

Francesco Addeviso<sup>1</sup>, Landon Tujague<sup>2</sup>, Benjamin Lee<sup>2</sup>, Emily Venable<sup>2</sup>, Patrick Massey<sup>2</sup>, R Shane Barton<sup>2</sup>, Massimo Max Morandi<sup>3</sup>, and Giovanni F. Solitro<sup>2</sup>  
<sup>1</sup>Azienda Ospedaliera Niguarda Ca' Granda, Mialn, Italy; <sup>2</sup>Louisiana State University Health Sciences Center, Shreveport, LA; University of Florida Health, Jacksonville, FL.  
giovanni.solitro@lsuhs.edu

**Disclosures:** Francesco Addeviso (None), Emily Venable (None), Benjamin Lee (None), Landon Tujague (None), Patrick Massey (None), R Shane Barton (None), Massimo Max Morandi (None), and Giovanni F. Solitro (None).

**INTRODUCTION:** Obtaining reliable screw fixation in bone constitutes a foundational skill to the orthopedic surgeon and training to place screws without stripping requires an effective application of biomechanical principles and repeated practice. Placing screws across bone fragments, or implants, such that maximal fixation is acquired at the bone-screw interface without compromising bony purchase requires a delicate balance of forces applied. Stripping at the bone-screw interface is a common intraoperative complication caused by axial failure of threads cut into bone due to misapplied torque that can lead to decreased pull-out strength, prolonged surgery times, additional hardware placement, or even hardware failure. While the incidence of bone stripping is not known, separate in-vitro studies reported stripping rates of 9% and 36% respectively. Current models for training screw placement involve placing screws into simulated bone using osteomimetic materials, typically ASTM F1839 regulated polyurethane foams, however, attempts to use 3D printed materials for simulations have shown promising results. One important specification of simulating screw insertion for orthopedics trainees is reproducing the haptics of stripping bone, such that trainees can learn to identify and avoid it in real time. Prior studies have shown immediate feedback in the form of a digital torque sensor to be effective at reducing bone stripping [10]. In the interest of being able to control this type of haptic feedback to simulate weaker or stronger bone in a 3D printed model, the current study aims to evaluate how different 3D printed infill patterns and their densities influence the torque at stripping (ST) and to correlate recorded torque values with those documented for various densities of ASTM F1839 regulated polyurethane foams. We hypothesized a proportionality between infill density and stripping torque for two infill patterns that have been considered.

**METHODS:** Bone surrogates were instrumented with 7mm diameter titanium cannulated screws with 20mm of threaded length and thread pitch of 2.1mm (Rondò, Citieffe, Bologna, Italy). The insertions were performed on bone surrogates with dimensions of 180mm × 30mm × 40mm pre-drilled with a 3.5 mm drill bit. The ASTM F1839 regulated polyurethane foams were chosen in densities of 10, 15, and 20 PCF (Sawbone, Vashon Island, Washington) in light of existing literature. The 3D printed surrogates were printed using 3D Honeycomb (see Figure 1a) and Gyroid (see Figure 1b) filling patterns and segmented in regions with increased infill density that ranged from 5 to 27% in 2% increments. The 3D printed models were designed in Autodesk Fusion 360 (Autodesk, San Francisco, CA) and made from Polylactic Acid (Beige, PLA) on a Prusa MK4 (Prusa Research, Prague, Czech Republic) with a layer height set to 0.2mm and top and bottom shell thicknesses of 1mm and 0.5mm, respectively. The instrumentation was performed by hand on an Intron E3000 bi-axial testing machine (Instron E3000, Norwood, MA). The load cell was mounted on a stage allowing free transversal movement while torque was recorded at a frequency of 100 Hz (see Figure 2). The screws were inserted until stripping and three repetitions were performed for each infill pattern and density. Linear regression was performed to evaluate the relationships between stripping torque and infill density. Paired T-test at 0.05 level of significance was used to identify differences between the two infill patterns.

**RESULTS:** The 3D Honeycomb infill ST ranged from 0.23Nm±0.02 for 5% density to 3.89Nm±0.14 for 27% density infill and a highly linear correlation was found between infill density and stripping torque ( $R^2=0.95$ ). The values found for the Gyroid infill were similar ( $p=0.294$  on paired T-test) and ranged from 0.32Nm±0.06 to 3.68Nm±0.46 for 5% and 27% infill respectively with an  $R^2$  of 0.94. The ST values found for the instrumentation of 3D printed surrogates were able to overlap the ST values of 0.54Nm±0.06, 1.44Nm±0.23, and 3.08Nm±0.53 found for 10, 15, and 20PCF ASTM F1839 regulated foam densities.

**DISCUSSION:** The results obtained in the current study suggest feasibility of 3D printed surrogates use in surgical training targeted to screw insertion. While bone surrogates are limited in the number of available densities, the proportionality found between stripping torque and infill density creates opportunities for increased number of training scenarios. The study's main limitation is given by the fact the screws were inserted along a single direction coherent with the axis along which the patterns are designed and printed. Therefore, these results can have a direct implementation in the surgical training of screw placements in specific known directions. Experiments involving screws at other inclinations are still needed to generalize the use of 3D-printed surrogates for screw insertion training.

**SIGNIFICANCE/CLINICAL RELEVANCE:** Simulation is an essential element of surgical training and screw stripping in bone instrumentation is a challenging intraoperative complication. While transfer validity remains to be proven, the results found open to the training of 3D printed surrogates.

**ACKNOWLEDGEMENTS:** We would like to thank Mr Alan Ogden for the assistance given in the execution of the experiments.

IMAGES AND TABLES:

