HIP MODEL TO TEACH PHYSICIANS

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Abstract

The rarity of pediatric septic arthritis in children makes it difficult to train new physicians to efficiently perform a hip aspiration procedure to diagnose and treat the condition. Septic arthritis involves a buildup of synovial fluid on the femoral head from bacterial infection and is an urgent situation, resulting in permanent damage if left untreated. There are currently no models on the market that can be used to teach the aspiration procedure on a pediatric hip. This team's goal is to create such a model to effectively train resident physicians in the procedure. The design uses artificial tissues that: mimic the properties of real human tissue, are molded around an artificial hip joint, and incorporate anatomical features relevant to the aspiration procedure. The artificial skin and joint capsule used in the model display young's moduli that fall below the target range of the native tissues by a factor of ten, but the modulus of the artificial fat is comparable to that of human fat tissue. The reusability of the model exceeds the goal based on self-healing tests. Overall, future work on the project should focus on the fabrication method of the joint capsule and the mold as that has proven to be the most challenging part of the project.

Background

- Septic Arthritis is a rare, but serious condition involving inflammation of the synovial membrane [4]
  - 2-10/100,000 (general population) [1]
  - ⅕ cases are in the hip [2]
- Treated by aspirating synovial fluid from the hip [4]
  - Aspirating= Withdrawing fluid using suction through a needle

Figure 1. Normal [left] & septic [right] hip [3]

Current Device:

Figure 2. Hip sonography training phantom [5]

- Kyoto Kagaku has an infant hip sonography training phantom[5]
  - diagnoses of hip dysplasia rather than septic arthritis
- Anatomically accurate to that of a 6 week old
- ultrasound (US) compatibility
- Very expensive at $4300 each

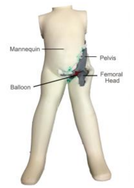

Figure 3. Spring 2016 final prototype

Previous Teams work:

- Past teams were able to produce clear images of distinct layers of skin, fat and joint capsules as well as of bones and the needle when viewed under ultrasound
- Downfall was that it needed to be submerged under water to be seen under ultrasound

Design Criteria

- Must be functional under X-Ray fluoroscopy and Ultrasound imaging
- Artificial tissues must mimic mechanical properties and acoustic impedances of native tissues
- Withstand 15 needle insertions within 1 hour practice session
- Include all anatomical structures relevant to the procedure including femoral vein and artery
- Size and weight requirements
  - 6 pounds
  - 18-20 cm femur length
- Budget of $500

Final Design

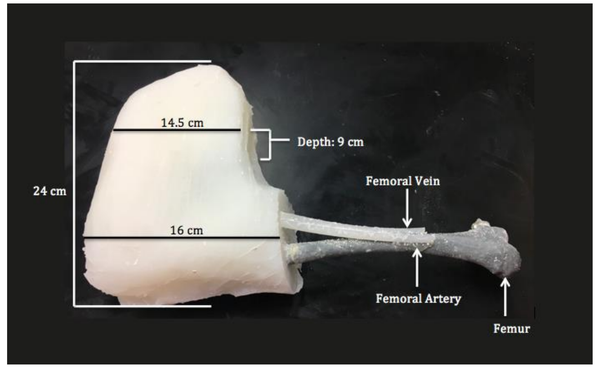

Figure 4. A ventral view of the final prototype.

- Weight: 5.4 lbs
- Radiopaque half pelvis and 30 cm long, 15 mm diameter femur
- 6.35 mm diameter polyethylene rods for femoral vein and artery
- 2:1 Part A: Part B mix of polyurethane for joint capsule
- 1:1 Part A: Part B mix of silicone with 5% silicone thinner and 1% cellulose powder for fat
- Did not purchase enough material to mold skin layer

Material Testing and Results

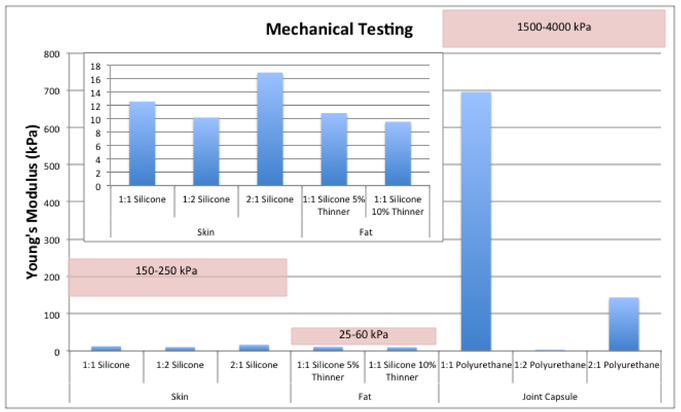

Figure 5. The young's modulus of the different materials (blue bars) compared to the target ranges of the native tissue (red boxes).

- A compression test, strain rate 1 mm/min for 10 minutes, was used to obtain stress-strain curves
- Different ratios of parts A and B of each material were tested to compare the mechanical properties to that of the native tissues
- All of the young's modulus results fell below the target values

Self Healing Testing and Results

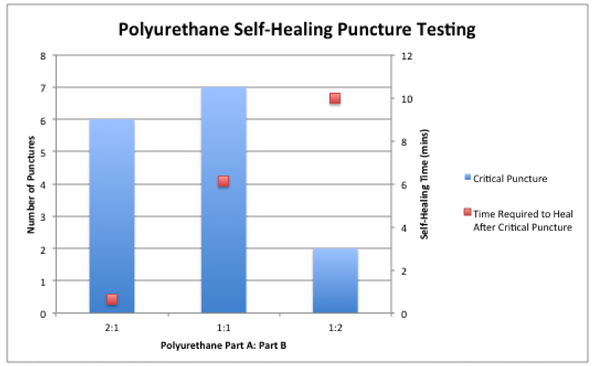

Figure 6. A depiction of the number of punctures each sample could withstand before it no longer self healed immediately (blue bars) and how long it took for the material to heal after this critical puncture (red squares).

- Critical puncture: the puncture at which a hole was visible to the eye after removal of the needle
- 2mm thick, 14.45mm diameter samples
- Dot drawn in center and punctured with 20 gauge needle
- Combining this data gives number of punctures each can withstand in an hour
  - 2:1 - 24 procedures per hour
  - 1:1 - 7 procedures per hour
  - 1:2 - 5 procedures per hour
- 2:1 polyurethane is the only ratio able to withstand 15 punctures per practice session

Future Work

- Ultrasound and X-ray testing
- Work with orthopedic department to fabricate a more replicable and anatomically accurate mold
- Modified pressure syringe
- Dyes to distinguish artery and vein if punctured
- Include pumping mechanism to simulate palpation of femoral artery
- Further puncture testing of model to complement sample material tests

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