SENSORIZED WRIST MODEL FOR TEACHING FRACTURE REDUCTION

Keshav Garg, Andrew Baldys, Mensah Amuzu, Marshall Schlick

Advisor: Dr. John Puccinelli, PhD **Client:** Dr. James Stokman, MD

ABSTRACT

No teaching tool exists for physicians to learn the process of casting a distal radius fracture (DRF) with objective, real-time feedback. Sensorizing an existing DRF simulator allows for an effective way to communicate reduction quality to the user through a graphical user interface (GUI). Future utility of this device includes providing an enhanced means of developing orthopaedic residents' technique, declaring objective competency of casting, and contributing data on appropriate casting forces and reduction angles required for satisfactory treatment of a distal radius fracture.

BACKGROUND

Motivation

- Distal radius fractures account for one-sixth of the injuries treated in an orthopaedic setting [1]
- A 2018 study of 8924 subjects found that the average cost of a closed-reduction DRF treatment is $2161 [2]
- Improper casting commonly causes bone malunion that could be mitigated with training [3]
- Training feedback is subjective, non-interactive, and delayed [4]
- No data exists which quantifies the casting procedure [5]

Current Methods

- Three-point molding technique (Fig. 1) used to align and reduce fragmented radius before casting [6]
- Trainees practice on life-like simulators, a common model being the Sawbones® distal radius fracture model [7]
- Not all facilities have access to fluoroscopy (live X-ray) for verification

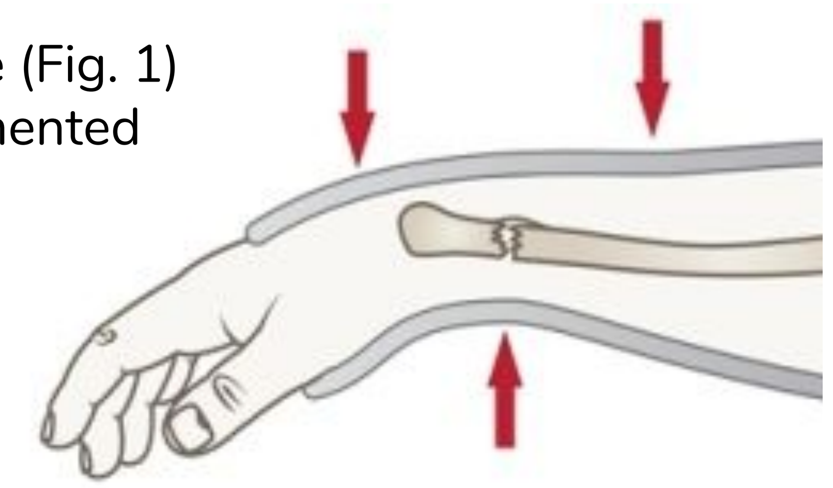


Figure 1. Red arrows indicate applied forces [6].

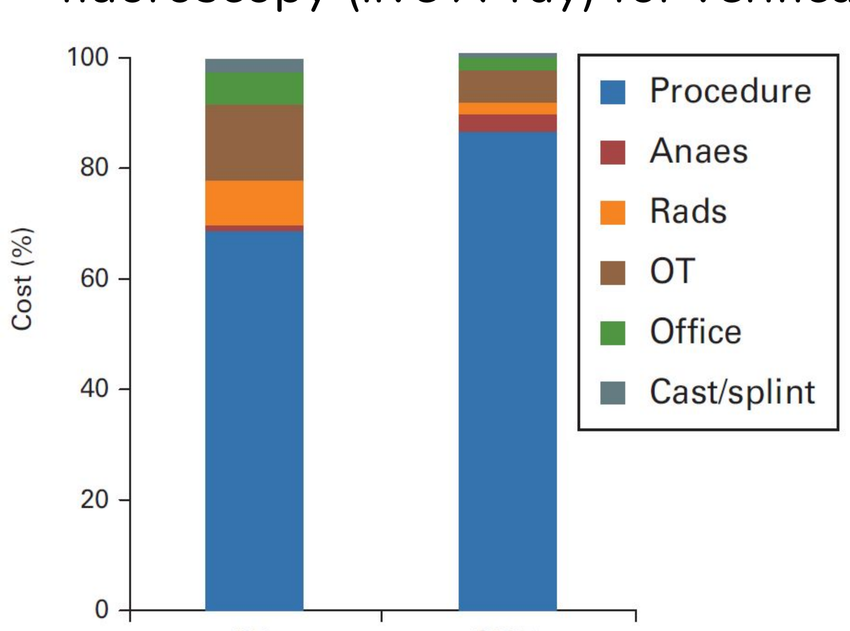


Figure 2. Division of cost for various aspects of a closed-reduction (CR) and open-reduction internal-fixation (ORIF) treatments of distal radius fractures [2].

Market Analysis

- Market consists of 154 orthopaedic residency programs nationwide with 3,300 current students and 640 entering yearly [8]
- Increasing demand for real-time objective feedback to facilitate smoother transitions between medical school and medical practice
- High projected ROI for programs that implement medical simulators [9]

Design Requirements

- Simulated depiction of fracture angle must be accurate to ±2°
- GUI must indicate intensity/position of force applied to fracture site
- Simulator must maintain physiological accuracy and withstand repeated castings to produce replicable readings over time

FINAL DESIGN

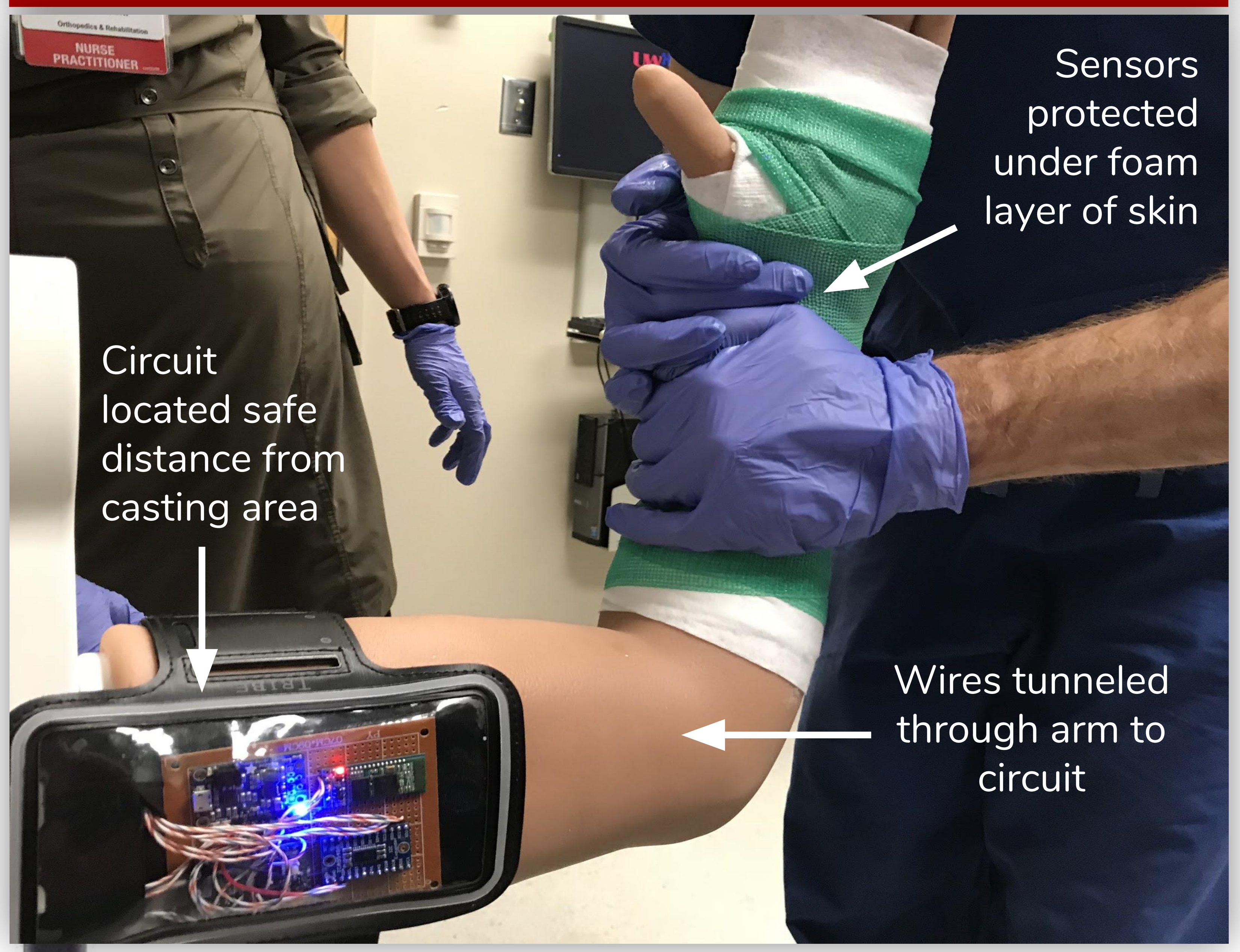


Figure 3. Trial of casting procedure at UW Hospital. Angle and force data acquired by implanted sensors, processed by attached circuit, and sent to computer for storage.

Design Summary

- Force-sensing linear potentiometer (FSLP) implanted in dorsal side of hand to measure amount/position of force
- Two inertial measurement units (IMUs) fixed to palmar side of radius communicate to determine angle of reduction
- Teensy 3.2 reads FSLP force values and IMU angle data
- GUI displays simulated fluoroscopy and force visualization
- Data exported for analysis after trial is terminated

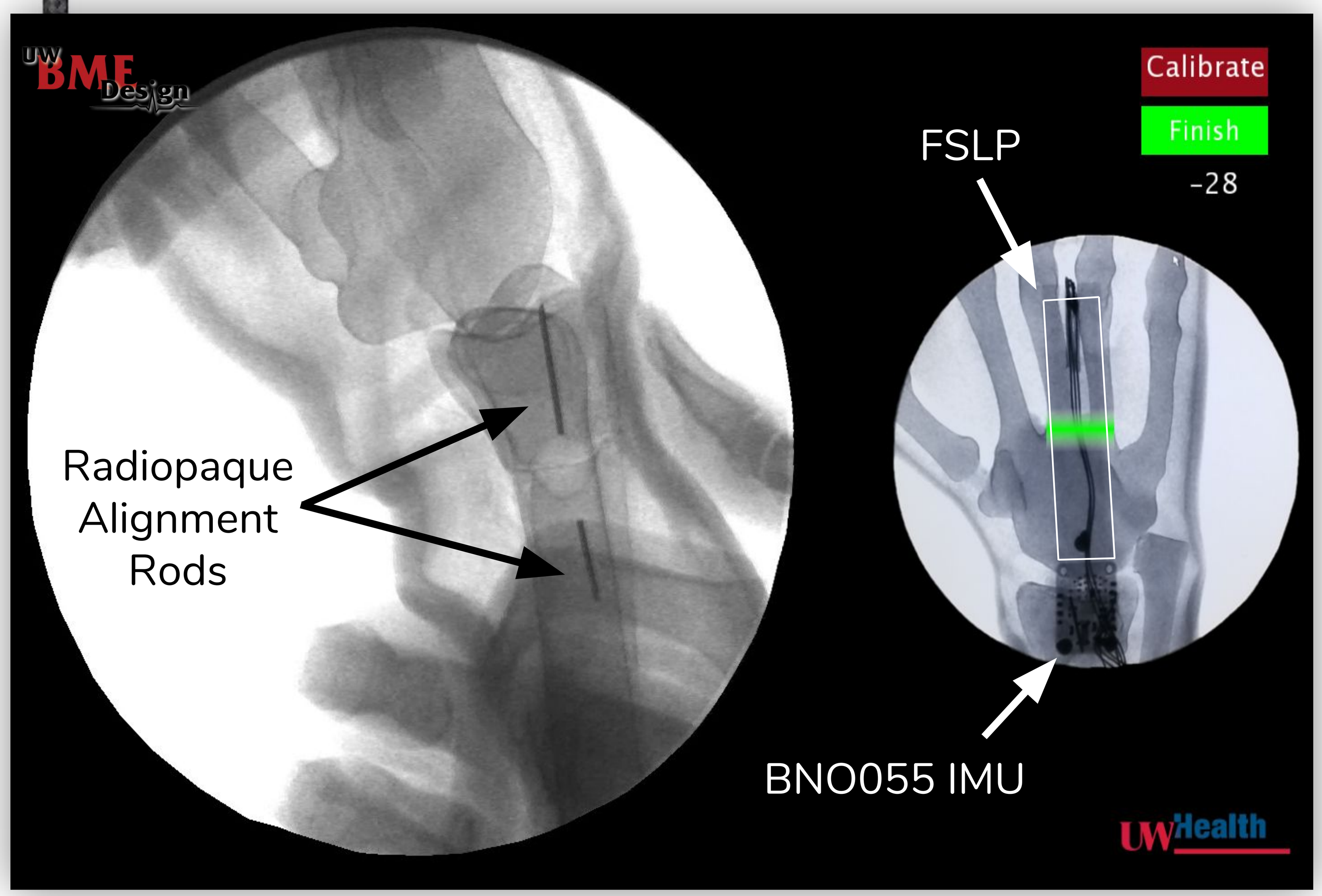


Figure 4. GUI displays real-time simulated fluoroscopy as well as a dynamic force indicator. System can be manually calibrated to match an expert physician's reduction.

TESTING / RESULTS

IMU Angle Validation

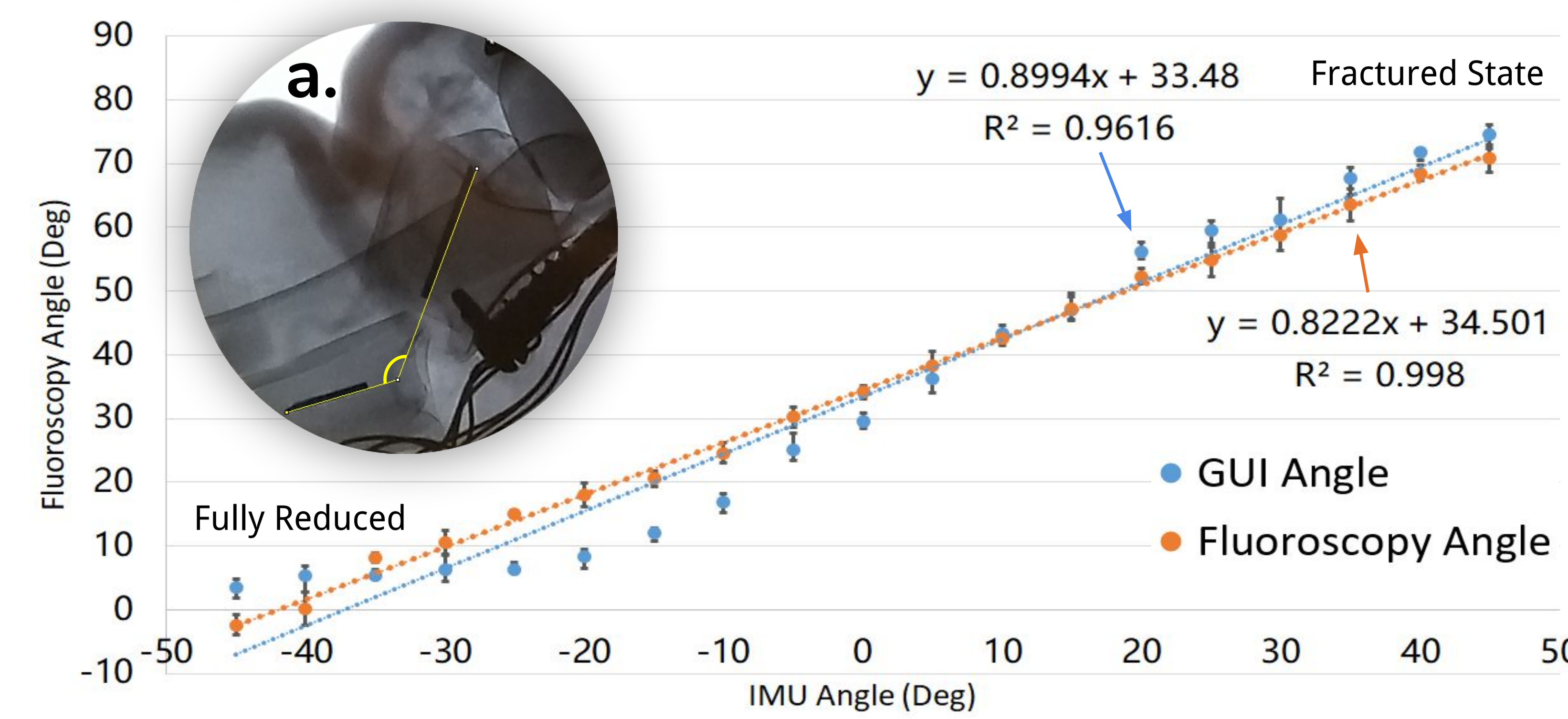
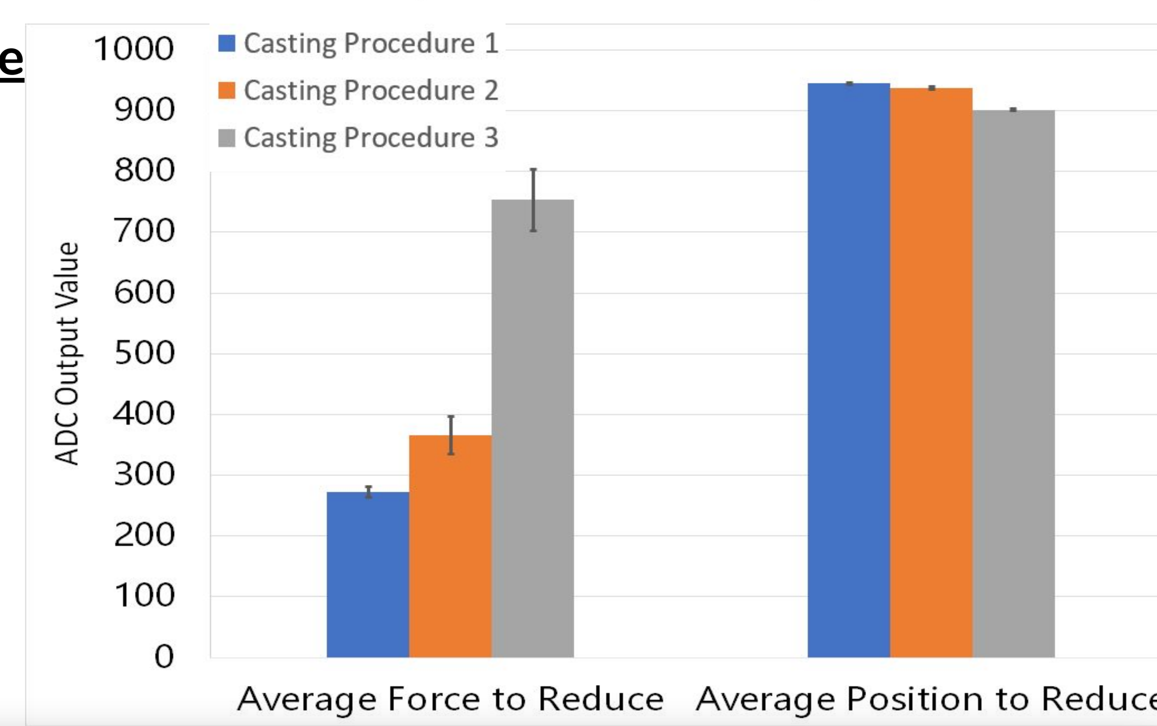


Figure 5. (a) Lateral view of model and ImageJ tools used to determine true fracture angles and calibrate IMUs. Graph depicts similarity between measured GUI angle and actual angle of model.

FSLP Data Capture

Figure 6. Data from expert physician casting procedures without GUI assistance. Average force and angle were calculated from each procedure.



FUTURE WORK

Data Collection

- Establish protocol for collection of normative expert data
- Prepare six models for Top Gun surgical simulation competition at the International Pediatric Orthopaedic Symposium (IPOS 2018)
- Evaluate casting data to determine whether real-time feedback is valuable and improves casting competency

Commercialization

- Partner with Sawbones® to incorporate sensors and simulated fluoroscopy into their simulator product line
- Develop casting education curriculum utilizing sensorized model
- Publish journal article in the Journal for Bone and Joint Surgery

ACKNOWLEDGEMENTS / REFERENCES

[1] J. Heckman, C. Court-Brown, P. Tornetta, K. Koval, and R. Bucholz, "Rockwood & Green's fractures in adults," *Philadelphia: Lippincott Williams & Wilkins*, 6th ed., 2006.
[2] E. Pang, J. Truntzer, L. Baker, A. Harris, M. Gardner, and R. Kamal, "Cost minimization analysis of the treatment of distal radial fractures in the elderly," *Bone Jt. J.*, vol. 100-B, no. 2, pp. 205–211, Feb. 2018.
[3] R. Meeson, C. Davidson, and G. Arthurs, "Soft-tissue injuries associated with cast application for distal limb orthopaedic conditions," *Schattauer*, pp. 1-6, 2011.
[4] A. Boyd, H. Benjamin, and C. Asplund, "Principles of Casting and Splinting", *Am. Fam. Physician*, vol. 79, no. 1, pp. 16-22, 2009.
[5] M. Halanski and K. Noonan, "Cast and Splint Immobilization: Complications," *Journal of the American Academy of Orthopaedic Surgeons*, vol. 16, no. 1, pp. 30-40, 2008.
[6] "Fracture Education: Management Principles," *The Royal Children's Hospital Melbourne*, 2012. [Online]. Available: http://www.rch.org.au/fracture-education/.
[7] "Colles Fracture Reduction and Casting Trainer," *Sawbones*, 2017. [Online]. Available: https://www.sawbones.com/.
[8] "How to Obtain an Orthopaedic Residency," *American Academy of Orthopaedic Surgeons*, 2018. [Online]. Available: https://www.aaos.org/.
[9] D. Bae, H. Lynch, K. Jamieson, C. Yu-Moe, and C. Roussin, "Improved Safety and Cost Savings from Reductions in Cast-Saw Burns After Simulation-Based Education for Orthopaedic Surgery Residents," *J. Bone Joint Surg. Am.*, vol. 99-A, Sept. 2017.

Special thanks to Dr. J. Stokman, Dr. J. Puccinelli, T. Jocewicz III, B.S., Dr. A. Nimunkar, Dr. K. Noonan, and Dr. M. Halanski