DEVELOPMENT OF AN UPPER EXTREMITY FRACTURE MODEL

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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 fifteen FSRs (Force Sensing Resistors) placed on metal trays on the forearm to measure applied force. After placement of the sensors, Dr. Halanski performed multiple reductions in order to set a baseline of data points for each sensor during reduction.

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

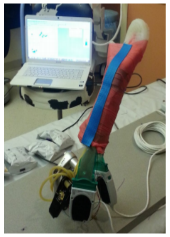


Figure 2: Previous model from design

PROBLEM STATEMENT

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

FINAL DESIGN

FSR Sensors

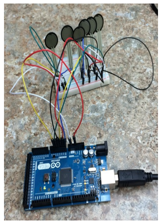


Figure 3: FSRs and arduino

- 15 FSR sensors
- 3 metal trays for stability with sensors glued on top
- 2 at distal position on each tray
- 3 located at proximal position
- 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

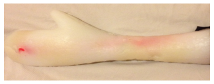


Figure 5: Platsil forearm mold

- 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

TESTING AND EXPERIMENTATION

Experimental Procedure

1. Dr. Halanski reduced fracture 20 times
2. Maximum pressure at each sensor was calculated
3. Calculated average maximum among 20 trials
4. Calculated standard deviation of maximum for each sensor

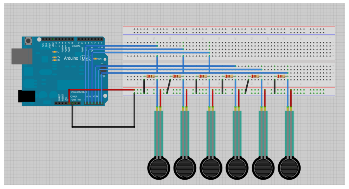


Figure 7: FSR sensors, breadboard and arduino microcontroller

Experimental Setup

Figure 8: Dr. Halanski's hand placement during testing

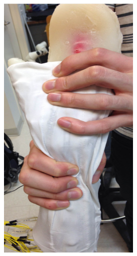
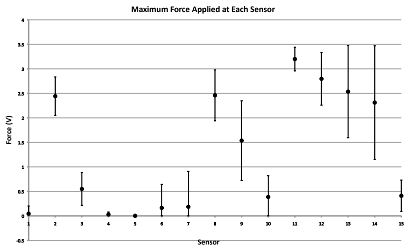


Figure 9: Hand placement

RESULTS



Graph 1: Average maximum pressures applied during casting across all 15 sensors

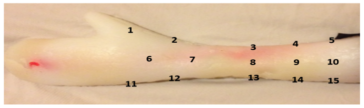


Figure 10: Placement of sensors during testing

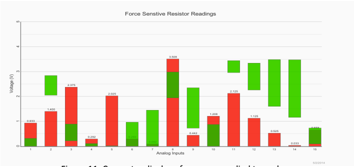


Figure 11: Computer display of pressure applied to each sensor

DESIGN CRITERIA

- Increase usability for residents
- Applied force output for each sensor
- Alignment detection
- Move fracture distally
- Create modular resistance
- Display baseline data on graph
- Create sleeve for sensors to make system transportable

CALIBRATION

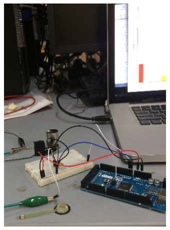
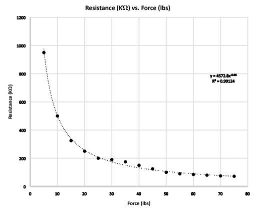


Figure 12: Setup during calibration



Graph 2: Conversion of voltage to force calibration curve

FUTURE WORK

- Compare baseline data (Halanski) to other orthopedic surgeons
- Improve tissue representation
- Make entire system wireless
- Minimize cost of device
- Improve sleeve to embed sensors
- Incorporate hand placement instructions
- Develop advanced system for visualization of forearm and pressure applied during casting
- Mount model on platform
- Combine pressure system with other groups working on project
- Compare baseline data to that of first year residents
- Implement temperature system
- Implement bone alignment system

ACKNOWLEDGEMENTS

- Mitch Tyler-advisor
- Dr. Matt Halanski-client
- Shlomi Laufer-sensors
- Dr. Carla Pugh Lab-sensors
- COE Student Shop-fabrication
- Gabe Bautista-previous design group
- Thomas Yen-previous advisor
- John Kao-tissue options
- Michael Bauer-programming

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

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