Self-measuring Orthopedic Drill

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BME BiomedicalEngineering

Introduction

Often when a bone is severely fractured a hard cast is not enough to keep it in place throughout the healing process. For this reason, screws or plates and screws must be inserted into the bone to hold it in place during healing. To insert these screws, the surgeon must drill into the bone with a surgical hand-held drill and drill bit. Once the hole's depth has been measured, the plate can be placed and the screws inserted through the drilled holes. These screws come in 2mm increments and using the correct size screw is extremely important in the healing process.

Figure 1: X-ray of radius and ulna with screws used in orthopedic surgeries

Background

The surgeon drills through the bone carefully as not to break through the opposite side of the bone too quickly, which leads to trauma. This action is known as plunging. Once the hole is drilled, the depth of the hole must be measured using a depth gauge (Figure 3). This process takes approximately 45 seconds per hole.

A device is desired that will accomplish two tasks. Firstly, the device must measure the depth of the hole so the proper size of screw can be selected for insertion. Secondly, the amount of plunge must be minimized. Reduction of the plunge distance will both decrease unnecessary trauma and increase the accuracy of the bone width measurement. This device will reduce surgical time and pain for the patient, saving the patient and hospital both time and money.

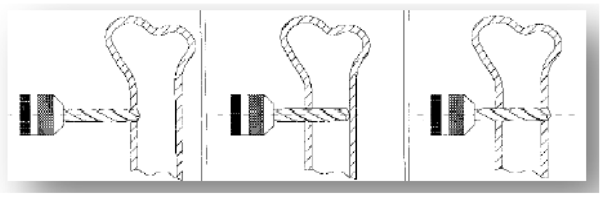

Figure 2: A diagram representing the different positions of the drill during surgery.

Figure 3: The depth gauge. Elimination of the need for this tool will save the orthopedic surgeon time during most of his surgeries.

Motivation: Eliminate the need for a depth gauge in orthopedic surgeries

Final Designs

Orthopedic Drill Design Criteria

- Accurate depth measurement (<1 mm)
- Reduce plunging
- Must not obstruct surgeon's vision
- Must cost under $1000 to produce
- Integration into current surgical instruments
- Sterile, autoclavable, non toxic, corrosion resistant

Hydraulic Slider

Materials used: ABS, Stainless Steel and ABS for final version, viscous fluid.

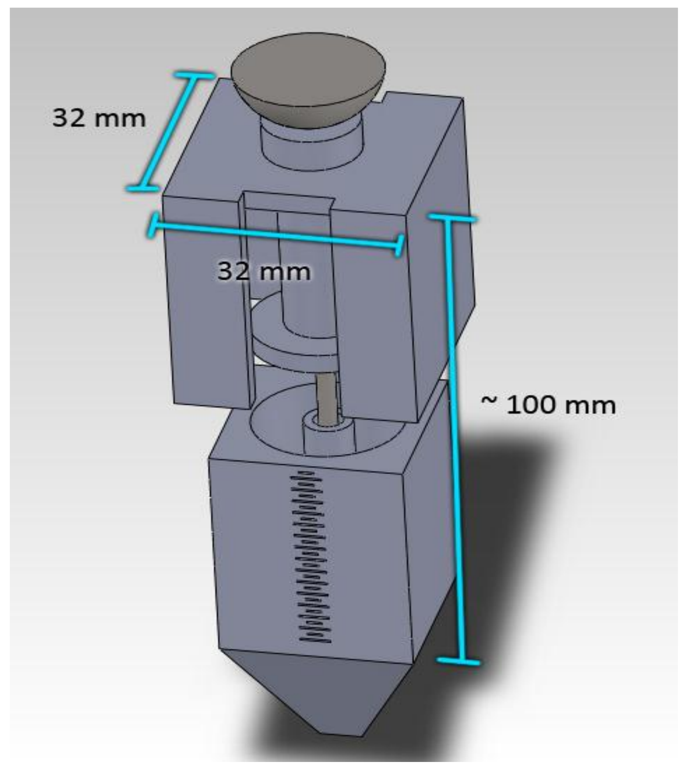

Figure 4. Hydraulic slider The two pieces, (top) slider and (bottom) well, of the hydraulic slider design with a mock drill bit (dark grey) in place. The slider is hyperextended in this form to show the plunger, well that will hold the non-newtonian or viscous fluid, and the incorporation of the drill bit.

- Ruler on the front and back allow easy viewing of depth
- Top slider moves down with the drill bit and engages the base when plunging is imminent
- Well in the base of the slider contains fluid that reduces plunging
- Utilizes a pointed base to maximize view of the drill bit entering the bone

Velocity Profiling

Materials used: Reed Switch, Resistor, Magnet, LabVIEW , NI myDAQ

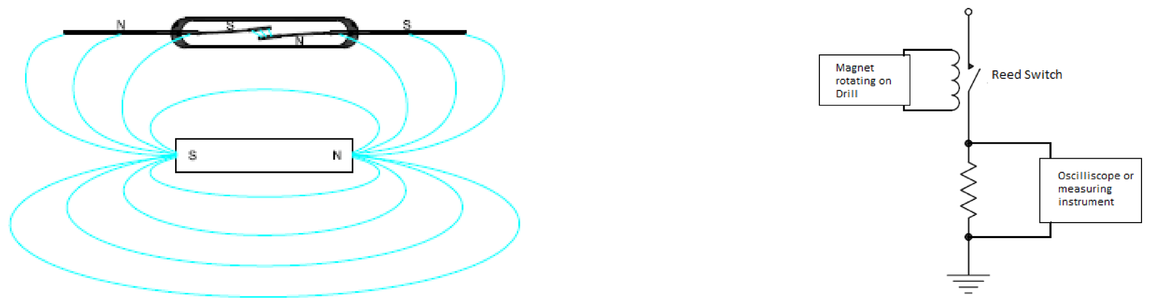

Figure 5. Reed Switch (left) The basic operation under the influence of a magnetic field. The field causes the blades of the switch to close, effectively completing the circuit. (right) The circuit utilized by a Reed Switch detection system. In our case, the measuring instrument is the myDAQ data acquisition tool.

- A Reed Switch consists of two ferromagnetic blades which make contact in the presence of a magnetic field
- Magnets mounted on the chuck of the drill are detected by the reed switch
- The closed circuit produced a voltage drop across a 10kΩ resistor, which was read by the NI myDAQ and recorded in the labVIEW computer program
- The angular velocity of the chuck displays a characteristic change in magnitude when the drill plunges from denser bone to less dense soft tissue
- Ultimately, circuitry will feed back on the motor of the orthopedic drill, causing the drill to stop rotating nearly instantaneously upon tissue change, decreasing plunging depth
- Analysis of the chuck velocity with respect to time will provide an estimate of the hole depth

Testing

To pair the hydraulic slider with the proper fluid and calculate the diameter of the plunger, we needed to gauge the maximum force generated during bone drilling. The forces generated are overestimates given that cow bone was used.

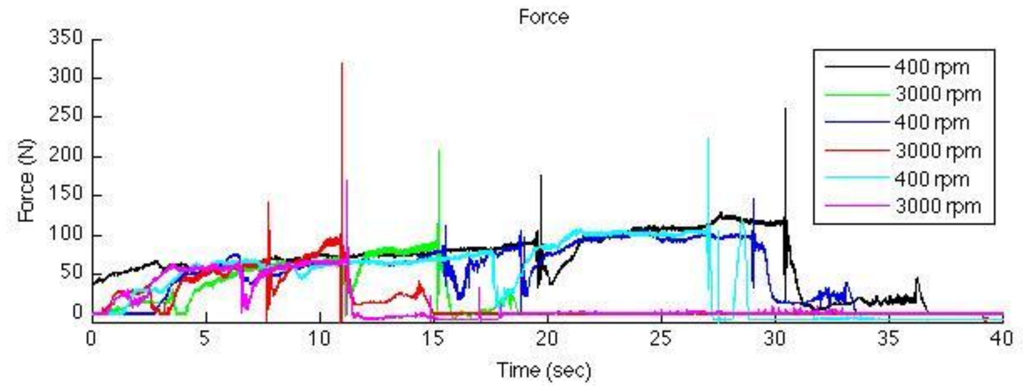

Figure 6: Forces developed while drilling through cow femur at slow and fast speeds. Measurements were recorded in Labview from a force plate and analyzed in Matlab.

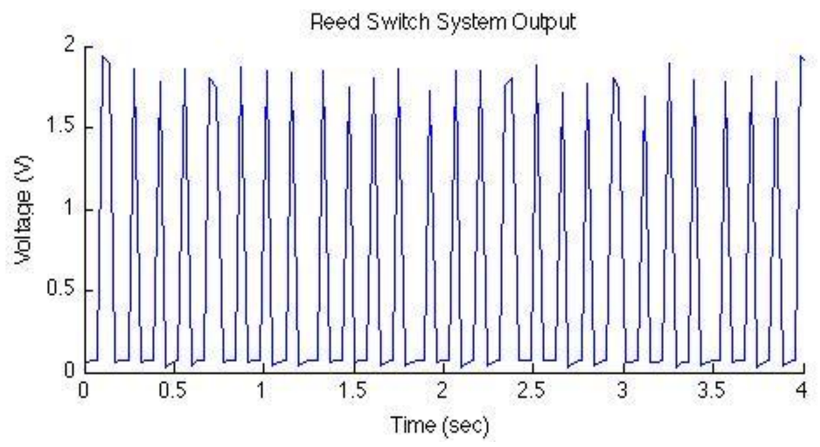

Figure 7: Signal from magnet passing reed switch for four seconds during drilling showing ~7 peaks/sec acquired through National Instrument's myDAQ.

The total number of peaks seen while drilling through bone were counted and compared to the actual distance the drill traveled through bone. From this a correlation factor was found.

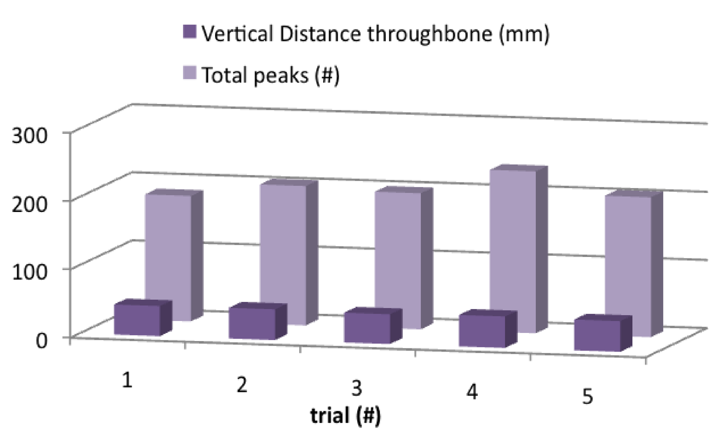

Figure 8: The total number of peaks seen while drilling through bone and the actual distance the drill traveled through bone.

A correlation of 0.218 mm/peak with a standard deviation of 0.016 mm/peak can be used to translate the total number of peaks observed to a traveling distance.

Next, plungers with various cross sectional areas were tested with different fluids.

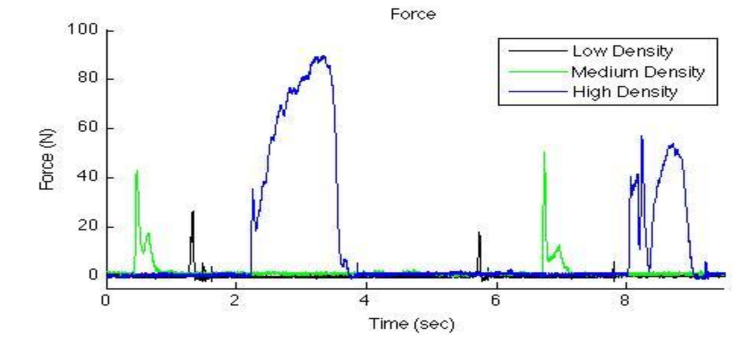

Figure 9: Forces developed while plunging (2mm diameter plunger) fast (first signal) and slow (second signal) into cornstarch and water solution (oobleck).

The necessary plunger area was calculated from the maximum forces generated in figure 6. Drilling trials with the addition of the hydraulic slider show reduction in plunging depth.

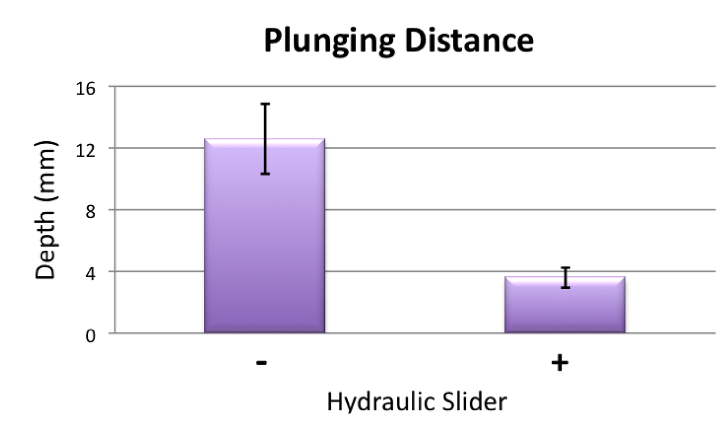

Figure 10: The average plunging depth without the hydraulic plunger was 12.6 mm. The addition of the hydraulic slider reduced plunging to 3.6 mm. Honey was the viscous fluid in the hydraulic slider well.

Conclusion

- ✓ Hydraulic slider reduced plunging
- ✓ Found applied force profile
- ✓ Accurately measures depth
- ✓ Measure chuck velocity
- ✗ Accurately measures hole depth
- ✗ Accurately relate chuck velocity to hole depth

We have constructed a functional hydraulic slider prototype that both reduces plunging and measures drilling depth but can not accurately measure hole depth. Once the plunger's surface area is perfected, this problem will be corrected and the device will decrease operative time. Should the hydraulic slider design fail to meet design criteria, we have designed a velocity profiling approach which could theoretically measure the hole depth within 1mm.

Future

Immediate Future

- Make hydraulic slider a closed system
- Add spikes and a bearing to prevent hydraulic slider from spinning while being used
- Vary plunger surface area to further decrease plunging

Future Semester

- Add locking and retractable spring mechanisms to hydraulic slider
- Construct hydraulic slider out of stainless steel
- Incorporate an accelerometer with velocity profiling approach

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Acknowledgements:

Amit Nimunkar
Austin Crow
Mitch Tyler
John Puccinelli
Eamon Bernardoni
Starcraft sucks

BME Design 400
Fall2011