PRESSURE SENSING DURING CAST APPLICATION FOR A DISTAL RADIUS FRACTURE

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Abstract

Casting is becoming a lost art in medicine, yet many children and adults need casts applied. While this appears to be a benign treatment, complications exist in placement of these devices. Typically medical students learn these techniques by trial and error. Often direct oversight is lacking in the teaching of these techniques. In this work, a sleek pressure sensing sleeve was designed to measure location and magnitude of force applied to a fracture model arm. A virtual 3D model displays the information accordingly.

Background

Client

- Research interests in safe immobilization and fracture reduction

The Distal Radius Fracture

- Most common cause is from fall onto outstretched arm (Fig. 1)
- Most commonly broken bone in the forearm
- 40% of all pediatric fractures occur on the forearm[1]

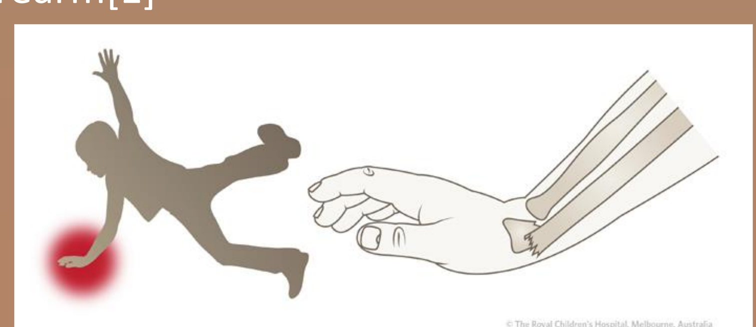

FIGURE 1. DISTAL RADIUS FRACTURE[2]

Current Teaching Methods

- Fractures set using three-point molding (Fig. 2)
- Students learn via trial and error

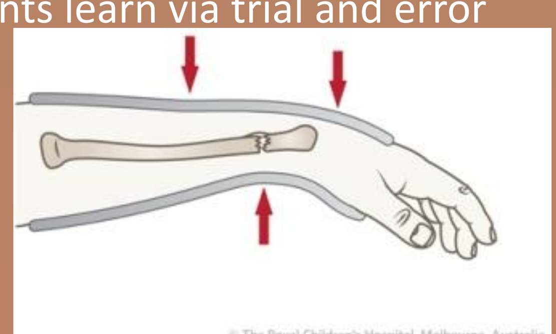

FIGURE 2. THREE-POINT MOLDING[3]

Common Injuries Due to Incorrect Application

- Malunion/improper bone healing
- Skin abrasions and infections

Design Criteria

- Removable pressure sensing sleeve that is sleek with limited protrusions
- Ability to record pressure of at least 20 N over duration of casting procedure
- Real-time visual feedback of pressure change
- Withstand casing procedures
- Expenses must be under $1,000

Final Design

Sensor Materials

- Ripstop: conductive
- Velostat: piezoresistive
- Neoprene: non-conductive

Sensor Design

- Sensors standardized into small, medium, and large sizes with sensing areas of 7 cm^2, 17.5 cm^2, and 47.25 cm^2 respectively
- Velostat layers are between two conductive layers with a neoprene layer on top to act as an insulator and provide water resistance.
- Twelve total sensors distributed among the three locations relevant in three-point molding.

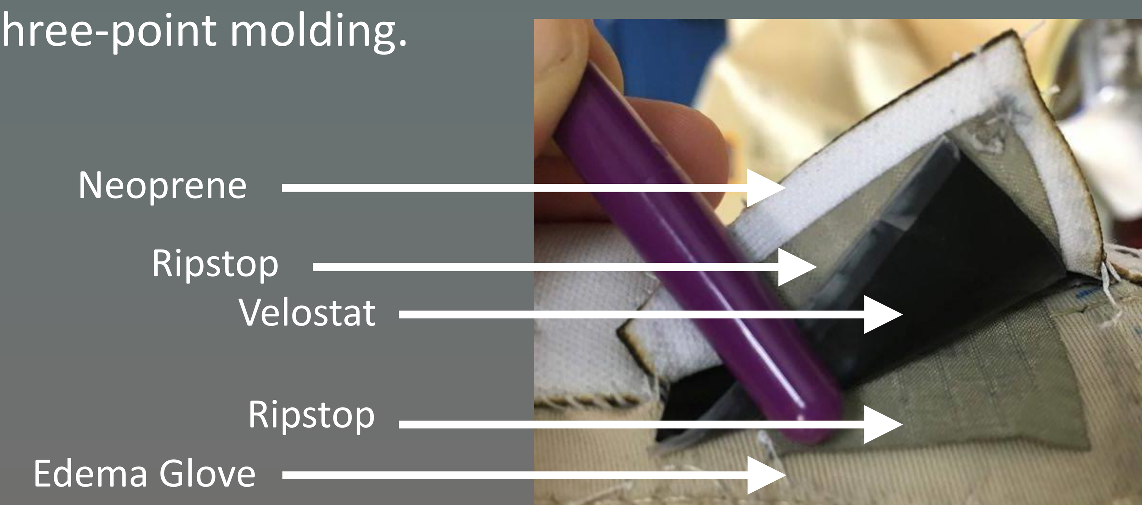

FIGURE 3. SENSOR LAYERS

Conductive Thread

- Two lines of conductive thread per sensor are sewn along the sleeve.

FIGURE 4. CONDUCTIVE THREAD KNIT STITCH

Real-Time Visual Feedback

- Sensor locations mapped onto arm using 3D Sensor Mapping LabVIEW VI

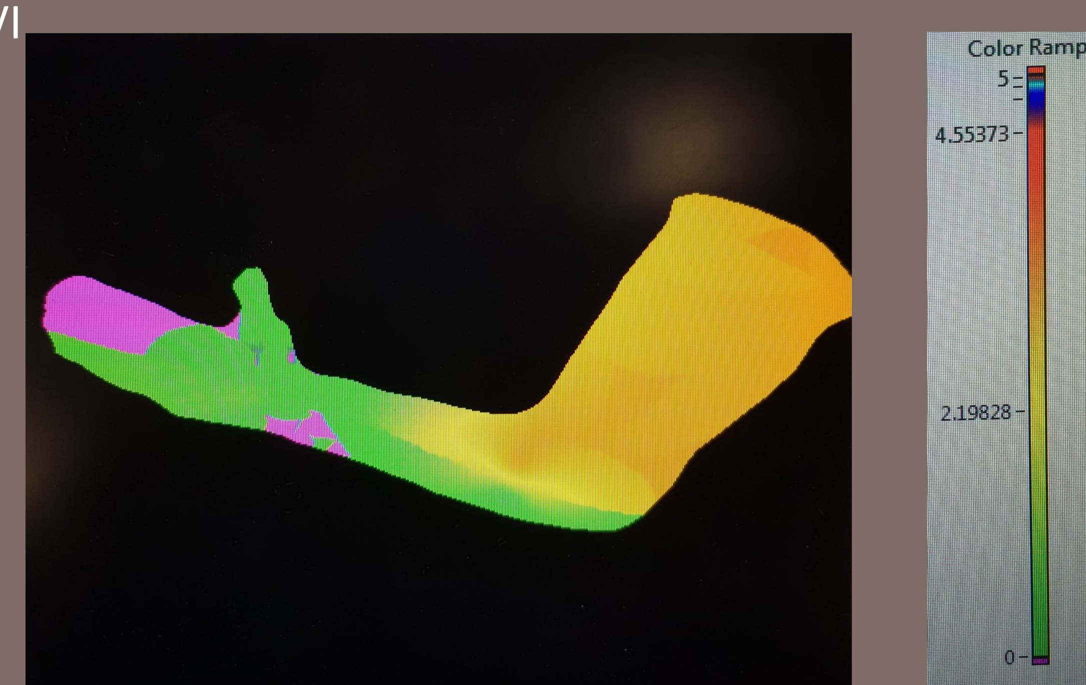

FIGURE 5. IMAGE DISPLAYED WHEN FORCE IS APPLIED AT PROXIMAL END OF FOREARM

Experimental Testing

Velostat Layer Testing

- Masses of 10g, 100g, 200g, 500g, 1000g were applied to one sensor of each size containing 1-6 layers of Velostat to determine the number of layers that results in appropriate sensitivity and ranges.
- Voltages did not vary significantly after certain layers were reached
- Small sensors have five layers and medium and large both have six

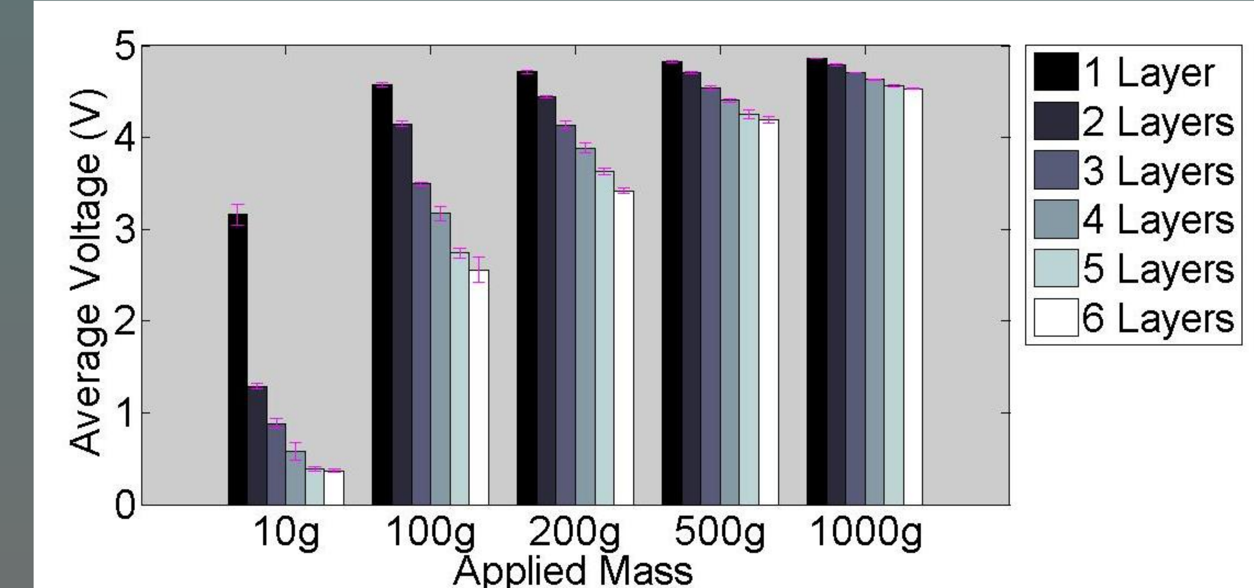

FIGURE 6. AVERAGE VOLTAGE VS. MASS FOR MEDIUM SENSORS WITH 1-6 LAYERS OF VELOSTAT

Location of Force

- To determine if the output voltage reading depends on the location of force applied to the sensor, we applied a 100g weight at five different locations on one sensor .
- Averaged data from each sensor location and applied T-Test

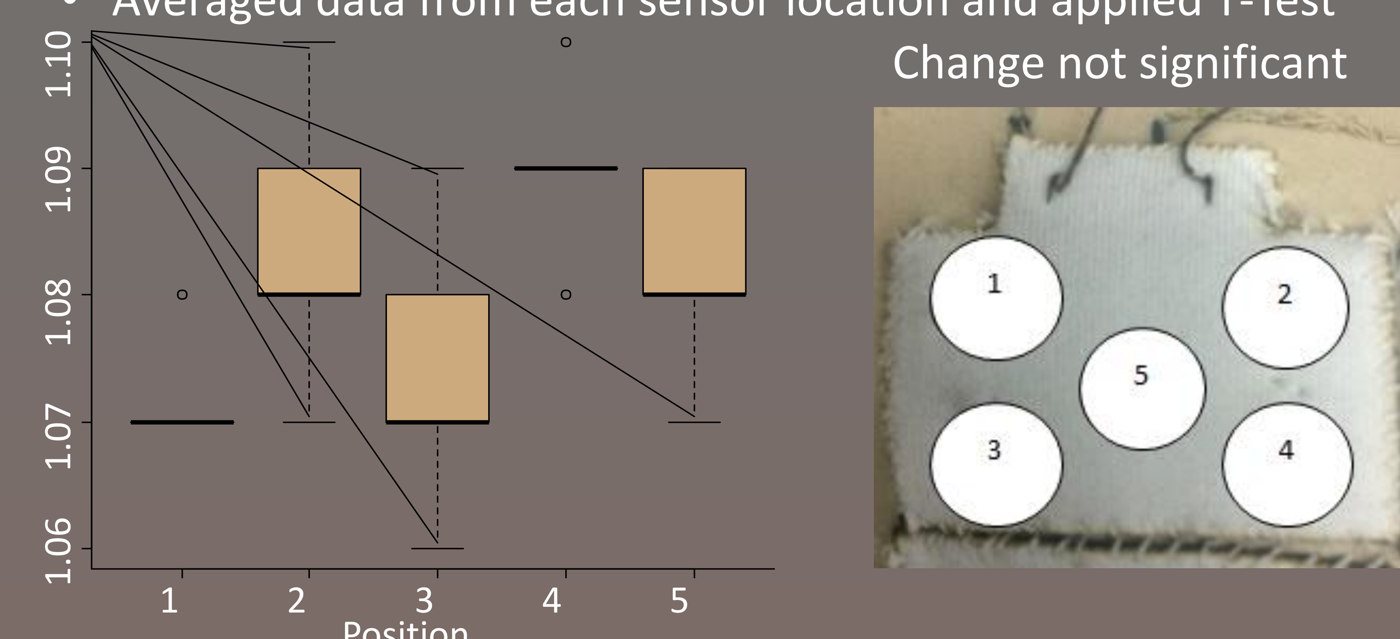

FIGURE 7. AVERAGE VOLTAGE READINGS AT CORRESPONDING LOCATIONS MARKED ON THE SENSOR

Calibration

- The relationship between voltage and force is exponential with 3.47 V being the maximum voltage output.

$$Force = 0.001363e^{3.693*V}$$

- Can be used to convert voltage output to force applied

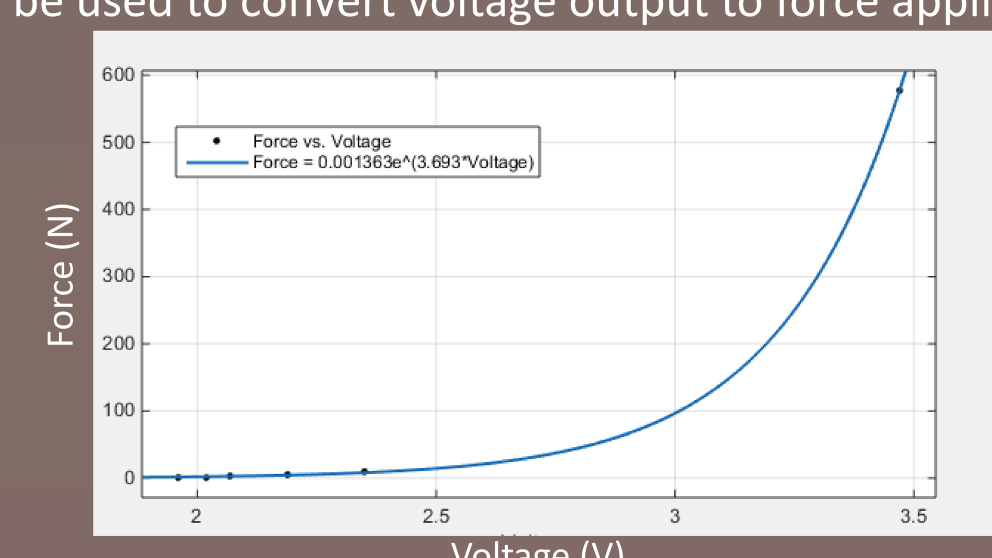

FIGURE 8. CALIBRATION CURVE

Future Work

Further Calibration

- Have the client perform casting using the device
- Apply calibration equation to results in order to quantify appropriate force ranges.
- Adjust visual feedback to these results.

Arduino and Circuit

- Incorporate Lilypad Arduino, optimized for e-textiles.
- Improve physical design of sleeve such that all electronics can be sewn on.
- Ideally resistors and circuit wiring could be sewn directly onto sleeve and eliminate the need for a breadboard

Temperature and Alignment

- Monitor skin surface temperature and bone alignment during cast application in combination with the previous device.
- Display real-time feedback for all these data simultaneously in a user-friendly, visual interface.

References

1. Biomed Central. (October, 2010 30). *Pattern of fractures across pediatric age groups: analysis of individual and lifestyle factors.* Retrieved from http://www.biomedcentral.com/1471-2458/10/656

2. Bear, David M., Nicole A. Friel, Charles L. Lupo, Raymond Pitetti, and W. Timothy Ward. "Hematoma Block Versus Sedation for the Reduction of Distal Radius Fractures in Children." *The Journal of Hand Surgery:* 57-61. Print.

3. Image retrieved from: www.rch.org.au/clinicalguide/guidline_index/fractures

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