Low Risk, High Impact: 3-D Printed Fracture Models for Resident Education

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Introduction

As additive manufacturing (AM) becomes more ubiquitous, orthopaedic standards of care are also evolving towards patientspecific precision medicine.There exists a wide spectrum of clinical uses for AM within the operating room -from patient-specific implants, to single-use custom cutting guides.[1] The educational utility of 3-D printing should not be overlooked. For cases involving trauma, 3-D models of bone fractures can be created quickly and cheaply using CT or MR images.These models can serve as valuable teaching tools, as they allow learners to manipulate and reduce the fracture in a low-risk, low stress scenario. This may improve confidence and visuospatial skills that are required during surgery. Currently, there is a lack of data describing the impact of these tools on resident trainee competence.[2,3] The objective of this study was to quantify the influence of tactile learning on resident trainee performance during a variety of trauma-based operations. It was hypothesized that pre-operative utilization of AM models by a resident population would lead to improvements in confidence, accuracy, and efficiency in the operating room, as indicated by Ottawa Surgical Competency Operating Room Evaluations (O-Scores).[4]

Methods

This preliminary (Institutional Review Board-approved) study involved 7 learners that performed a total of 34 surgical procedures. Trainees performed the same procedure on two separate patients.The first surgery (n = 17) was performed in the absence of supplemental learning tools (i.e. AM models). For the second surgery, cases were randomly assigned to either receive a 3-D printed physical model of the fractured bone (n = 11) or to omit it (n = 6). Briefly, the following procedure was used for "second surgeries": An algorithm randomly determined whether the trainee would receive a 3-D printed model of the fracture or if they would serve as a control. If selected for an AM model, pre-operative CT scans of fractures were scrubbed of all patient-identifying information and submitted to the research lab. CT scans were segmented, converted into 3-D renderings, and printed with 0.125 mm resolution. The physical models were provided to the trainees at least 24 hours before surgery. Following surgery, the attending surgeon evaluated the ability of the trainee to independently perform the surgical procedure with an O-Score. This scale uses a 1-5 rating in 8 different categories. An overall average score of 1 indicates that the trainee needed total hands-on guidance from the attending surgeon or was unable to perform the procedure. An average score of 5 indicates that the learner performed the procedure without any guidance. Shapiro-Wilk tests were performed to test for normality. For non-Gaussian data, a MannWhitney-Wilcoxon Test was performed to identify potential differences between groups. Otherwise, two-tailed, equal variance t-tests were used to assess unknown responses across groups.The significance level was set at $p < 0.05$ and post-hoc Bonferroni corrections were used.

Results

A significant improvement in O-Score was observed between the first and second case for resident trainees who received physical models (P-value = 0.0004, Table 1). Specifically, the average O-score was 2.43 ± 0.91 for the first case

Table 1.

Category	Control Case 1	Control Case 2	AM Model Case 1	AM Model Case 2
Preprocedure Plan	2.83 ± 0.98	2.83 ± 0.75	2.09 ± 0.83	3.73 ± 0.65
Case Preparation	2.67 ± 0.82	2.67 ± 0.52	2.36 ± 0.67	3.55 ± 0.52
Knowledge of Procedural Steps	2.83 ± 1.17	3.00 ± 0.63	2.45 ± 1.13	3.73 ± 1.01
Technical Performance	2.83 ± 0.75	2.83 ± 0.75	2.36 ± 1.12	3.73 ± 1.01
Visuospatial Skills	1.67 ± 0.52	1.67 ± 0.52	1.82 ± 0.75	4.18 ± 0.87
Postprocedure Plan	3.33 ± 0.82	4.00 ± 0.00	3.55 ± 1.04	3.82 ± 0.40
Efficiency and Flow	2.67 ± 0.82	2.50 ± 0.55	2.27 ± 0.79	3.55 ± 0.82
Communication	2.67 ± 0.52	2.67 ± 0.52	2.55 ± 0.93	3.55 ± 0.69
O-score	2.69 ± 0.80	2.77 ± 0.53	2.43 ± 0.91	3.73 ± 0.75

and 3.73 ± 0.75 for the second case. A significant difference in O-score was not observed for the control cases (p-value = 0.799), with small changes in average scores between first and second cases (2.69 ± 0.80 and 2.77 ± 0.53, respectively). Significant increases in sub-scores were observed in 7 of 8 categories for the group that received physical models. Most notably, visuospatial skills showed the greatest increase in rating for the physical model groups, with average ratings increasing from 1.82 ± 0.75 to 4.18 ± 0.87 between the first and second case (p-value = 0.0001). In addition, pre-operative planning ratings were greatly improved in the physical model group between the first and second case, with the average ratings increasing from 2.09 ± 0.83 to 3.73 ± 0.65. The only rating that did not significantly improve in this group was "post-operative plan," which only increased marginally. There were no significant differences in ratings for all 8 categories in the control group.

Discussion

The results from this study suggest that AM models are an excellent addition to the education curriculum for resident surgeons. The immense improvement in visuospatial rating in particular, which involves mastery of positioning instruments as intended, demonstrates the importance of catering to a variety of learning styles. Although it was not a primary outcome measure, it should be noted that the 3-D models were inexpensive to create. Models typically cost < $10 of material to build. There are several limitations associated with this study. First, the pool of learners was relatively small, and years of residency experience varied (PGY-2 through PGY-5). Because this study was performed in the trauma department, many different injuries with varying fracture complexity were included in the dataset. Even when considering these shortcomings, the results of this study show that 3-D printed models provided effective tools which may improve overall outcomes. In the future, we plan to continue this study to strengthen these preliminary results.

Significant/Clinical Relevance

The results of this study demonstrate the ease and utility of AM models of fracture for improving resident trainee comprehension and performance during surgery.

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