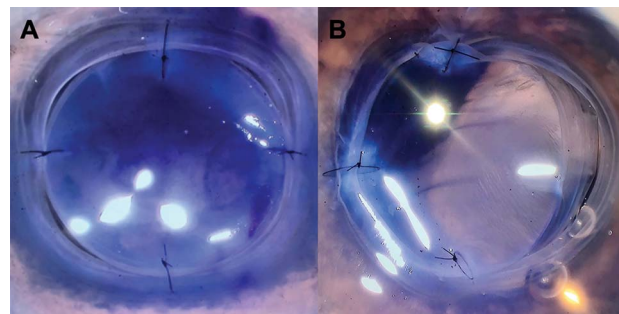


Figure 3. Representative porcine eyes after completion of the corneal suturing task. *A:* Outstanding corneal suturing score (22/24 or 92%) with all 4 cardinal sutures demonstrating suture length between 0.8 mm and 1.2 mm, radiality within 10 degrees, and appropriately taut tension. Only 2 points were deducted for sub-optimal suture depth. *B:* Poor corneal suturing score (8/24 or 33%) with only 3 of 4 cardinal sutures present because 1 suture was pulled through. The 3 sutures demonstrate inconsistent suture length, depth, radiality, and tension.

ophthalmology residents, 5 in each group, participated in the remote wet lab. Three participants were interns (postgraduate year 1). There were no statistically significant differences in age or previous operative or wet-lab experience between the remote(+) and remote (–) groups. The

Table 1. Baseline resident characteristics.

	Remote(+)	Remote(–)
	N = 5	N = 5
Level of training		
PGY-1	2	1
PGY-2	2	3
PGY-3	0	1
PGY-4	1	0
Age ± SEM, y	30 ± 1.4	31.4 ± 2.1
Sex, M/F	2/3	1/4
Race/ethnicity		
White	0	1
Black/African American	2	1
Asian	3	3
Structured wet labs		
0	2	1
1-3	2	3
4-10	1	1
Unstructured wet labs		
0	2	1
1-3	1	1
4-10	1	3
11-25	1	0
OR cases		
0	2	2
1-3	2	2
4-10	1	0
>25	0	1

OR = operating room; PGY = postgraduate year; remote(+) = trial 1 remote feedback, trial 2 no feedback; remote(–) = trial 1 no feedback, trial 2 no feedback, trial 3 remote feedback; SEM = standard error of the mean

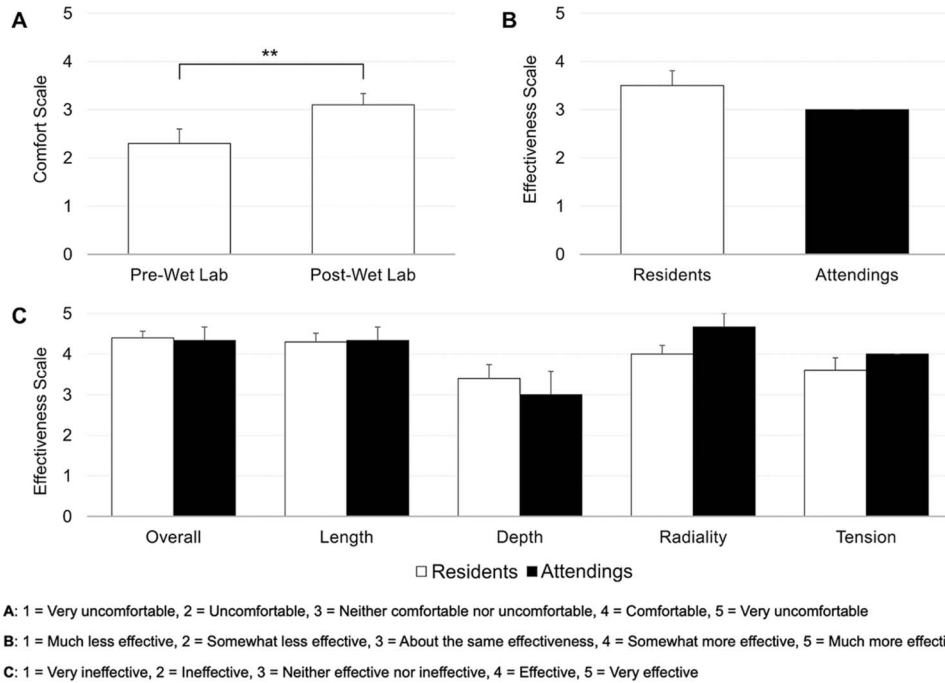


Figure 4. Subjective resident and attending results from Likert scale surveys. **A:** Resident overall comfort with corneal suturing before (2.3 ± 0.3) and after (3.1 ± 0.2) the remote wet lab significantly improved ($P = .002$). **B:** Both residents and attendings rated the remote wet lab as effective or more effective compared with previous in-person wet labs (3.5 ± 0.3 and 3 ± 0 , respectively). **C:** Overall, residents and attendings rated the remote wet lab highly effective for corneal suturing (4.4 ± 0.2 and 4.3 ± 0.3 , respectively). There was agreement between residents and attendings on the effectiveness of the remote wet lab for each component of corneal suturing, with the lowest scores for both groups on depth (3.4 ± 0.3 and 3.0 ± 0.6 , respectively).

3 anterior segment attendings who provided remote feedback each held a different faculty rank (assistant, associate, and full professor) and similarly had different previous in-person wet-lab instruction experience (1–3, 11–25, and >25 wet labs, respectively).

F4 **Figure 4** highlights resident and attending subjective feedback. Among all residents, regardless of intervention group, there was a statistically significant increase in resident comfort with corneal suturing after the remote wet lab ($P = .002$). Compared with previous in-person wet labs, the remote wet lab was rated at least as effective as previous in-person wet labs by residents (3.5 ± 0.3) and attendings (3 ± 0). Similarly, for overall corneal suturing effectiveness, the remote wet lab was rated highly effective by residents (4.4 ± 0.2) and attendings (4.3 ± 0.3). The effectiveness of teaching

corneal suture depth was lowest rated by residents (3.4 ± 0.3) and attendings (3.0 ± 0.6).

Figure 5 highlights objective corneal suturing performance results for the remote(+) and remote(–) groups. The remote(+) group performed better than the remote(–) group overall in trial 1. However, this difference was not statistically significant ($P = .057$). The remote(+) group performed significantly better than the remote(–) group in the suture depth component ($P = .028$) for trial 1. In trial 2, both groups performed similarly overall and in all suturing components.

All residents rated the prewet-lab virtual lecture highly effective (4.4 ± 0.2). Residents and attendings both found the virtual whiteboard during the remote wet lab highly effective (4.6 ± 0.2 and 4.7 ± 0.3 , respectively). Comparing

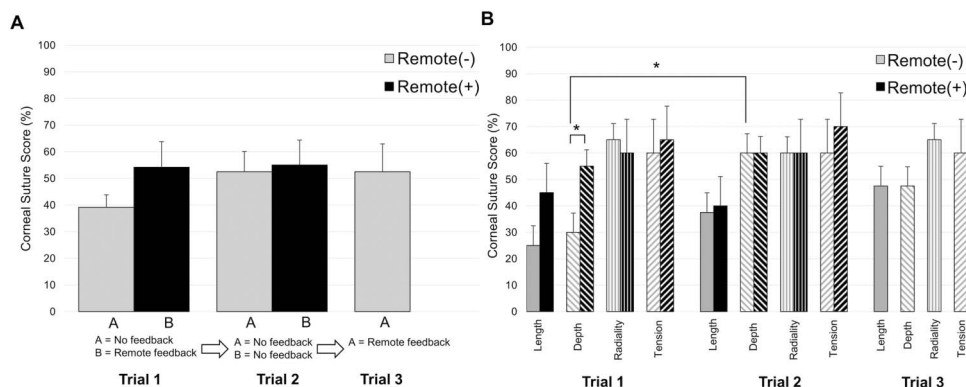


Figure 5. Objective resident corneal suturing performance. **A:** Mean corneal suturing scores for residents in the remote(+) and remote(–) groups for each trial. For trial 1, the remote(+) group ($54.2 \pm 9.6\%$) performed better than the remote(–) group ($39.2 \pm 4.7\%$), although this difference was not statistically significant ($P = .057$). Both groups ended with similar corneal suturing performance. **B:** Breakdown of corneal suturing scores by corneal suturing component for remote(+) and remote(–) groups for each trial.

and remote(–) groups for each trial. In trial 1, the remote(–) group scored lower on both length ($25 \pm 7\%$) and depth ($30 \pm 7\%$) compared with the remote(+) group ($45 \pm 11\%$ and $55 \pm 6\%$, respectively); however, this difference was only statistically significant for depth ($P = .22$ and $.028$, respectively). By trial 2, the remote(–) group had improved to similar corneal suturing performance across all corneal suturing components, including length and depth ($38 \pm 10\%$ and $60 \pm 10\%$, respectively), compared with the remote(+) group ($40 \pm 10\%$ and $60 \pm 8\%$, respectively). These remote(–) group length and depth improvements from trial 1 to trial 2 were only statistically significant for depth ($P = .20$ and $.040$, respectively).

interns with more advanced residents (postgraduate year 2 or higher) prewet lab, interns were overall significantly less comfortable with corneal suturing (1.2 ± 0.2 and 2.7 ± 0.3 , $P = .002$). Interns, compared with the other residents, found all components of the remote wet lab equally effective with the exception of suture tension (2.7 ± 0.3 and 4.0 ± 0.3 , $P = .029$). Objectively, interns performed similarly compared with the other residents in overall corneal suturing (2.9 ± 0.4 and 3.1 ± 0.3).

Attendings rated the remote lab as highly effective in evaluating all 5 components of the modified global rating scale of operative performance: 4.3 ± 0.3 for respect for tissue, 4.7 ± 0.3 for time and motion, 4.3 ± 0.3 for instrument handling, 4.3 ± 0.7 for flow of operation, and 4.7 ± 0.3 for knowledge of procedure. One attending found the remote wet lab less effective (2) at providing an external view of resident hand positioning; however, all attendings felt verbal communication (4.7 ± 0.3), microscope view (4 ± 0), and external view of body positioning (4.3 ± 0.3) were highly effective in the remote wet-lab setup. All participants involved in this study remained asymptomatic up to 2 weeks after the remote wet lab, with none of the participants requiring COVID-19 testing.

DISCUSSION

This randomized prospective study demonstrates the feasibility of a remote wet lab for microsurgical education during the COVID-19 pandemic. Residents were not comfortable with corneal suturing, either overall or with any of its components, prior to this study. However, after participation in one remote wet-lab session, their comfort with corneal suturing significantly improved. Both residents and attendings found the remote wet lab effective, and all features of the modified global rating scale of operative performance could be effectively evaluated.^{11,12} The remote wet-lab setup is simple and of low cost. It relies on standard wet-lab equipment and everyday items, including a smartphone and laptop. Most importantly, all residents and attendings in this study were able to stay safe by complying with government-mandated social distancing requirements, institutional health screening, and wearing of necessary PPE. This is the first study, to our knowledge, to demonstrate the utility of a remote wet lab in the microsurgical training of ophthalmology residents.

The remote(+) group that started with attending remote feedback performed better overall at corneal suturing in trial 1 than the remote(-) group that did not start with attending remote feedback. Although this overall performance difference was not statistically significant ($P = .057$), the suture depth performance difference between the 2 groups was statistically significant ($P = .028$). Both groups performed similar to each other in the absence of remote feedback in trial 2. This observation reinforces the importance of practice in corneal suturing skill mastery. When the remote(-) group was crossed over and given attending remote feedback for trial 3, their corneal suturing performance did not improve further. This lack of persistent improvement suggests that more advanced suturing

mastery likely requires more time and practice than allotted in this study. The modified Mayo Clinic corneal suturing rubric used in this study could be further modified to better detect more subtle performance differences in future studies.¹⁰ Potential aspects of suturing performance amenable to grading include suture placement accuracy (ie, within 1 clock hour of each cardinal direction) and time elapsed for each suture pass.

Of interest, both residents and attendings rated the remote wet lab as effective, or even more effective, than previous in-person wet labs. This could be due to a variety of factors. First, use of the virtual whiteboard was unanimously graded as highly effective (4.6 ± 0.2 for residents and 4.7 ± 0.3 for attendings). Second, having both the microscope and external views available together on 1 screen provided a more ergonomic and comprehensive viewing experience. Third, the porcine eye and wet-lab supplies were prepared in advance, whereas most in-person wet labs require residents to prepare their own stations. Finally, residents have been significantly lacking in operative cases due to the pandemic such that any opportunity for one-on-one surgical mentorship might have enhanced the perceived learning experience. A surprising finding in our study was that interns performed and more advanced residents in the corneal suturing task. This might be attributed to not only our grading rubric not effectively capturing all aspects of corneal suturing, such as time per suture pass, but also the recently integrated ophthalmology internship at UCSF, which provides early surgical subspecialty and ophthalmology training.¹³

This study is limited by its small sample size and single institution design. Validating the utility of the remote wet lab with a larger number of residents from other academic centers and expanding to multiple surgical maneuvers beyond corneal suturing will be important future directions of investigation. In addition, the remote wet lab could create new surgical teaching opportunities, such as for rare procedures with only a few experts, or international educational opportunities, such as remote teaching at conferences and at institutions across the globe. Although residents and attendings rated the remote wet lab as effective in all components of corneal suturing, suture depth received the lowest scores. Using technology such as microscope-integrated optical coherence tomography to directly visualize and guide proper suture depth could address this issue and has been shown to enhance performance of ophthalmology residents in select anterior segment maneuvers.^{9,14,15} The Zoom video conferencing platform used in this study integrated the different cameras well. However, 1 limitation was the inability to deactivate the autofocus feature from the smartphone camera while in Zoom, which occasionally blurred the microscope view. Future studies could overcome this limitation by using a manual focus mode or by locking focus and exposure on the smartphone camera. One attending rated the external view of hand positioning less effective (2), which could be improved by adding an additional camera from another angle to provide a profile view of the resident.

Because of the COVID-19 pandemic–related decrease in surgical volume and prohibition of in-person training activities, virtual surgical training options through remote didactics, including surgical video teaching conferences and surgical webinars, have become more frequent.^{7,16–19} Training programs might rely more heavily on virtual reality simulators, such as the Eyesi (VRmagic), which have been shown to improve ophthalmic surgical efficiency and outcomes.^{20–22} Similarly, mobile microsurgery platforms, especially those that are cost-efficient, might become integrated into the surgical training curriculum.^{23–28} Nonetheless, attending feedback will continue to play a crucial role in the development of ophthalmology resident microsurgical skills, regardless of the used educational platform.²⁹

Even prior to COVID-19, approximately 10% of U.S. ophthalmology residents struggled surgically.⁴ The COVID-19 pandemic has had a significant impact on surgical training for all ophthalmology residents, with some programs decreasing surgical volume by more than 75% for 4 months to 6 months.¹⁸ This surgical training void has not only significant educational implications but also significant mental health implications. Recent surveys have shown that more than 80% of ophthalmology trainees report COVID-19 has negatively impacted their surgical training, more than 50% report an increase in stress levels, and nearly one third of ophthalmologists report some degree of depression.^{17,30} The long-term clinical impact of these negative surgical and psychological changes for ophthalmology residents remains to be seen, but it is clear that COVID-19 will continue to significantly affect all ophthalmologists for the foreseeable future. As such, expeditiously implementing safe and innovative microsurgical teaching platforms, such as remote wet labs, should be a priority at academic medical centers. The solutions need not be perfect because any improvements are a step forward in the unprecedented new normal of the COVID-19 pandemic.

WHAT WAS KNOWN

- Microsurgical wet labs are essential for developing intraocular surgical skills and preventing intraoperative complications.
- Because of the COVID-19 pandemic social distancing requirements, all in-person wet labs have been cancelled.

WHAT THIS PAPER ADDS

- The remote wet lab is a new, low-cost, social distancing–compliant platform for microsurgical education during the COVID-19 pandemic.
- Residents and attendings rated the remote wet lab as equally or more effective compared with previous in-person wet labs and overall effective in corneal suturing.

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Disclosures: *G.D. Seitzman is a consultant for Dompé Pharmaceuticals. J.M. Schallhorn is a consultant for ZEISS and Vanda Pharmaceuticals. The other authors have no financial or proprietary interest in any material or method mentioned.*



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000 Remote corneal suturing wet lab: microsurgical education during the COVID-19 pandemic

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A new remote wet lab allowing residents to maintain social distancing during the COVID-19 pandemic and perform a corneal suturing task on porcine eyes with remote attending feedback is described.