Sensorized Broken Wrist Model for Teaching Casting via Simulated Fluoroscopy

Team Leader:	Marshall Schlick
BSAC:	Mensah Amuzu
BPAG:	Andrew Baldys
BWIG:	Keshav Garg
Client:	Dr. James Stokman, MD
Advisor:	Dr. John Puccinelli, PhD

Background / Significance

- Distal radius fractures in the ER
  1⁄6 of all adult fractures treated (1⁄3 **of all pediatric**) [1,2]

- Three-point molding technique used to align and reduce fragmented radius before casting [3]

- Non-surgical fracture reduction has rate of 23.5% malunion [4,5]

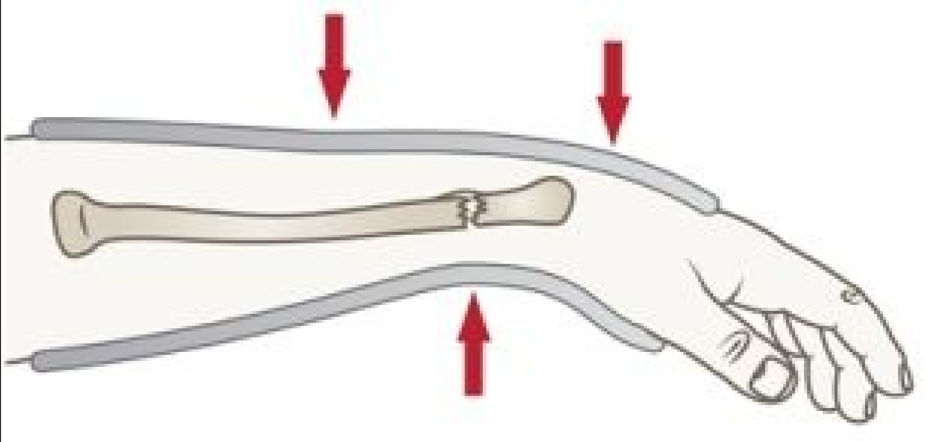

Figure 1. Red arrows indicate applied forces [6].

Problem Statement

- Students practice on life-like simulators (Sawbones®)
  Unaware of reduction angle or force applied during casting

- Current evaluation of procedure is subjective [7]
  Growing interest for testing casting competency [8,9]

- Create a simulator with accurate objective feedback

Figure 2. Colles' Fracture Reduction And Casting Technique Trainer [10].

Client Descriptions

- Collaborating with UW Orthopedic surgeons
  - Dr. Halanski is project's originator
  - Primary contact is Dr. Stokman
  - Dr. Noonan is chair of AAOS Pediatrics Program Committee

Figure 3. From left to right: Dr. Halanski, Dr. Stokman, and Dr. Noonan [11].

Design Requirements

- Design sensorized arm model to detect forces and fracture angles during casting
  - Force detection of 1-100 N (± 1 N accuracy)
  - Angle accuracy (± 2°)

- GUI to wirelessly display casting forces and reduction angles

- System must reliably withstand 300+ castings

- Rechargeable battery life: 15 hours of continued use

- Six prototypes desired
  Top Gun resident training competition at IPOS 2018

Previous Work

- Developed prototype compliant with PDS (Fall 2017)
- Force detection, data display on GUI, wireless connectivity
- Collected 11 trials from expert surgeons at IPOS
- Received feedback concerning sensor location and feel

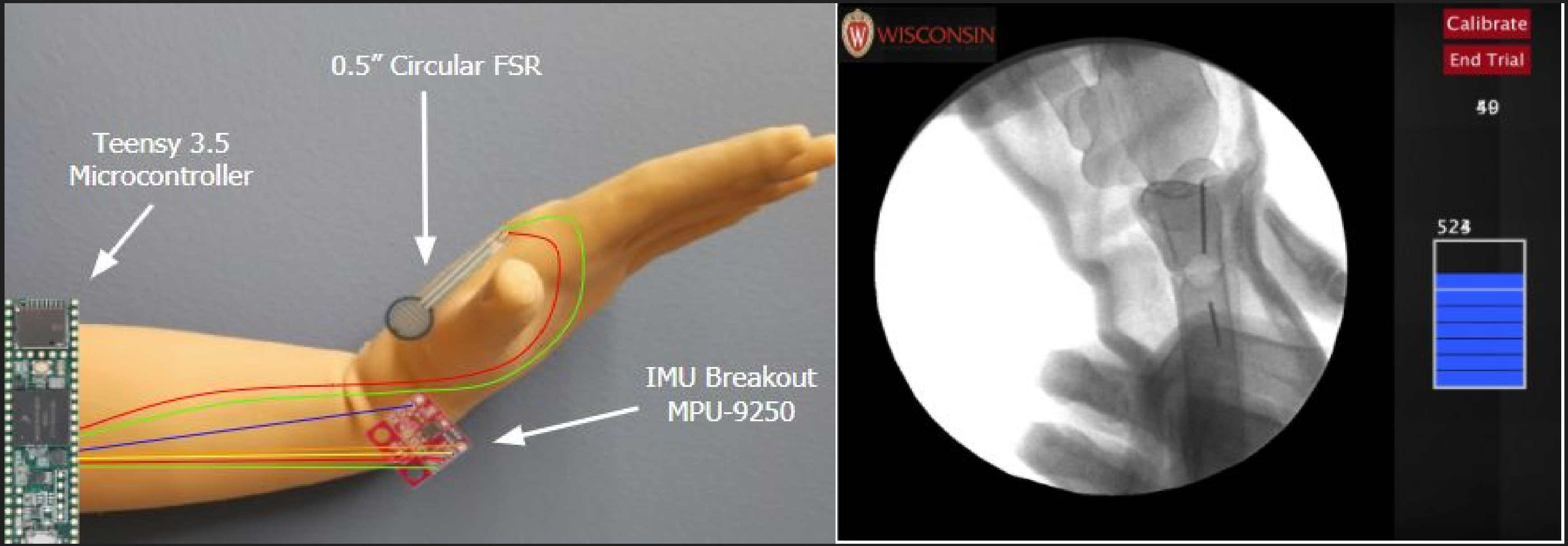

Figure 4: Lateral view of prototype with embedded sensors (left) and GUI display of simulated fluoroscopy (right).

Proposed Design Improvements

- Use magnetometer in IMU to find positional data from a localized magnetic field

- Install a force-sensing linear potentiometer (FSLP) to replace force-sensing resistor (FSR) = force and location data simultaneously

Figure 5. Stock photo of desired FSLP [12].

Testing and Evaluation

- Calibrate FSLP with MTS
- IMU Validation:
  - Angle accuracy
    - Compare IMU angle data to reduction angle under X-ray
    - Mean angle difference ± SD
  - Position accuracy
    - Multiple trials collecting 3D position of perfectly reduced model
    - Mean (x,y,z) positional data ± SD
- Evaluate casting competency of trainee using device

Figure 6. Dr. James Stokman reducing the previous model using the interactive GUI.

Testing and Evaluation

- Calibrate FSLP with MTS

- IMU Validation:
  - Angle accuracy
    - Compare IMU angle data to reduction angle under X-ray
    - Mean angle difference ± SD
  - Position accuracy
    - Multiple trials collecting 3D position of perfectly reduced model
    - Mean (x,y,z) positional data ± SD

- Evaluate casting competency of trainee using device

Figure 6. Dr. James Stokman reducing the previous model using the interactive GUI.

Testing and Evaluation

- Calibrate FSLP with MTS

- IMU Validation:
  - Angle accuracy
    - Compare IMU angle data to reduction angle under X-ray
    - Mean angle difference ± SD
  - Position accuracy
    - Multiple trials collecting 3D position of perfectly reduced model
    - Mean (x,y,z) positional data ± SD

- Evaluate casting competency of trainee using device

Figure 6. Dr. James Stokman reducing the previous model using the interactive GUI.

Logistics and Marketability

- Produced an instructional video for simulated fluoroscopy
- Collaborating with Sawbones to integrate this technology into their products
    - Colles' Fracture training model retails for $1,364.75
    - Modifications to model cost approximately $100.00
- Product would ideally come pre-calibrated out-of-the-box

Project Timeline

2/19 - 3/4

- **Receive materials**
- **FSLP calibration**
- **MPU9250 coding**

3/5 - 3/18

- **Implant components**
- **IMU validation**
- **Code alterations**

3/19 - 4/8

- **Casting competency evaluations (two phases)**
- **Device alterations**

4/9 - 4/22

- **Data analysis**
- **Prepare journal article for submission**

References and Acknowledgments

[1] J. D. Heckman, C. Court-Brown, P. Tornetta, K. J. Koval, R. W. Bucholz, and editors, "Rockwood & Green's fractures in adults," *Philadelphia: Lippincott Williams & Wilkins*, 6th ed., 2006.
[2] A. Abraham, H. H. Handoll, T. Khan, " Interventions for treating wrist fractures in children," *Cochrane Database Syst Rev.*, vol. 16, no. 2, CD004576, Epub 2008 Apr 16.
[3] "Fracture Education: Management Principles," *The Royal Children's Hospital,* Melbourne. [Online]. Available: http://www.rch.org.au/fracture-education/management_principles/ Management_Principles/.
[4] A. Elmi, A. Tabrizi, A. Rouhani, F. Mirzatolouei, "Treatment of neglected malunion of the distal radius: a cases series study," *Medical Journal of the Islamic Republic of Iran*, vol. 28, no. 7 2014;
[5] K. J. Prommersberger, S. C. Froehner, R. R. Schmitt, U. B. Lanz, MD, "Rotational Deformity in Malunited Fractures of the Distal Radius," *The Journal of Hand Surgery,* Vol. 29, no. 1, pp. 110-115, Jan, 2004.
[6] "Fracture Education: Management Principles," *The Royal Children's Hospital,* Melbourne. [Online]. Available: https://www.rch.org.au/clinicalguide/guideline_index/fractures/Distal_radius_and_or_ulna_metaphyseal_fractures_Emergency_Department_setting
[7] A. Boyd, H. Benjamin, and C. Asplund, "Principles of Casting and Splinting", *Am. Fam. Physician*, vol. 79, no. 1, pp. 16-22, 2009.
[8] R. L. Angelo, R. K. Ryu, R. A. Pedowitz, W. Beach, J. Burns, J. Dodds, L. Field, M. Getelman, R. Hobgood, L. McIntyre, A. G. Gallagher, "A proficiency-based progression training curriculum coupled with a model simulator results in the acquisition of a superior arthroscopic Bankart skill set," *Arthroscopy,* vol. 31, no. 10, pp. 1854-71, Epub 2015 Sep 2.
[9] W. D. Cannon, W. E. Garrett Jr., R. E. Hunter, H. J. Sweeney, D. G. Eckhoff, G. T. Nicandri, M. R. Hutchinson, D. D. Johnson, L. J. Bisson, A. Bedi, J. A. Hill, J. L. Koh, K. D. Reinig, "Improving residency training in arthroscopic knee surgery with use of a virtual-reality simulator. A randomized blinded study," *J Bone Joint Surg Am*, vol. 96, no. 21, pp. 1798-806, 2014 Nov 5.
[10] "Colles' Fracture Reduction And Casting Technique Trainer." [Online]. Available: *sawbones.com/colles-fracture-reduction-and-casting-technique-trainer.html*
[11] *UW Health*. [Online]. Available: www.uwhealth.org/findadoctor/.
[12] "Pololu - Force-Sensing Linear Potentiometer: 4.0″×0.4″ Strip, Customizable Length." *Pololu Robotics & Electronics.* [Online]. Available: www.pololu.com/product/2730.

A special thanks to Dr. Puccinelli, Dr. Nimunkar, Dr. Stokman, Dr. Noonan, Dr. Halanski, and all previous BME design teams for their support and guidance.