Development of Teaching Model for Distal Radial & Ulnar Fracture Casting

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ABSTRACT:

Background: Casting is often preferred as the common treatment method for pediatric forearm fractures and is assumed to be safe. However, little formal, hands-on training exists for young medical professionals. This can result in complications arising from cast application or removal. A pediatric fracture simulator was created needed to teach proper techniques of cast application, reduction, immobilization, and cast removal.

Methods: Bone fracture was mimicked using ½" PVC bones with ball joints at the fracture site. Stretched latex tubing was used to maintain the angulated forearm position. Soft tissue was mimicked using Plat-Sil 10 gel (Polytek Development Corp, Easton, PA). The fracture simulator also includes temperature, pressure and alignment sensors to provide immediate feedback to the user and to monitor fracture reduction, force applied during three-point molding, and temperature on a computer interface. The sensors were covered by a protective layer made from aluminum screen material covered by an additional thin PlatSil layer.

Results: The alignment sensors were verified to allow less than 15 degrees of rotation and less than 2 millimeters of translation through manual testing with photo analysis and x-ray verification with an expert user. Qualitative testing with a casting expert showed that the prototype had a realistic feel. Thermistors were proven to be accurate within 1 degree.

Conclusions: Future studies involving the effectiveness of the device as a teaching tool is required. The prototype serves to fill a void in cast application and removal technique.

Introduction:

While casting is often assumed to be a low-risk treatment option for forearm fractures, it has also become a lost art among physicians and medical residents, putting patients at an increased risk of injury. Cast immobilization is frequently overlooked as more and more residents are being trained on newer forms of treatment and surgical techniques [1].

As most young physicians have come to learn casting techniques – both application and removal – through trial and error, casting has become an area of greater concern for orthopedists across the nation [2]. In fact, in a recent study of about 400 physicians from a large multispecialty, multi-location pediatric group of approximately 400 physicians, casting was the number one cause of litigation, and about 35% of the claims paid an average of $120,000 each [2].

When applying the cast to the immobilized limb, the physician should be concerned about potentially burning the patient's skin from the hot casting materials as well as failing to immobilize the limb properly. A cast that is too tight becomes a rigid tourniquet that restricts proper blood flow to the limb; a cast applied too loosely will fail to hold the proper reduction and the fracture will heal improperly. Proper reduction of the fracture is confirmed with additional x-rays [1]. Acceptable angulation is less than 15 degrees but more angulation is allowed in younger children and preferred over a surgical option. Rotational alignment is verified by observing minimal distance in bone widths at fracture edges [3].

An additional danger of casting occurs when the cast is removed with a cast saw. Incorrect cast saw usage can result in cuts and burns. The most easily preventable factor is the technique used by the physician when cutting through the cast, further emphasizing the importance of proper training on methods of cast removal. Shuler and Grisafi explain that the cast saw blade should be removed from the cast material after each cut to allow for cooling of the blade. Without cooling, the average temperature of the blade can increase about 41°F, putting the patient at an increased risk of obtaining a burn or abrasion [4].

The focus of this project is to construct a distal radial and ulnar fracture simulator to teach proper techniques of cast application, reduction, immobilization, and cast removal. The fracture simulator must mimic the size of a child's forearm, provide immediate feedback to the user in a custom user interface and monitors fracture reduction (angulation less than 15 degrees and displacement of less than 2 mm [3]), force applied during three-point molding, and temperature of skin surface. The sensor data is displayed on a custom user interface. The device also must be reusable, easy and safe to transport, as it will be used as a training tool in various hospitals throughout the nation.

Materials and Methods:

The most internal component for the final design is a PVC bone structure with rounded mating surfaces at the fracture site. The resistance provided by the interwoven latex tubing forces the user to maintain proper alignment as shown in Figure 1. SoftPot flexible linear 50 mm potentiometer sensors (Trossen Robotics, Downers Grove, IL) at the fracture site also give immediate feedback on the degree of alignment. The potentiometers were positioned perpendicular to one another as show in Figure 2 to allow recording of rotational motion.

The bone structure is encased by a custom molded layer of Plat-Sil 10 gel that mimics the properties of muscle. A plaster cast of a pediatric forearm was used as a mold. The internal components were held in place using titanium wires to ensure the PVC pipes were located in the center.

Pressure mapping system (Tekscan F-Scan system, South Boston, MA) were secured to the Plat-Sil 10 gel using velcro on the dorsal and ventral sides of this gel layer and can be used to determine when a user is applying the proper pressure. Thermistor temperature sensors (DigiKey, Thief River Falls, MN) are located on the lateral sides of the gel and used to determine when skin burns might occur. A Kevlar protective mesh strip (3M, St. Paul, MN) prevents possible damage to the sensors during the removal of the cast. Data is collected and integrated into a custom user interface to allow real time or retrospective evaluation of casting procedures as shown in Figure 3. The device (Figure 4) closely mimics the feel of a real fractured wrist according to an expert user, a practicing orthopedic surgeon.

Results:

Alignment testing was performed to calibrate the output from the potentiometer to an angle of misalignment. This was done for both sensors by manually securing the bottom PVC pipe with a vice and manually rotating the top pipe. Photos were taken and the potentiometer output was recorded for each angle. After testing was completed for an array of 20 different angles, ImageJ (NIH, open source) was used to measure the angle created by the two PVC pipes. The potentiometer outputs were mapped to angle values and was validated with x-ray as shown in Figure 5.

Upon working with the prototype, our client, a casting expert, commented on the realistic feel of the prototype. This is likely attributed to the viscoelasticity of the latex tubing. He is interested in moving the fracture site more distal (ie closer to the hand) in future prototypes. In addition, it was discovered that 2 layers of the aluminum screen is too stiff. Therefore, a small strip with 2 layers of aluminum screen will be incorporated under a layer of Kevlar tape.

The temperature reported from the 4 thermistors used in the prototype over a ranging from 20^{o}C to 80^{o}C. This was done by comparing the thermistor to the output from an electronic thermometer as show in Figure 6.

Discussion:

The uniqueness of this forearm fracture model is exhibited through the all encompassing nature. This model is a combination of multiple sensors and resistance mechanism against alignment. More testing is necessary to prove the effectiveness of a device as a teaching model.

There are no other commercially available devices. Previous research by Halanski et al used a forearm model composed primarily of PVC pipes arranged in a L-shape covered by a thin layer of copper foil or "skin". When contacted by the cast saw, a simple circuit is completed which indicates contact was and possible damage to the skin could have resulted. This prototype, however, is not a dynamic model [1].

Other options for pressure sensors were considered. Accuracy and cost were considered the most important design considerations. In addition, a temperature mapping system was also considered due to high level of accuracy and easy of visual interpretation. Due to high cost, a more simplistic option with two thermistors was selected for the temperature probes. The researchers assumed the increased temperature due to exothermic reaction of plaster or fiberglass hardening would not be localized. Multiple options were also considered for alignment sensors but due to the high degree of motion a pre-existing joystick mechanism was selected to ensure high accuracy.

Currently, there are no competing commercially available devices that allow physicians to train on proper fracture reduction. The fracture simulator gives physicians the opportunity to gain more hands-on experience in properly reducing fractures before ever having to practice on a live patient and without the risk of possible litigation.

References:

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Figure Legends:

Figure 1: PVC fracture structure with latex tubing.
Figure 2: Perpendicular placement of potentiometers to measure rotational alignment.
Figure 3: Custom user interface.
Figure 4: Final prototype.
Figure 5: Potentiometer outputs mapped to angles.
Figure 6: Thermistor testing data.