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Addressing the Pandemic Training Deficiency: Filling the Void with Simulation in Facial Reconstruction

Shiayin F. Yang, MD; Allison Powell, MSE; Sudharsan Srinivasan, MSE; Jennifer C. Kim, MD; Shan R. Baker, MD; Glenn E. Green, MD; David A. Zopf, MD, MS

Objective/Hypothesis: To assess the use of a three-dimensional (3D) printed, multilayer facial flap model for use in trainee education as an alternative method of teaching surgical techniques of facial reconstruction.

Study Design: Cohort study.

Methods: A 3D printed facial flap simulator was designed from a computed tomography scan and manufactured out of silicone for low-cost, high-fidelity simulation. This simulator was tested by a group of Otolaryngology–Head and Neck Surgery trainees at a single institution. The simulator group was compared to a control group who completed an exercise on a traditional paper facial flap exercise. Both groups underwent didactic lectures prior to completing their respective exercises. Pre- and post-exercise Likert scale surveys measuring experience, understanding, effectiveness, and realism were completed by both groups. Central tendency, variability, and confidence intervals were measured to evaluate the outcomes.

Results: Trainees completing the facial flap simulator reported a statistically significant ($p < 0.05$) improvement in overall expertise in facial flap procedures, design of facial flaps, and excision of standing cutaneous deformities. No statistically significant improvement was seen in the control group.

Conclusions: Trainees found the facial flap simulator to be an effective and useful training tool with a high level of realism in surgical education of facial reconstruction. Surgical simulators can serve as an adjunct to trainee education, especially during extraordinary times such as the novel coronavirus disease 2019 pandemic, which significantly impacted surgical training.

Key Words: Facial reconstruction, Mohs reconstruction, surgical simulation, medical education, COVID-19.

Level of Evidence: NA

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INTRODUCTION

The novel coronavirus disease 2019 (COVID-19) pandemic has had unprecedented effects on the healthcare system, including medical and surgical training. During the height of the pandemic, there was widespread cessation of elective procedures, restriction of resident involvement, and redeployment of resident trainees to assist with the surge of critical COVID-19-positive patients. Regional and national conferences, traditional grand rounds, and didactic lectures were postponed or canceled. All these changes have significantly impacted resident education and training; of which, the cumulative effects have yet to be realized.

Specific hands-on surgical training, especially for procedures that are rare or complex in nature, is essential to training residents in surgical and procedural specialties. Given the dramatic decrease in hands-on training during the COVID-19 pandemic, alternative methods of education may be valuable to continue the education of these residents. Surgical simulation has been used successfully as an adjunct education tool in training across multiple surgical specialties[1–4] and can be used by trainees as an alternative means to practice procedures in a safe and effective manner. A recent 2020 systematic review demonstrated a wide range of three-dimensional (3D) printed simulators for otolaryngology training, with most studies demonstrating positive feedback and high confidence in the value of the simulators.[5]

Local flaps are the workhorse of facial reconstruction. They are composed of skin and subcutaneous tissue with a vascular supply that is transferred to an adjacent or nearby site to repair a cutaneous defect. For a novice surgeon, flap design and mechanics can be difficult to understand and execute. Facial reconstruction requires an in-depth knowledge of facial aesthetic and functional

From the Department of Otolaryngology–Head and Neck Surgery (S.F.Y.), Vanderbilt University Medical Center, Nashville, Tennessee, U.S.A.; Department of Otolaryngology–Head and Neck Surgery (S.F.Y., J.C.K., S.R.B.), University Michigan Health Systems, Ann Arbor, Michigan, U.S.A.; University of Michigan Medical School (A.P., S.S.), Ann Arbor, Michigan, U.S.A.; Department of Otolaryngology–Head and Neck Surgery (G.E.G., D.A.Z.), University of Michigan Health Systems, CS Mott Children's Hospital, Ann Arbor, Michigan, U.S.A.; and the Department of Biomedical Engineering (D.A.Z.), College of Engineering, University of Michigan, Ann Arbor, Michigan, USA.

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Send correspondence to Shiayin F. Yang, MD, Department of Otolaryngology–Head and Neck Surgery, Vanderbilt University Medical Center, 1215 21 Avenue South, Suite 7209, Nashville, TN 37232. E-mail: shiayin.yang@vumc.org

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subunits. To properly create and transfer a local flap, the surgeon must be able to conceptualize the design and its final position without distortion of facial anatomy.[6,7] Outcomes are highly dependent on surgeon experience. Given the sensitivity of operating on the face, many surgical trainees may not have the opportunity to gain experience in planning and dissecting local flaps early in training. This pre-existing limitation in exposure has been dramatically exacerbated by the unprecedented deceleration in hands-on experiences due to the COVID-19 pandemic. Cadaveric human tissue is a possible alternative to patient experience for earlier hands-on experience. However, accessing cadaveric human tissue can be difficult due to scarcity and expense. Moreover, cadaveric and biologic tissue cannot be maintained for reference or to longitudinally track progress. Thus, surgical simulation can allow for cost-effective, specialty-specific teaching in a zero-risk environment devoid of patient morbidity or mortality.

The objective of this study was to investigate the use of a 3D printed facial flap simulator as a tool for surgical training in design and execution of local flaps in comparison to standard teaching techniques in facial reconstruction.

METHODS AND MATERIALS

The study received board exemption by the Institutional Review Board at the University of Michigan Health Systems.

Study Design

Otolaryngology trainees ranging from postgraduate year (PGY) 1 through 6 were invited to participate in the study. Participants were randomized and blinded based on PGY into a control group and a simulator group. Prior to performing the local flap exercise, each group completed a pre-exercise Likert scale survey with six domains to assess prior experience, understanding, and design of local facial flaps (Table I). All participants were then provided with didactic lectures on design and implementation of a rhombic and O-T flap by an experienced facial plastic and reconstructive surgeon. Two flaps were selected for the trainee to design to test their knowledge of a simple (O-T) flap and more complex (rhombic) flap. After the didactic session, the control group exercise was to design O-T and rhombic flaps of appropriate size, configuration, and location as well as illustrate the anticipated location of standing cutaneous deformities on a paper facial illustration.

The control exercise was designed to embody a common method (drawings or textbook illustrations) of teaching facial flaps outside the operating room. Participants in the control group were given a paper illustration of a face with preprinted cheek and forehead defects. The control group was instructed to draw how they would close both defects based on their didactic lecture on rhombic and O-T flaps. After completion of the exercise, the control group answered the same questions as they did in the pre-exercise survey and completed an additional Likert scale survey with five domains (Table II) to assess the utility and realism of the exercise, its effectiveness as a training tool, and if the exercise improved the trainees understanding and confidence in performing local facial flaps. Refer to Supporting Data 1 for complete pre- and postsurvey.

A 3D printed facial simulator model that was previously validated by experienced facial plastic surgeons

TABLE I.
Pre-Exercise 5-Point Scale Evaluation Survey Completed by the Control and Facial Flap Simulator Groups.

Survey Domain	Definitions of Scale				
Overall expertise in facial flap procedures	(1) None	(2) Some	(3) Moderate	(4) Moderate–significant	(5) Significant
Expertise in suturing techniques for procedure					
Expertise in borders of esthetic units					
Expertise in design of O-T flaps					
Expertise in design of rhombic flaps					
Expertise in excision of standing cutaneous deformities					

TABLE II.
Post-Exercise 5-Point Scale Evaluation Survey Completed by the Control and Facial Flap Simulator Groups.

Survey Domain	Definitions of Scale				
Improve expertise in facial flaps Increase confidence in performing facial flaps	(1) No improvement	(2) Some improvement	(3) Moderate improvement	(4) Moderate–significant improvement	(5) Significant improvement
Value	(1) No usefulness	(2) Some usefulness	(3) Moderate usefulness	(4) Moderate–significant usefulness	(5) Significant usefulness
Realism	(1) Not realistic	(2) Somewhat realistic	(3) Moderately realistic	(4) Moderately–significantly realistic	(5) Significantly realistic
Effectiveness as training tool	(1) Not effective	(2) Somewhat effective	(3) Moderately effective	(4) Moderately–significantly effective	(5) Significantly effective

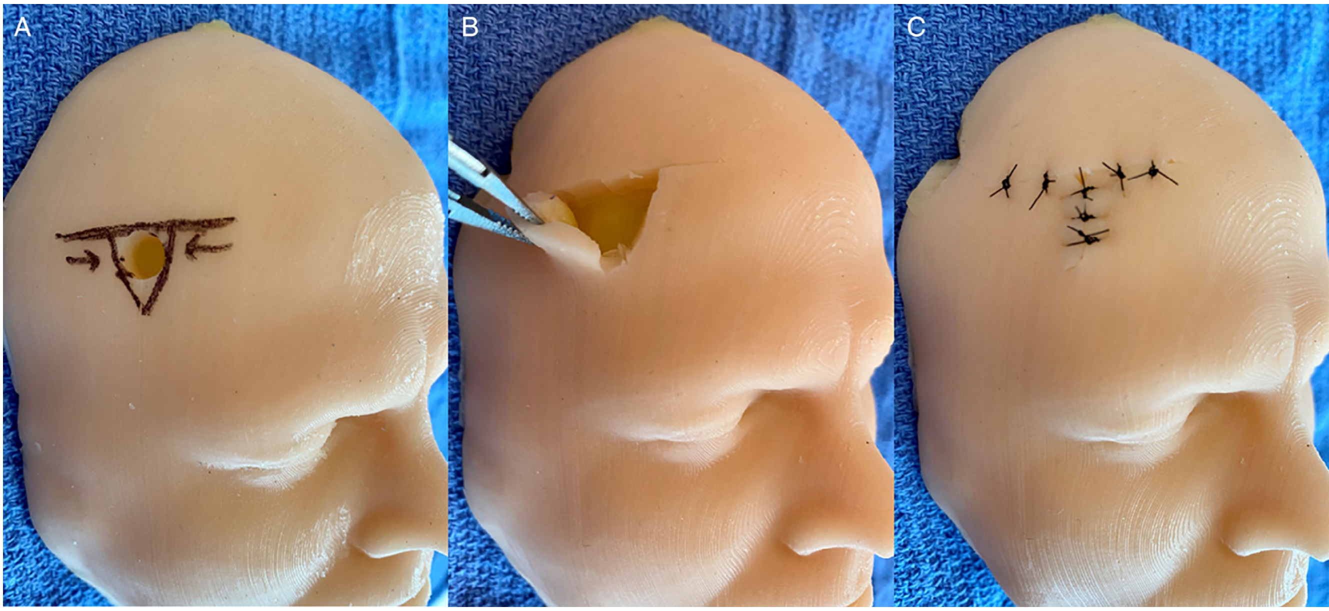

Fig. 1. Facial flap simulator model for O-T flap. A, Design of O-T flap around defect. B, Elevation and undermining of O-T flap. C, Final O-T flap position and closure with sutures.

was used by the simulator group.[8] The simulator model was designed from a computed tomography scan for anatomic landmarks. The layers include a 3-mm skin depth and a 6-mm depth of fat made of silicone and a silicone composite. The simulator group designed O-T and rhombic flaps of appropriate size, configuration, and location on the facial flap simulator. Unlike the control group, the simulator group also was required to incise, undermine, remove standing cutaneous deformities, and close the facial defect with the flap using sutures on the simulator. The goal of using the simulator was to provide a model that closely resembled human tissue and to allow trainees to realistically practice flap design and appreciate tissue dynamics and tension lines during execution (Figs. 1 and 2). Participants in the simulator group were given the facial simulators with existing cheek and forehead soft tissue defects. Participants completed pre- and post-exercise surveys (Tables I and II). Refer to Supporting Data 2 for complete pre- and postsurvey. The two-dimensional paper control group was compared to the 3D facial simulator group. The performance of both groups was rated by a blinded experienced facial plastic and reconstructive surgeon.

Statistical Analysis

Measures of central tendency, variability, and confidence intervals were generated to evaluate the outcomes. Paired 2-tailed t-tests were conducted to analyze pre- and post-exercise surveys (P = .05).

RESULTS

Fifteen Otolaryngology–Head and Neck residents and fellows participated in the study: seven in the control group and eight in the simulator group. Each training year was represented in each group. The most common methods of learning facial flap procedures during training were reading, observation, lectures, videos, and participation in surgical cases. Participants in the control group performed an average of 45 facial flaps during their training, and those in the simulator group performed an average of 44 facial flaps. There was no statistically significant difference in terms of the number of flaps performed between the two groups. The mean rating of the participants' current understanding of facial flap procedures was 3 on a scale of 1 (never been taught) to 5 (expert understanding).

Survey score results of the simulator group demonstrated a statistically significant improvement among four of the six domains including overall expertise in flap procedures (P = .022), expertise in O-T flaps (P = .008), expertise in rhombic flaps (P = .028), and expertise in excision of standing cutaneous deformities (P = .008). No statistically significant difference was seen in any of the pre- and post-survey domains of the control group. The simulator group gave high ratings across the domains of usefulness, effectiveness, and realism of the model as a training tool (Table III). The control group gave average to below average ratings across all survey domains. Grading by an experienced facial plastic surgeon reported that it was easier to assess skill and understanding of the simulator group compared to the control group. The average rating, scale of 0 to 10, by the experienced facial plastic surgeon for the simulator group was 8.9 and the control group was 7.14. There was no statistically significant difference between the two groups.

DISCUSSION

Resident training, particularly surgical and procedural specialties, has been profoundly altered during the

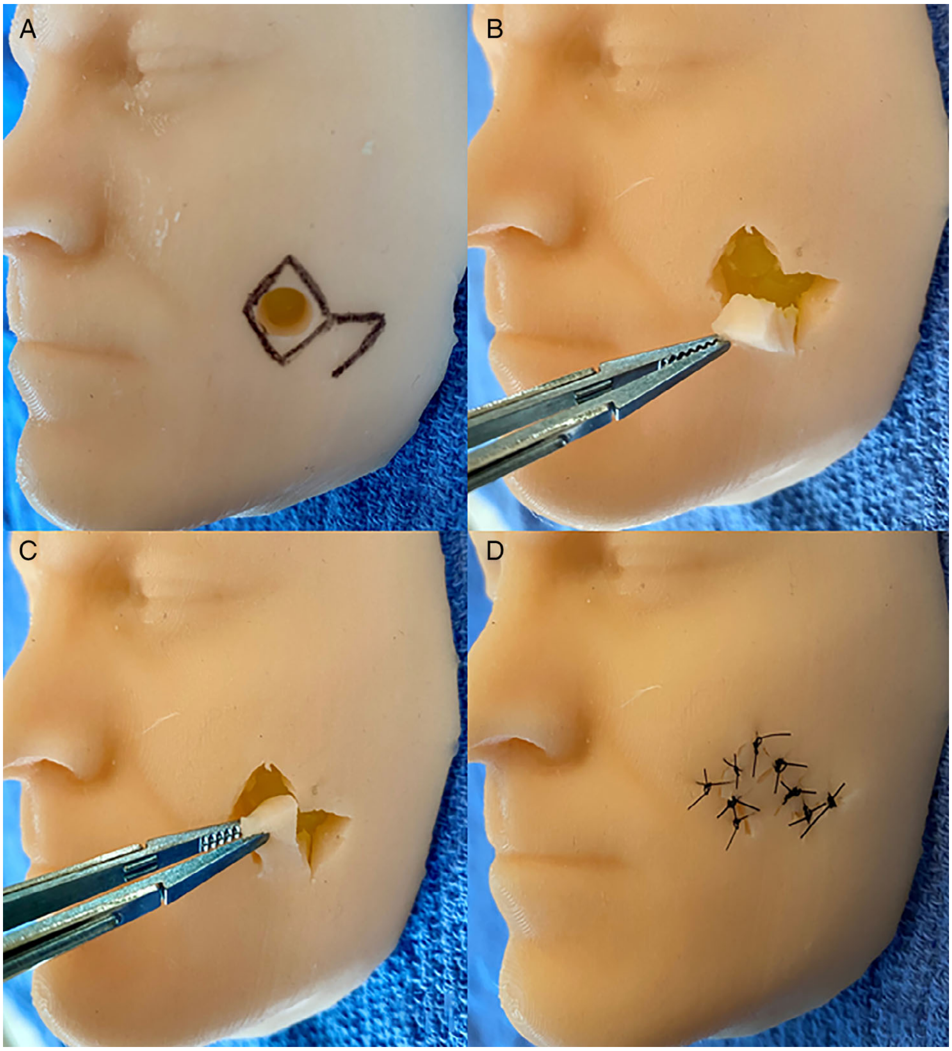

Fig. 2. Facial flap simulator model for rhombic flap. A, Design of rhombic flap around defect. B, Elevation and undermining of rhombic flap. C, Rotation of elevated rhombic flap into defect. D, Final rhombic flap position and closure with sutures.

TABLE III.
Mean Survey Domain Ratings from the Facial Flap Simulator and Control Groups.

Domain	Simulator Group Rating, Mean (SD) (95% CI) n = 5	Paper Group Rating, Mean (SD) (95% CI) n = 5
Improvement in expertise level	3.67 (1.12) (2.55–4.78)	2.71 (1.11) (1.60–3.83)
Improvement in confidence level	3.89 (1.05) (2.83–4.94)	3.00 (1.15) (1.85–4.15)
Utility of exercise	4.33 (1.12) (3.22–5.45)	3.29 (0.95) (2.33–4.24)
Realism of exercise	3.22 (1.30) (1.92–4.52)	2.71 (1.38) (1.33–4.09)
Effectiveness as training tool	4.11 (1.05) (3.06–5.17)	3.43 (1.27) (2.16–4.70)

COVID-19 pandemic due to the cancelations and reductions of elective procedures, decreased patient interaction, elimination of in-person group gatherings, and redistribution of healthcare efforts to COVID-19 patients. To account for these transitions, many board certifying bodies have made accommodations for trainee requirements. For example, the American Board of Otolaryngology–Head and Neck Surgery has adjusted requirements for first year residents to have 6 months of flexibility to care for COVID-19 patients and allow this time to be used toward training requirements.[9] Despite these accommodations, managing COVID-19 patients is not the same as caring and participating in surgical procedures specific to one's residency training. Furthermore, the cessation of elective procedures ranged from 6 weeks to 3 months and even with the resumption of elective procedures, and case volumes have been gradual to ramp up due to concern for resurgence of COVID-19 cases. The duration of the shutdown, with indolently persistent first wave and potential subsequent wave cases, represents a significant amount of time during residency training, which ranges between 4 and 6 years, in which residents were unable to participate in cases necessary for surgical competency and that count toward key indicator cases. In addition, this pandemic may have even more significant implications for trainees later in their career, that is, fellows who may only have 1 to 2 years to obtain specialized training.

Given the significant impact of COVID-19 on surgical training and the uncertainty of the duration and the potential for resurgence, alternative means of specialty-specific education are essential for continued resident education. Our study evaluated the use of surgical simulation as an alternative method for surgical training of local flaps in facial reconstruction. Local flap techniques are critical in residency training in the fields of Otolaryngology–Head and Neck Surgery, Plastic Surgery, General Surgery, Ophthalmology, and Dermatology. We believe a local flap simulator would be a valuable alternative training tool to study given its wide application across multiple specialties.

Simulated models have been successfully used across the multiple surgical specialties to allow for hands-on experience and have demonstrated efficacy in surgical skills training.[1,10–13] This study demonstrated that the use of facial flap simulators resulted in improved trainee expertise in flap design and in confidence when performing facial flap procedures. Simulation as a realistic training tool was highly rated by participants. It was also preferred over the paper model for the purpose of assessment by experienced facial plastic surgeons in evaluating trainee competency and understanding of facial flaps. These findings support that the 3D printed facial models augmented trainees' foundation of knowledge prior to patient exposure.

Given these findings, we believe simulated facial models not only are useful as an adjunct to surgical learning but also can have broader applications including teaching during times of crisis and global outreach. The global pandemic of COVID-19 led to a cessation of elective surgeries and social distancing, which resulted in a drastic decrease in patient interaction and group learning. At our institution, during the period of March 21, 2020 to May 29, 2020, a state mandate halted elective surgical procedures. As such trainee exposure to local facial flap procedures, among other similar elective procedures, precipitously dropped to essentially zero. Although this absolute pause was lifted on May 29, ongoing protocols to maintain safe surgical system operations have reduced clinical opportunities. The long-term effects of this pandemic on surgical training have yet to be seen, but there is concern that it may result in decreased experience and inability to obtain adequate numbers of key indicator cases by trainees.[14] Preliminary survey feedback from residents and program directors across many surgical specialties demonstrated a decrease in surgical volume and transition to virtual educational platforms.[15–19] Elimination of elective cases resulted in a decrease in the availability of facial flap procedures. Although simulated facial models do not replace supervised patient surgical training, it may serve as a crucial education tool by safely allowing for continued learning opportunities.

The limitations of this study include the small sample size and confinement to a single institution and specialty. Another limitation is that the study only assesses short-term learning. Despite these limitations, we believe that the findings of this study demonstrate promise as a learning tool. To further understand and characterize the benefits of simulated model learning, we are planning on continuing the study across multiple institutions and specialties (general surgery, plastic surgery, oculoplastic, and oral maxillofacial surgery).

CONCLUSION

This study provides initial validation data for a 3D printed facial flap simulator as a potential training tool for surgical residents and fellows to gain experience in performing local facial flap procedures. This model demonstrates value in surgical education as it can allow surgical trainees earlier, higher volume exposure to outcome-sensitive local facial flap procedures. It additionally lends itself as an educational tool to allow for continued resident training during the COVID-19 pandemic and future scenarios requiring reduction in traditional healthcare operations.

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