Development of a Pediatric Soft Tissue Model:
The Iterative Design and Refinement of a Soft Tissue Covering for a Pediatric Distal Humerus Fracture Fixation Simulator

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Introduction to Pediatric Humerus Fractures

• Most common fracture that requires surgery in children

• Surgical technique:
  • Fracture is reduced by surgeon, if necessary
  • Wires are drilled into the patient’s humerus to maximize fracture stability
  • Fluoroscopy used to correctly reduce fracture and determine wire position and trajectory in the body

• Surgical training for this procedure is very limited
Introduction of the Simulator

• Surgical training simulator to train surgeons for pediatric humerus fracture pinning

• Simulator components:
  • Artificial humerus
  • Foam soft tissue covering
  • IR camera system to simulate fluoroscopic images of wire placement and trajectory

• Simulator procedure:
  • Surgeons view initial fluoroscopic images on laptop
  • Surgeons determine where wires should be placed to maximize fracture stability
  • Surgeons then drive wires into humerus and make wire position and trajectory adjustments as needed
Design Constraints
Improved Soft Tissue Covering

• Obstruct surgeon view of humerus
• Realistic feeling of soft tissue when palpating and drilling through tissue
• Reduce degradation of soft tissue due to stress concentrations from rectangular hole
• Increase variability of possible wire placements by increasing hole size
• Method developed must be replaceable between training sessions
First Design Iteration:
Rectangular Foam Insert

• Met constraints:
  • Obstruct view of humerus
  • Method developed must be replaceable between training sessions

• Unmet constraints:
  • Realistic feeling of soft tissue when palpating and drilling through tissue
  • Reduce degradation of soft tissue due to stress concentrations from rectangular hole
  • Increase variability of possible wire placements by increasing hole size

• Qualitative observations:
  • Foam insert is dislodged with repeated wire placement and extraction
  • Insert dislodges when arm is flexed
Second Design Iteration
Tapered Circular Silicone Insert

• Met constraints:
  • Obstruct view of humerus
  • Method developed must be replaceable between training sessions
  • Reduce degradation of soft tissue due to stress concentrations from rectangular hole
  • Increase variability of possible wire placements by increasing hole size

• Unmet constraints:
  • Realistic feeling of soft tissue when palpating and drilling through tissue

• Qualitative observations:
  • Tapered insert to avoid dislodging of insert from repeated wire placement and extraction
  • Difficult to insert wires through thick silicone insert
  • Insert dislodges when arm is flexed
Final Design Iteration
Silicone Sleeve

• Met constraints:
  • Obstruct view of humerus
  • Method developed must be replaceable between training sessions
  • Reduce degradation of soft tissue due to stress concentrations from rectangular hole
  • Increase variability of possible wire placements by increasing hole size
  • Realistic feeling of soft tissue when palpating and drilling through tissue

• Unmet constraints:
  • None
Findings from Final Model

• All initial design constraints met
• Model allows for full flexion of arm which is representative of actions performed during surgery
• Thin silicone sleeve allows for realistic feeling of soft tissue when drilling
• Thin silicone sleeve allows for realistic tactile feeling when palpating humerus
• Increased hole size allows the humerus to be replaced without removing entire soft tissue covering
Testing of Final Model
Quantitative Data to be Collected

• Wear testing:
  • How does the silicone sleeve withstand wear in comparison to the foam insert in the first design iteration? How many surgeons can train with the same silicone sleeve before it needs to be replaced?

• Increased wire placement variation:
  • Compare possible wire placements between small rectangular hole and larger circular hole

• Reduction in stress concentration:
  • Stress concentration calculation of small rectangular hole versus larger circular hole

• Survey of surgeons:
  • Conduct survey of surgeons who had experience with previous simulator model
  • Introduce the revised final model
  • Ask participants to rate their experience with the previous simulator and rate their experience with the revised model
Conclusion

• Final model will be tested to determine level of success
  • Gathering and interpretation of quantitative data
  • Survey of surgeons

• Final model will be distributed to gather training data from various institutions, this data will be utilized to analyze the effectiveness of the simulator in training surgeons

• This methodology could be expanded upon to increase realistic representation of additional surgeries and surgical techniques
  • Application to other surgeries that require limb manipulation
  • Possibly incorporate these developments to be compatible with a fracture reduction simulator