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Comparing Feedback Techniques in Bilobe Flap Simulation Using 3D-Printed Facial Models

Aryan Shay, MD[1], Isabella Zaniletti, PhD[2], Hannah Coffman, BS[1], Sagar Mehta, MD[3], and Gresham Richter, MD[1]

Abstract

Objective. To compare live versus delayed feedback on trainee performance of bilobe flaps using 3-dimensional (3D)-printed facial simulators and determine whether these effects are sustained on repeat performance.

Study Design. Cohort study.

Setting. University of Arkansas for Medical Sciences.

Methods. 3D-printed facial models with a nasal ala defect were provided to 18 subjects. Subjects were stratified and randomized based on their training level into 1 of 3 groups corresponding to live feedback (Group 1), delayed feedback (Group 2), and no feedback (Group 3). Subjects performed a bilobe flap following a structured lecture. Four weeks later, subjects independently repeated the exercise on the contralateral ala. Likert surveys were used to assess subjective parameters. Objective grading was performed by a plastic surgeon, which included a point system and score for the overall appearance.

Results. Following exercise 1, Group 1 reported a significant improvement in knowledge ($P < .001$), which was sustained after exercise 2 ($P < .001$); Group 2 reported a significant improvement after exercise 1 ($P = .03$) but was not sustained ($P = .435$). After the second exercise, Group 1 and Group 2 improved their confidence in bilobed repair ($P = .001$ and $P = .003$, respectively), but this was greater for Group 1. Group 1 showed a significant improvement in their design time following exercise 2 ($P = .007$). There were no significant differences between groups on total time for repair, total score, and appearance.

Conclusion. 3D-printed models are valuable in teaching the bilobe flap for nasal defects, with live feedback providing the greatest level of improvement in self-reported knowledge and confidence.

Keywords

3D printing, bilobe, facial simulator, feedback, local facial flap, resident education

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Over the past decade, the field of otolaryngology has seen a rapid increase in the use of 3-dimensional (3D)-printed materials in clinical practice and education.[1-9] While 3D printing is a general term that describes the conversion of a virtually designed object into a physical object using one of several different types of printing methods, the first method of 3D printing (termed stereolithography) was patented in 1986 by Charles Hull in the United States for rapid prototyping in the automotive and aerospace industries.[2,4] Today, the technology has expanded to several industries due to the variety of production materials and processing methods, improved access, and decreased costs.[1-4] Within otolaryngology, the relatively inexpensive 3D printing method of fused deposition modeling has been a popular choice for creating high-fidelity surgical models such as temporal bones and facial flap models, which have proven to be reliable simulators for surgical training.[6,10-13] With increased availability and experience with this technology, there has been heightened interest in incorporating 3D printing in otolaryngology residencies in order to augment surgical training especially in the era of coronavirus disease 2019 (COVID-19).[14-19]

Performing local facial reconstruction is critical for resident training and can constitute as a key indicator case according to the Accreditation Council for Graduate Medical Education. Of particular interest is the bilobe

[1]Department of Otolaryngology–Head and Neck Surgery, Arkansas Children's Hospital, University of Arkansas for Medical Sciences, Little Rock, Arkansas, USA
[2]Children's Hospital Association, Lenexa, Kansas, USA
[3]Department of Surgery–Division of Plastic and Reconstructive Surgery, Arkansas Children's Hospital, University of Arkansas for Medical Sciences, Little Rock, Arkansas, USA

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Corresponding Author:
Aryan Shay, MD, Resident Physician, University of Arkansas for Medical Sciences, 4301 West Markham Street, #543, Little Rock, AR 72205, USA.
Email: adshay@uams.edu

flap for nasal reconstruction, which is a commonly performed local facial flap and is considered a core procedure by experts in the field.[6,20] However, independently performing local facial flap reconstruction can be a challenging task for trainees due to the inherent geometric complexity of certain designs and lack of experience.[6] Further exacerbating this issue is the fact that many institutions saw a significant decrease in elective cases during the early stages of the COVID-19 pandemic. A survey distributed in August 2020 to facial plastic and reconstructive surgery fellowship directors reported a 27.9% decrease in cosmetic/aesthetic surgery and a 22.6% decrease in reconstructive surgery.[21] In another survey, otolaryngology residents and fellows reported that 89.7% of trainees felt their education and training were negatively impacted by COVID-19, and 68% were strongly concerned about their ability to receive adequate surgical training.[22] Therefore, some otolaryngology departments began to employ 3D-printed facial flap simulators as a resident training tool. This proved to have a significant improvement in trainee expertise in facial reconstruction compared to traditional 2D approaches using paper and pen.[14] Due to the recent adoption of this technology, further investigation on how to optimize the delivery of 3D modeling is important, especially in light of the COVID-19 pandemic where remote or delayed feedback may be employed.

The primary objective of this study was to compare the effect of in-person, live feedback versus delayed feedback on trainee confidence and performance of bilobe flaps using 3D-printed facial simulators and whether these effects were maintained on repeat performance. Specifically, confidence was defined as the self-reported response to survey domains on knowledge and confidence, while performance was defined by objective parameters including time to completion (flap design time and total exercise time) and objective grading of the flap appearance by a single surgeon. We hypothesized that subjects who received in-person (real-time) feedback during the initial exercise would have higher confidence and performance scores when repeated independently versus those who received delayed or no feedback during the initial exercise.

Methods

The University of Arkansas for Medical Sciences (UAMS) Institutional Review Board (IRB) reviewed a determination application and deemed that this study did not constitute human subject research and thus IRB oversight was not required. Subjects invited to participate were comprised of otolaryngology trainees and medical students from UAMS. Of note, the first author (A.S.) and third author (H.C.) did not participate in the study exercises as they were involved with researching and creating the lecture material, which may have impacted self-reported confidence measures. Subjects were first stratified by their training level (medical student, postgraduate year [PGY]-1, PGY-2, PGY-3, PGY-4, PGY-5). Subjects in each training level were then randomized via simple randomization into 1 of 3 groups corresponding to in-person live feedback (Group 1), delayed feedback (Group 2), or no feedback (Group 3). All subjects completed the same pre-exercise survey (Supplemental Figure S1, available online). Additionally, a Likert scale was used to assess subject knowledge and confidence in local facial reconstruction using a bilobe flap, abbreviated as Q1, Q2, and Q3 (**Table 1**). All participants then attended an in-person lecture on bilobe flap reconstruction for nasal defects led by a fellowship-trained plastic surgeon (S. M.). After the lecture, all participants were provided with a 3D-printed facial flap simulator with a predetermined nasal ala defect and instruments for suturing (**Figure 1**). All participants were then instructed to design and perform a bilobe flap for this defect. Participants were then separated based on their assigned group to perform this first exercise.

Group 1 participants were moved to a separate room. While performing their exercise, the same plastic surgeon (S.M.) was available to answer questions and provide direct feedback to individuals. Group 2 and Group 3 participants remained in the same lecture room and were instructed to complete the exercise individually, without any form of feedback during the exercise. Following the exercise, all participants completed a postexercise survey (Supplemental Figure S2, available online), which included the same Likert scale from the pre-exercise survey (**Table 1**). Additionally, subjects submitted 1 picture of their design and 1 picture of the completed flap in this survey for objective grading by the instructing author (S.M.) outlined in Supplemental Figure S3, available online. Participants in Group 2 were then instructed to solicit feedback from the instructing author within a 1-week period either in person or through electronic communication (emailing, text messaging, or calling). Subjects in Group 2 were instructed to solicit feedback specifically on their 2 photographs regarding the design and overall appearance and to discuss items from the grading rubric from Supplemental Figure S3, available online, as they related to the photographs. Participants in Group 3 did not receive any form of feedback.

Approximately 4 weeks later, all participants individually repeated the same exercise on the contralateral nasal ala. Unlike the first exercise, there was no live or delayed feedback portion for any of the groups, and no lecture was provided. Similar to the first exercise, all participants completed a postexercise survey (Supplemental Figure S4, available online) that included the same Likert scale from the pre-exercise survey questions (**Table 1**). Objective scoring from the instructing author was performed in the same manner as the first exercise. Of note, for the objective scoring on both exercises, only the subject identification number was associated with each photograph.

Table 1. Pre-Exercise and Postexercises Likert Scale Survey on Bilobe Flap Competency

Domain	Scale				
Q1. How would you rate your knowledge of choosing the most appropriate type of flap for nasal reconstruction?	1—None	2—Minimal knowledge (ie, choosing the most appropriate in limited cases)	3—Basic knowledge (ie, choosing the most appropriate in some cases)	4—Strong knowledge (ie, choosing the most appropriate in most cases)	5—Excellent knowledge (ie, choosing the most appropriate in all cases)
Q2. How would you rate your knowledge on recalling the steps to performing a bilobe flap?	1—None (can recall little to no steps)	2—Minimal knowledge (can recall some steps)	3—Basic knowledge (can recall most steps)	4—Strong knowledge (can recall all steps but may miss details)	5—Excellent knowledge (can recall all steps)
Q3. How confident are you in clinically performing a bilobe flap for nasal reconstruction?	1—Not confident (ie, unable to perform most steps; would require faculty to complete)	2—Minimally confidant (ie, able to perform some steps; would require faculty to complete)	3—Somewhat confident (ie, able to perform all steps; would require faculty guidance)	4—Mostly confident (ie, able to perform all steps; sometimes would require faculty guidance)	5—Very confident (ie, able to perform all steps; without faculty guidance)

3D Printing

Planning and modeling began with the acquisition of anonymized computed tomography head images. The images were converted to STL files using the open-source software, 3D Slicer (https://www.slicer.org/). The mold of the facial structure was created with polylactic acid using a Prusa i3 MK3 3D printer (Prusa Research). A thin 20 mm × 100 mm piece of polyester mesh was placed over the nose to improve tissue strength. The skin mold was measured at 3 mm thickness (similar to the model by Powell et al.[6]) and primarily created with Smooth-ON Dragonskin 10. The overall cost for materials was approximately $50.25 per model.

Statistical Analysis

The primary outcomes (Q1-Q3, score, appearance, design time, total time) were summarized at each time point using mean and standard deviation, and groups were compared using 1-way analysis of variance models. The change in the outcomes was estimated with a mixed model for repeated measures over time with the Bonferroni adjustment for multiple testing. The estimated mean change between time points was calculated, along with the 95% confidence interval (CI) and *P* value. Counts and percentages were used to describe the remaining items in the survey, and groups were compared using χ^2 or Fisher's Exact test, as appropriate. All analyses were conducted in SAS Enterprise Guide v8.3 and results were evaluated at the significant level of .05.

Results

A total of 18 participants were included in the study with 6 participants in each group. Cohort characteristics and general responses are depicted in **Table 2**. There were no statistically significant differences between the 3 groups prior to the first exercise. The median number of prior facial flaps was 5 for Group 1, 1 for Group 2, and 1 for Group 3.

Following the first exercise, Group 1 reported that their feedback was very helpful (5/6), and mostly helpful (1/6), while Group 2 reported very helpful (1/6), mostly helpful (2/6), somewhat helpful (2/6), and minimally helpful (1/6). Of note, participants in Group 2 used email (n = 3, 50%), in-person (n = 2, 33.3%), and text messaging (n = 1, 16.7%) as their primary method of communication for feedback. Participants reported that the lecture was very educational (7/18), mostly educational (10/18), and somewhat educational (1/18), with no statistical difference between groups.

Likert scale responses to participants' subjective level of bilobe flap competency, along with design time, total time, score, and appearance at all 3 time points (pre-exercise, postexercise 1, postexercise 2) can be found in **Table 3**.

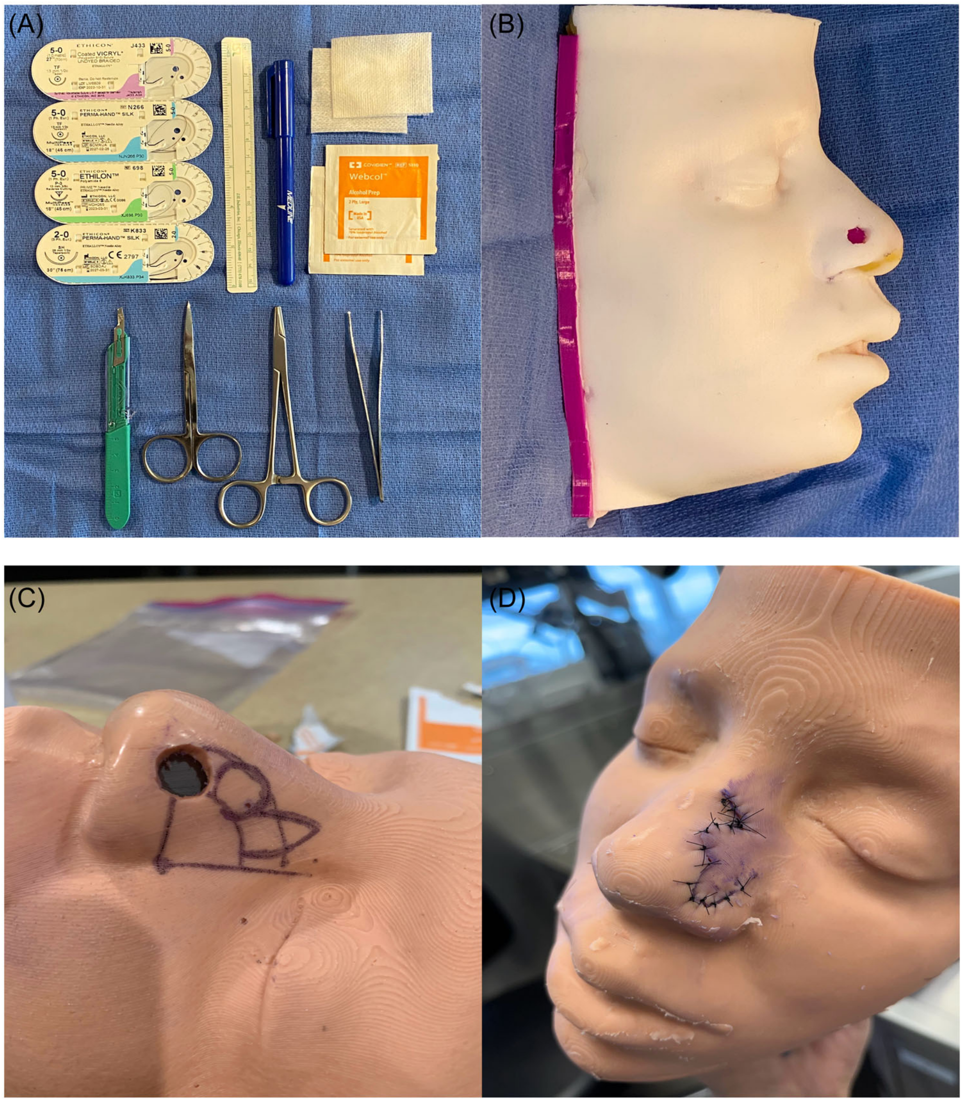

Figure 1. Three-dimensional-printed facial flap simulator model. (A) Instruments and equipment used for the study. (B) A model with predetermined nasal ala defect. (C) Example of a design for the bilobe flap. (D) Example of a completed exercise.

A comparison of the change of Likert survey responses from pre-exercise, postexercise 1, and postexercise 2 is illustrated in **Figure 2**. In comparison to the pre-exercise time point, following exercise 2 Group 1 demonstrated a total increase of 0.3 for Q1 (95% CI [−0.4, 1.1]; $P = .999$), 1.8 for Q2 (95% CI [1.3, 2.4]; $P < .001$), and 2.2 for Q3 (95% CI [1.3, 3.1]; $P = .001$); Group 2 demonstrated a total increase of 1 for Q1 (95% CI [0.6, 1.5]; $P = .002$), 0.5 for Q2 (95% CI [−0.2, 1.2]; $P = .435$), and 1.2 for Q3 (95% CI [0.6, 1.7]; $P = .003$); Group 3 demonstrated a total increase of 0.3 for Q1 (95% CI [−0.2, 0.9]; $P = .641$), 0.7 for Q2 (95% CI [−0.1, 1.4]; $P = .208$), and 0.3 for Q3 (95% CI [−0.3, 1]; $P = .869$).

A comparison of objective changes in flap design, total flap time, total score, and overall appearance over time is illustrated in **Figure 3**. In comparison to the first exercise time point, following exercise 2 Group 1 decreased their design time by 8 minutes (95% CI [3.4, 12.6]; $P = .007$); Group 2 decreased by 10 minutes (95% CI [0.6, 19.4]; $P = .042$); Group 3 decreased by 8 minutes (95% CI [−0.78, 16.78]; $P = .066$). Regarding total time for the exercise, Group 1 decreased by 4.7 minutes (95% CI [−16.8, 26.2]; $P = .602$); Group 2 increased by 1.5 minutes (95% CI [−17, 14]; $P = .813$); Group 3 decreased by 14.2 minutes (95% CI [−11.6, 40; $P = .217$). For the overall score, Group 1 increased by 0.7 points (95% CI [−0.8, 2.1]; $P = .286$); Group 2 increased by 0.5 points (95% CI [−1.5, 2.5]; $P = .542$); Group 3 decreased by 0.2 points (95% CI [−2.2, 1.9]; $P = .842$). For the overall appearance, Group 1 decreased by 0.3 (95% CI [−1.2, 0.5]; $P = .363$); Group 2 decreased by 0.2 (95% CI [−1.4, 1.1]; $P = .741$); Group 3 increased by 0.2 (95% CI [−1.8, 2.1]; $P = .833$).

Discussion

Despite the challenges that COVID-19 has imparted on surgical education, several training programs have taken

Table 2. Cohort Characteristics and General Subject Responses

Characteristics	Group 1 (N = 6)	Group 2 (N = 6)	Group 3 (N = 6)	*P* value
Training level				
Medical student	1	1	1	
Transitional year PGY-1	0	0	1	
Otolaryngology PGY-1	1	1	1	
Otolaryngology PGY-2	1	1	1	
Otolaryngology PGY-3	1	1	0	
Otolaryngology PGY-4	1	1	1	
Otolaryngology PGY-5	1	1	1	
Median number of prior performed facial flaps (Interquartile range)	5 (0, 10)	1 (0, 15)	1 (0, 3)	.715
Facial reconstruction knowledge				.623
None	1	3	2	
Minimal knowledge	1	1	2	
Basic knowledge	3	2	1	
Strong knowledge	0	0	1	
Excellent knowledge	0	0	0	
Feedback helpfulness				.001
No feedback	0	0	6	
Not helpful	0	0	0	
Minimally helpful	0	1	0	
Somewhat helpful	0	2	0	
Mostly helpful	1	2	0	
Very helpful	5	1	0	
Change in bilobe flap confidence after exercise 1 compared to baseline				.013
No improvement	0	0	0	
Minimal improvement	0	0	1	
Mild improvement	0	6	2	
Moderate improvement	2	0	2	
Significant improvement	4	0	1	
Change in bilobe flap confidence after exercise 2 compared to exercise 1				.629
No improvement	0	0	1	
Minimal improvement	1	2	1	
Mild improvement	2	3	3	
Moderate improvement	3	1	1	
Significant improvement	0	0	0	

the opportunity to implement innovative simulation tools, including 3D printing, as effective adjuncts for increasing trainee confidence and experience. While simulation has traditionally been studied in a live group setting, it is imperative that programs adapt this method in the event of another national social distancing mandate. Depending on the policy and educational activity, this may include small group versus individual live teaching, solo procedural practice with or without remote feedback, immersive technology (virtual reality, augmented reality, mixed reality), or online platforms. Prior studies have confirmed that 3D-printed facial flap simulators are highly rated for training and more effective than traditional paper facial illustrations.[6,14] In our study, we primarily aimed to address whether in-person training on bilobe flaps using 3D-printed facial simulators would lead to higher performance when repeated at a later time when compared to trainees who received delayed or no feedback.

Following the second exercise, trainees in Group 1 demonstrated a statistically significant improvement in their subjective bilobe knowledge and performance confidence domains of Q2 (1.8, $P < .001$) and Q3 (2.2, $P = .001$) when compared to their baseline, though their reported knowledge of choosing the most appropriate flap for a nasal defect in Q1 was not significantly changed. In Group 2, there was a significant improvement in Q1 (1, $P = .002$) and Q3 (1.2, $P = .003$) only. Finally, in Group 3, there was no significant change in any of the subjective domains following exercise 2. Subjectively, the only area where Group 3 did report a significant improvement was

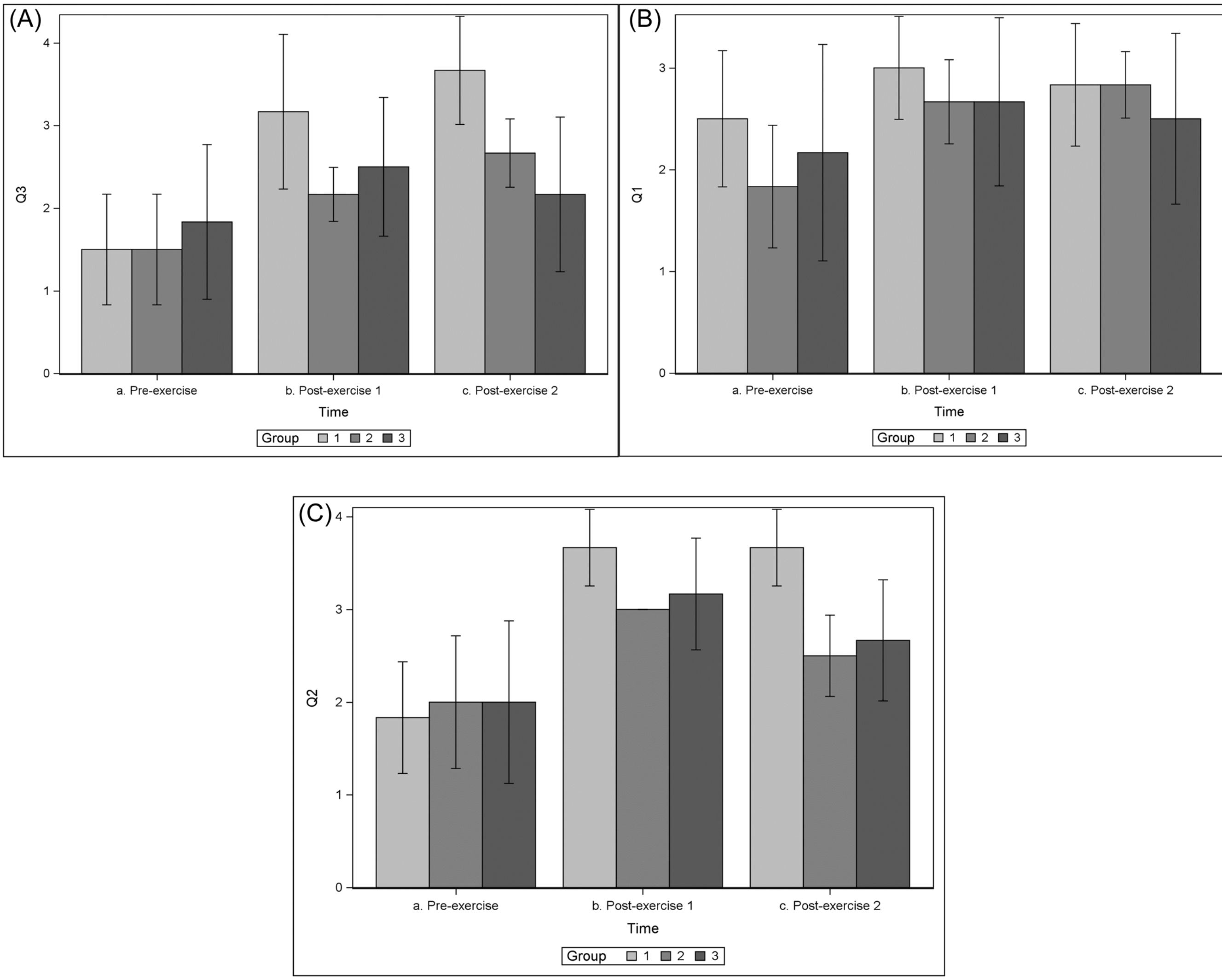

Figure 2. Bilobe flap competency responses from pre-exercise, postexercise 1, and postexercise 2. (A) Responses to Q1. (B) Responses to Q2. (C) Responses to Q3.

at the end of exercise 1 for Q2 (1.2, $P = .016$), but this was not sustained on their repeat performance for exercise 2. Interestingly, Q2 was the only domain where all groups shared a significant improvement on their postexercise 1 survey. This suggests that the lecture portion did help with trainee's perception of confidence, likely due to the immediate temporal relationship between the lecture and the activity.

These findings partially support our primary hypothesis that direct feedback leads to higher subjective scores versus those receiving delayed or no feedback, as demonstrated by the higher and statistically significant scores seen for both Q2 and Q3 in Group 1. However, Group 2 did report higher levels of knowledge for Q1, which would partially go against the leading hypothesis. This may be explained by Group 2 having a lower pre-exercise score in this domain compared to Group 1 (1.8 vs 2.5, respectively). Additionally, while difficult to control, those in Group 2 may have used the extra time between exercise 1 and soliciting feedback to develop more refined questions during their feedback session. Interestingly, there was no difference in the subjective domains between groups when examined at each time point independently. This would suggest that while Group 1 had the most significant level of improvement in terms of bilobe knowledge and confidence, the overall scores were not statistically different between groups. Within the psychology literature, evidence shows that while trainees who receive feedback during or after an exercise improve their overall performance when repeated at a later date, those who receive feedback during their performance showed a higher level of improvement than those who received feedback after the performance.[23] While the design of this study is inherently different, the same principle can applied in that having true feedback is better than no feedback, and that the timing and content of the feedback do have an influence on subsequent performance.[24-26]

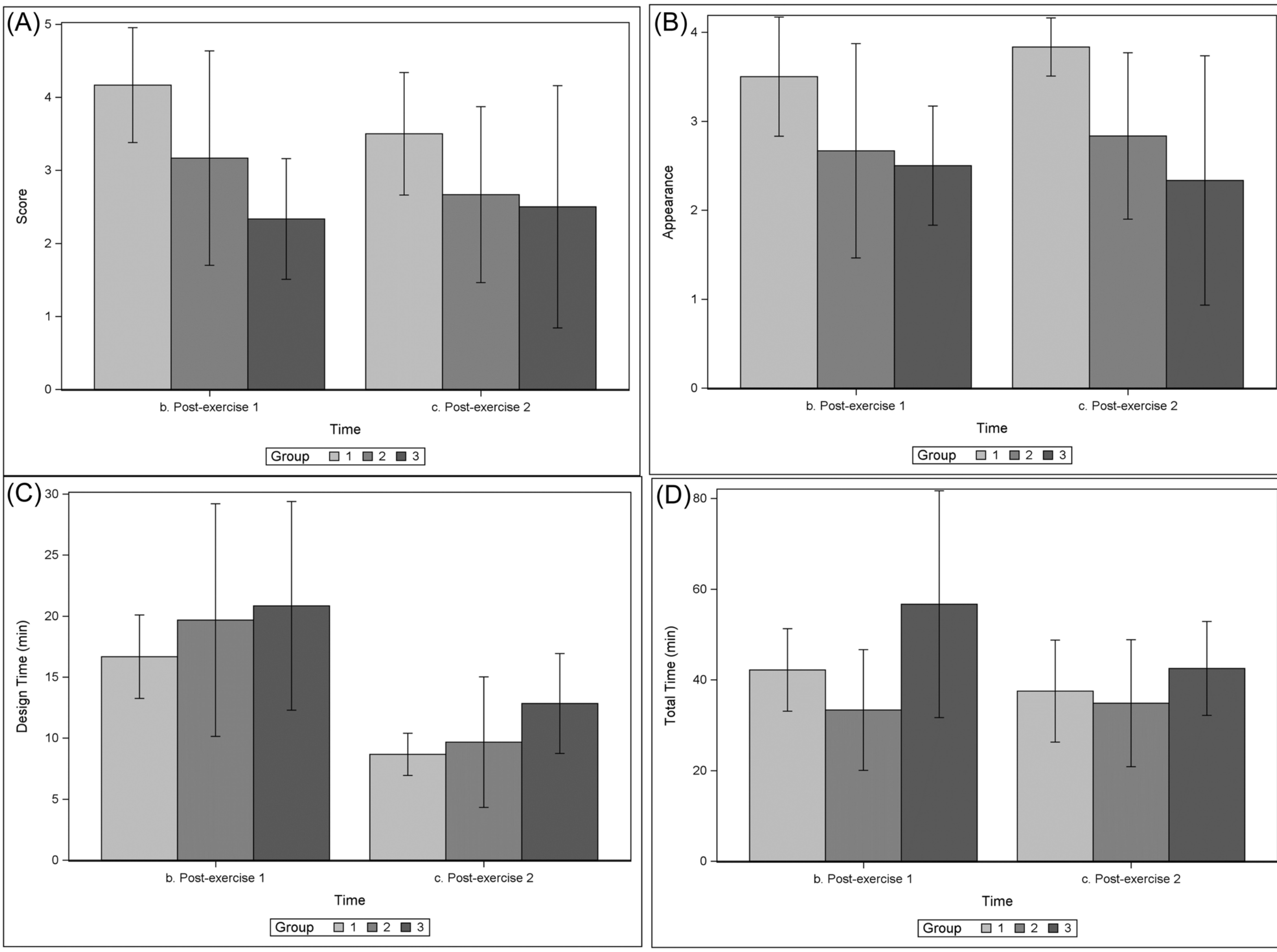

Figure 3. Objective domains from pre-exercise, postexercise 1, and postexercise 2. (A) Score. (B) Appearance. (C) Design time. (D). Total time.

Regarding objective parameters, Group 1 and Group 2 demonstrated a statistically significant decrease in their time to design the bilobe flap (8 minutes, $P = .007$ and 10 minutes, $P = .042$, respectively), though total time was not significantly different for either group. Group 3 showed no statistically significant improvement or worsening in their design time and total time. This suggests that lecturing alone without any type of feedback does not improve trainee design speed, and within the parameters of our study, any improvement from this group is likely from the general benefit of task repetition. In isolation at each time point, there were no statistically significant differences between groups. Again, this would partially support our initial hypothesis since Group 1 did have a significant improvement in at least design time when compared to baseline, but this was also shared with Group 2. One explanation for this can be found from the higher-scored subjective responses from Group 1. This would support some findings in the literature that trainee self-perception influences certain objective outcomes in surgery.[27,28] For example, one study showed decreased knot-tying performance in surgical residents under high-anxiety conditions.[27] While we did not account for the level of stress in this study, it could be extrapolated that those with reported lower levels of confidence and knowledge are likely to feel more "stressed," which may affect their overall performance. Additionally, there was no improvement in the total amount of time for the exercise in any group. Intuitively, we would anticipate that the total time required per exercise would decrease with an increase in total number of exercises performed. With only 1 additional exercise on a complex task such as designing and performing a bilobe flap, our data would likely not capture any true differences in total time.

This same complex interplay appears to also be involved when examining group differences between total objective score and overall appearance of the bilobe flaps. Among all groups, there was no difference in overall appearance and score after exercise 1 and exercise 2. Additionally, there was no statistically significant improvement or worsening of these objective parameters among all 3 groups. As such, this finding opposes the primary hypothesis. In other words, those who received in-person feedback were no different in terms of the

Table 3. Pre-Exercise and Postexercise Group Responses on Bilobe Flap Competency

Domain	Pre-exercise: Mean (SD)				Postexercise 1: Mean (SD)				Postexercise 2: Mean (SD)			
	Group 1	Group 2	Group 3	P value	Group 1	Group 2	Group 3	P value	Group 1	Group 2	Group 3	P value
Q1[a]	2.5 (0.8)	1.8 (0.8)	2.2 (1.3)	.532	3 (0.6)	2.7 (0.5)	2.7 (1)	.687	2.8 (0.8)	2.8 (0.4)	2.5 (1)	.701
Q2[a]	1.8 (0.8)	2 (0.9)	2 (1.1)	.937	3.7 (0.5)	3 (0)	3.2 (0.8)	.107	3.7 (0.5)	2.5 (0.5)	2.7 (0.8)	.014
Q3[a]	1.5 (0.8)	1.5 (0.8)	1.8 (1.2)	.789	3.2 (1.2)	2.2 (0.4)	2.5 (1)	.204	3.7 (0.8)	2.7 (0.5)	2.2 (1.2)	.028
Score[b]					4.2 (0.9)	3.2 (1.8)	2.3 (1)	.092	3.5 (1)	2.7 (1.5)	2.5 (2.1)	.525
Appearance[c]					3.5 (0.8)	2.7 (1.5)	2.5 (0.8)	.275	3.8 (0.4)	2.8 (1.2)	2.3 (1.8)	.136
Design Time[d]					16.7 (4.3)	19.7 (11.9)	20.8 (10.7)	.743	8.7 (2.1)	9.7 (6.7)	12.8 (5.1)	.350
Total time[d]					42.2 (11.4)	33.3 (16.6)	56.7 (31.3)	.198	37.5 (14.1)	34.8 (17.5)	42.5 (12.9)	.673

[a]Question and rating scale from **Table 1**.
[b]Total score out of 6 points, described under Methods.
[c]Single score for overall appearance, described under Methods.
[d]Design time is defined as the total time in minutes used to mark and plan the bilobe flap. Total time includes design time plus the total amount of time in minutes to complete the exercise.

objective scoring and appearance of the bilobe flaps when compared to those who received delayed or no feedback. This finding is a testament to the complexity of performing a bilobe flap. While our results do show some subjective and objective improvement in certain groups, expertise is unlikely to be achieved after only attending a lecture and performing 1 prior exercise. This suggests that while the simulation is a helpful task overall, the exercise would need to be repeated several times in order to detect any differences. Furthermore, this lends support to the idea that interval training is the better model for surgical learning as opposed to mass training.[29,30] In essence, our study method was an example of a single training period (ie, mass training) followed by a test exercise several weeks later. Although our study design did not account for this (ie, short, spaced-out practice sessions versus a long, single-day practice session), our results may guide future study designs. For example, performing 1 bilobe flap per week may be a better educational model as opposed to performing several in a single day.

While 3D printing for otolaryngology trainee education has been primarily reported as early as 1997 for temporal bone simulation,[9] its use within the field of facial plastic surgery for education in soft tissue and local flap reconstruction has been limited. To our knowledge, the first use of 3D printing in general for craniofacial reconstruction was in 1989 for presurgical planning and practice of complex bony defects.[31] For soft tissue reconstruction, the earliest study was in 1995 studying personalized 3D-printed cleft lip and palate models in 2 infants,[32] then later in 2009 as a proof of concept model for training in rhinoplasty.[33] However, it was only in 2015 that 3D-printed facial models were first studied with a group of trainees, specifically for teaching cheiloplasty in a cleft lip model.[34] In another study from 2017, trainees freely practiced on a 3D-printed face, though there was no subjective or objective reporting in this study. The most recent study on 3D-printed facial flap simulators was by Yang et al in 2021 where they showed after a single exercise that those who had performed an O-T flap and rhombic flap using a 3D-printed model reported a statistically significant increase in self-reported expertise in facial flap procedures versus those who had only used paper and pen illustrations.[14] Our study results would support their findings that the use of 3D-printed facial models does improve trainee confidence in performing local facial flaps. Expanding on this area of surgical simulation research and specifically for local facial reconstruction, our study is unique for a few reasons. First, we aimed to simulate a possible "social distancing" scenario where a trainee would attend a lecture, perform an exercise that could be completed at home, and then receive feedback at a later time. While logistically this exact study environment could not be achieved, Group 2 was created with this goal in mind in order to compare to the traditional in-person feedback or no-feedback scenarios. Second, we describe a method for objective grading on these models and provide descriptions of their meaning. Third, we assessed trainee retention of skills by having a second exercise performed individually without feedback and were able to compare against a control group.

Limitations

The findings of this study should be evaluated in the context of a few study limitations. First, we acknowledge the limited sample size per group and the implications this has for statistical analysis. As a result, we were underpowered to make meaningful analyses if we performed a sub-analysis stratified by training level. Second, the experience with using a 3D printer may not be applicable to centers without a simulation center trained in this technology, though its use is becoming more widespread. Regarding the survey items, in retrospect, Q1 was likely not a valid question for this pilot study as the lecture did not cover all possible types of nasal reconstruction. Future studies on this topic would rework the survey questions to better reflect the lecture content. In addition, there was no standardized distance or angle for the photographs used, which may have limited comparison between models during the grading process. Furthermore, we acknowledge that the various communication methods presented for Group 2 for their delayed feedback, while intentional, may have contributed to within-group variability. Also, we recognize that texting is not the ideal form for providing feedback. However, Group 2 was meant to reflect the variability in surgical training and feedback, and how communication methods may have been limited during COVID. We also acknowledge that subjects may have been influenced by the design of the first exercise during the second exercise since both were performed on the same model, though it is unclear within this study how much of an effect this truly had on performance. Related to this point, while only the subject identification number was associated with each image for the objective grading portion of each exercise, the instructing author was not fully blinded since the same models were used for each exercise and their photographs were not standardized. Though intentional in design, this effect was more apparent following the first exercise as the instructing author needed to use the photographs from exercise 1 to provide feedback for Group 2. Lastly, it has yet to be studied whether the skills obtained from these specific exercises influence surgical performance. For future investigations we would aim to address the above limitations by including more refined survey questions regarding lecture content, providing new models for each exercise, standardizing the photographs for feedback and grading, increasing power through a multi-institutional effort, and including multiple blinded reviewers.

Conclusion

Our study shows that the use of a 3D-printed facial simulator allows for improved trainee confidence in performing a bilobe flap for local nasal reconstruction of alar defects. While receiving feedback does improve trainee confidence in performing a bilobe flap, those who receive live feedback may have more of a benefit. There was a near-equal improvement in design time only for those who received feedback, though the total time for the exercise was not different between groups. The feedback technique did not influence the objective score or appearance of either exercise. Given our findings and within the context of our limitations, we advocate that, if implemented, the use of similar 3D-printed models for bilobe flap repair is best utilized for the live, interpersonal setting when possible.

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Author Contributions

Aryan Shay, Conception, literature review, design, data acquisition, data analysis, data interpretation, manuscript drafting, presentation; **Isabella Zaniletti**, data analysis, data interpretation, manuscript editing; **Hannah Coffman**, literature review, data acquisition, manuscript editing; **Sagar Mehta**, data acquisition, data interpretation, manuscript editing; **Gresham Richter**, design, data interpretation, manuscript editing.

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Supplemental Material

Additional supporting information is available in the online version of the article.

ORCID iD

Aryan Shay http://orcid.org/0000-0002-0220-0757

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