**INTRODUCTION:** The development of perfusable tissue-engineered microvasculature would substantially advance the creation of human tissue for reconstructive surgery, as engineered tissues are currently limited in size by the diffusion of nutrients and oxygen. Much of this stems from the challenge of generating large, experiment-specific bioreactors for microvascular constructs, as current commercially-available perfusion chambers cost hundreds to thousands of dollars each. We have developed a low-cost perfusion device that uses glass coverslips and poly-dimethylsiloxane to create a sterile chamber for perfusion culture of collagen-based cellular constructs, enabling repeated live-imaging of 3D engineered tissues. Our model facilitates the pursuit of reliable microvascular networks for the development of tissues for human body repair and advancement of “body-on-a-chip” research for personalized medicine.

**METHODS:** 3D-modeling software (Fusion 360) was used to design molds and frames, which were printed on a 3D printer (Prusa i3 MK3S) in poly-lactic acid (PLA). Positive molds were filled with poly-dimethylsiloxane, which was cured to form chambers, as well as several other necessary perfusion circuit components, including bubble traps, mason jar lid chambers, and media reservoir lid adapters.

**RESULTS:** Two types of perfusion chamber were built for under $8 per device and reused repeatedly. The current tissue culture devices were built with 18 × 10 × 4 (L × W × H) mm³ or 18 × 18 × 4 mm³ dimensions, and the chamber size was readily customizable to meet the needs of individual experiments. The devices supported static and perfusion cell culture without contamination, and live imaging was demonstrated during static culture. During perfusion, the devices withstood flow rates that replicated arterial intra-luminal shear stresses (15 dyne/cm²) without leakage. Devices permitted intermittent imaging with light, fluorescent or confocal microscopy, which offers substantial benefit for monitoring of experiments and collection of imaging data at multiple timepoints. Notably, the novel bubble trap successfully prevented large and small bubbles from reaching the cellularized devices, which is crucial as these bubbles can damage cells and block microchannels. The perfusion circuit also included a lid adapter, which enables 50 mL conical tubes to serve as self-oxygenating media reservoirs, and these lids allowed cell culture media to be exchanged with sterile syringes.

**CONCLUSIONS:** 3D printing has substantially increased the ability for plastic surgeons to address the problems that they face, both in the operating room and in research. Through rapid prototyping of tissue culture devices, we have enhanced caregiver understanding of craniosynostosis anatomy more so than 2D models. Based on this information, we recommend surgeons consider the unique advantages of these models as a powerful communication tool during patient consultations for improved caregiver understanding of craniosynostosis.

**Live Imaging Tissue Culture Made Easy: A Novel Device for Perfusion Cell Culture and Live Imaging**

**Presenter:** Ryan Bender, BS

**Co-Authors:** Xue Dong, MD, PhD, Jason Harris, MPH, Sarah Caughey, BA, Nabih Berri, MD, Jason Spector, MD

**Affiliation:** Weill Cornell Medicine

**RESULTS:** A total of 73 self-identified craniosynostosis caregivers completed the survey [mean age 32 ± 5 years, majority White (94%) and women (71%)]. ANOVA testing demonstrated that caregivers ranked 3D-printed and AR models significantly higher than 2D models for learning about craniosynostosis anatomy (P < 0.05) and increasing their trust in surgeons (P < 0.05). In terms of ease of caregiver anxiety, both the unicoronal and bicornal AR models were rated as more innovative (P < 0.05) than their respective 2D models. 3D-printed models were seen as equally realistic and innovative compared with AR or 2D models.

**CONCLUSIONS:** Our findings indicate that both 3D-printed and AR models can enhance caregiver understanding of craniosynostosis anatomy more so than 2D models. Based on this information, we recommend surgeons consider the unique advantages of these models as a powerful communication tool during patient consultations for improved caregiver understanding of craniosynostosis.

**Live Imaging Tissue Culture Made Easy: A Novel Device for Perfusion Cell Culture and Live Imaging**

**Presenter:** Ryan Bender, BS

**Co-Authors:** Xue Dong, MD, PhD, Jason Harris, MPH, Sarah Caughey, BA, Nabih Berri, MD, Jason Spector, MD

**Affiliation:** Weill Cornell Medicine
developed a low-cost tissue-engineering perfusion circuit that facilitates the growth of large cellular constructs while enabling repeated live-imaging. Our devices can easily be replicated, with an ease of customization that makes them vitally effective for bench-to-bedside translational research. Our devices allow us to move toward the in vitro generation of vascularized tissue flaps that would facilitate reconstruction of the human body without donor-site morbidity.

Implementation and Utilization of a 3D Printed Hand Surgical Simulator for Surgery Residency Education

Presenter: Daniel Farrell, BA

Co-Authors: Seth Noorbakhsh, BA, Travis Miller, MD, Justin Chambers, PhD, W. Thomas McClellan, MD, FACS

Affiliation: West Virginia University

PURPOSE: Work-hour restrictions, increasing breadth of knowledge required of trainees, and the desire to optimize patient safety have driven surgical residency programs to incorporate more simulation learning into their curriculums.1 We designed and created a polychiaction 3D-printed hand training model that is anatomically accurate based on CT scan to be incorporated in surgical curriculums. The model is customizable, with the ability to incorporate different types of fractures in each hand bone.2 Our goal was to analyze the effectiveness of the device in an educational setting amongst a population of plastic surgery residents.

METHODS: Seventeen residents of Stanford University’s integrated plastic surgery program tested the models via a 1-hour learning session. The models given to each resident included an oblique 5th metacarpal shaft fracture, transverse 5th proximal phalanx fracture, oblique 5th middle phalanx fracture, transverse 5th dorsal phalanx tip fracture, 4th metacarpal neck fracture, spiral 4th proximal phalanx fracture, and oblique 4th distal phalanx fracture. Participants were asked to perform reductions of the polyfracture models via different techniques, including CRPP, lag screw placement, and open reduction with dorsal plating. Participants were then asked to assess their results utilizing c-arm fluoroscopy and adjust fracture reduction accordingly. Data were recorded with a pre- and post-session survey to assess the educational utility of the device and then analyzed via paired T-tests.

RESULTS: Seventeen residents participated in the study, ranging in age from 26 to 36 (mean = 30.18) and in training from PGY1 through PGY6 (mean = 3.18). Residents reported (via five-point Likert scale) statistically significant improvement of mean scores in the following competencies before and after the session: level of comfort utilizing a surgical power drill (Pre = 3.41 Post = 4.12, P = 0.018), tactile feedback to drill bone (Pre = 3.12 Post = 3.94, P = 0.008), spatial reasoning to control drill (Pre = 2.76 Post = 3.88, P = 0.003), avoiding plunging though bone (Pre = 2.82 Post = 3.76 P = 0.001), hand fracture reduction techniques (Pre = 2.71 Post = 3.65 P = 0.003), placing lag screws (Pre = 2.41, Post = 3.35, P = 0.003), and explaining the basics of internal fixation to another resident surgeon (Pre = 2.59, Post = 3.65, P = 0.001). Residents additionally agreed with statements on the post-session surveys such as: “This simulator would help residents with spatial reasoning skills” (4.65/5) and “I would recommend residency programs utilize this device in their curriculum” (4.71/5).

CONCLUSIONS: This study shows that our hand simulator can be an effective tool in surgical residencies to simulate hand fracture management and to hone the basic psychomotor and visuospatial skills needed to be a competent surgeon. Common hand surgery skills, such as proprioception while drilling bone and visuospatial orientation while utilizing fluoroscopy, translate well in multiple operative settings. Our device’s low cost, reusability, and ability to represent a wide range of fractures show that it has the potential to replace other surgical simulators in training curriculums. Further study of a longitudinal curriculum is warranted.

REFERENCES:
1. Akhtar KSN, Chen A, Standfield NJ, et al. The role of simulation in developing surgical skills. *Curr Rev Musculoskelet Med* 2014;7:155–160.
2. Farrell DA, Miller TJ, Chambers JR, et al. Three-dimensionally-printed hand surgical simulator for resident training. *Plast Reconstr Surg*. 2020;146(5):1100–1102.

3D-printed Positioning Guide: A New Design in Virtual Surgical Planning of Craniosynostosis Surgical Correction

Presenter: Katelyn Lewis, BS

Co-Authors: Alexandria R. Waler, MD, Daniel Brock, BSME, Rajendra Sawh-Martinez, MD, MHS