DEVELOPMENT OF AN UPPER EXTREMITY FRACTURE MODEL

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1. ABSTRACT

The team created an upper extremity fracture model to enable medical school residents to train and learn to apply and remove casts from a forearm fracture. The team decided on final product incorporating a wooden dowel with a hinge system for resistance and several FSRs (Force Sensing Resistors) placed on the forearm to measure applied force. After placement of the sensors on the forearm, torque was applied and the sensors gave individual and accurate force readings on a live bar graph.

2. BACKGROUND

Motivation

Fractures are common in pediatrics, representing a major public health problem. Between 0 and 16 years of age, 42% of boys and 27% of girls experience at least one fracture and 84% of those fractures are upper limb fractures [1].

Forearm injuries are very common, counting for 40% of all pediatric fractures. Most forearm fractures occur in the radius but sometimes can be both a radial and ulnar fracture. Distal radius fractures account for 75% of all forearm fractures in children. Often distal radius fractures are accompanied by a wrist fracture due to contact [2].

The most serious complication of casting is compartment syndrome which is a condition of increased pressure within a closed space that disables blood flow and tissue perfusion. Thermal injuries can also occur after casting. The most common related problem is skin breakdown which may be caused by pressure from a wrinkled, unpadded or under-padded area of the arm [3].

Figure 1: Distal radius fracture

Current Devices

- No current models
- Medical school residents learn in situ
- Continuation project from last year
- Prototype detected pressure, temperature and alignment
- Not user friendly
- Poor visualization of applied pressure
- Foot pressure mapping system
- Poor accuracy with alignment sensors
- Fracture location not distal
- Little to no modular resistance
- No hardware protection
- Very expensive

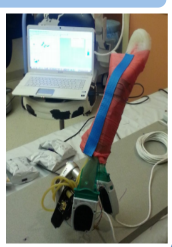


Figure 2: Previous model from design

3. PROBLEM STATEMENT

To develop a physiological representative pediatric forearm fracture model that provides modular resistance of the fracture, temperature, skin surface pressure, and bone alignment feedback for use by medical school residents in order to practice and learn safe, effective casting techniques.

5. FINAL DESIGN

FSR Sensors

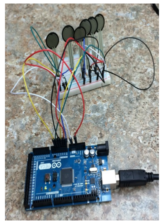


Figure 3: FSRs and arduino

- 10 FSR sensors
- 3 located at distal position
- 3 located at proximal position
- 4 along sides of forearm
- Supported underneath by wooden cutouts for stability
- Arduino (single board microcontroller)
- Bumpers allow evenly distributed forces (no point loading)
- Outputs force for each sensor

Modular Resistance

- Wooden dowel
- Tabs for "hinge"
- Bolt, wing nut and washer provide resistance
- Diameter of 1 inch
- Length of Platsil arm model
- Comparable to bone size
- Distal "fracture"
- Single bone fracture
- Resistance can be varied by tightening wing nut
- Fracture in one plane
- No twisting

Figure 4: Platsil arm model and hinge

Tissue Representation

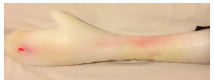


Figure 5: Platsil forearm mold

- Platsil (silicone mold rubber)
- Mold from 9 year old female
- Hollow & flexible
- Sensors placed on top and wrapped to secure position

Figure 6: Two pronged hinge made of wooden dowel

7. TESTING AND EXPERIMENTATION

Experimental Procedure

1. Test FSR sensors before adding bumpers
2. Test FSR sensors after adding bumpers
3. Measure applied force at various resistances

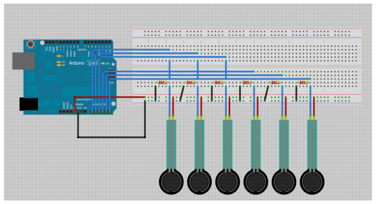


Figure 8: FSR sensors, breadboard and arduino microcontroller

Experimental Setup

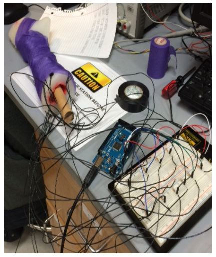


Figure 9: Experimental setup: mold and circuit

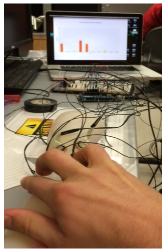


Figure 10: Applying pressure to the forearm model with computer display

8. RESULTS

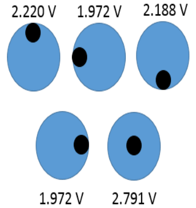


Figure 11: 100 g weight applied at different positions on FSR sensor without bumper demonstrated various outputs

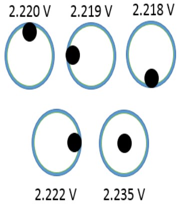


Figure 12: 100 g weight applied at different positions on FSR sensor with bumper demonstrated similar outputs

# of turns	FSR 1	FSR 2	FSR 3	FSR 4	FSR 5	FSR 6	FSR 7	FSR 8	FSR 9	FSR 10
0.00	8.646	1.032	15.554	0.001	23.593	17.009	14.976	11.488	23.593	25.935
0.25	6.759	3.891	13.512	0.0256	18.416	14.463	10.513	9.463	17.156	10.163
0.50	6.846	4.315	8.546	0.001	12.56	9.463	12.456	5.11	8.61	5.163
0.75	2.546	0.786	1.563	0.0003	13.156	0.001	5.419	6.13	0.163	0.135
1.00	0.001	0.303	0.529	1.179	12.629	0.001	2.88	0.052	0.003	0.24

Table 1: Forces recorded at various resistances on each FSR sensor

4. DESIGN CRITERIA

Primary Focus:
- Increase usability for residents
- Applied force output
- Alignment detection
- Move fracture distally
- Create modular resistance

Secondary Focus:
- Temperature detection
- Protection for sensors
- Representation of skin tissue
- Visual map of forearm and corresponding pressure during casting

6. CALIBRATION

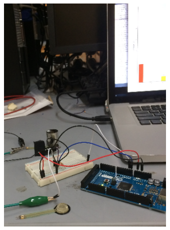
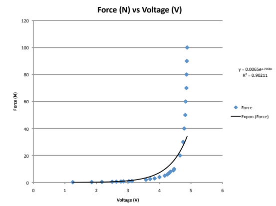


Figure 7: Setup during calibration



Graph 1: Conversion of voltage to force calibration curve

9. FUTURE WORK

- Provide baseline data from 3-5 orthopedic surgeons for comparisons of force required to reset a fracture
- Improve tissue representation
- Conceal wiring of FSRs
- Minimize cost of device
- Substitute material for wood dowel to increase shelf life and decrease wearing
- Develop an accessible variable system to easily increase or decrease resistance
- Embed sensors in tissue to model a smooth forearm
- Develop advanced system for visualization of forearm and pressure applied during casting

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11. REFERENCES

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[2] Wright, M. (July, 2010 16). *Forearm injuries and fractures*. Retrieved from http://www.patient.co.uk/doctor/Forearm-Injuries-and-Fractures.htm

[3] Boyd, A. (2009, January 01). *Principles of casting and splinting*. Retrieved from http://www.aafp.org/afp/2009/0101/p16.html