Replication of the mechanical loading of rotator cuff tendons for the development of implantable scaffolds

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Introduction

- The incidence of rotator cuff degradation and tear is 20% among Americans and approaches 50% for individuals over 80.[1]
- Up to 60% of surgical repairs result in tendon retear. [2]

As such, expanding techniques for rotator cuff tear repair is essential.

Aims

- **Design, fabricate, and pilot test a uniaxial testing system designed to apply physiologic strain to synthetic scaffolds**
- Replicate the in vivo loading environment of the tendon-to-bone interface
- Provide the Orthopaedic Bioengineering Research Laboratory with the first iteration of a scaffold testing system

Analysis and Design

System design

- Linear actuator(i) interfaces with scaffold using a lever mechanism(ii)
  - The lever creates a necessary mechanical advantage to apply strains that are equivalent to physiologic loading
- Slider and rails(iii) ensure uniaxial loading to effectively replicate in vivo environment
- Cell culture cap and media port(iv) allow for influx of incubator environment while maintaining sterility
- Load cells(v) record strain

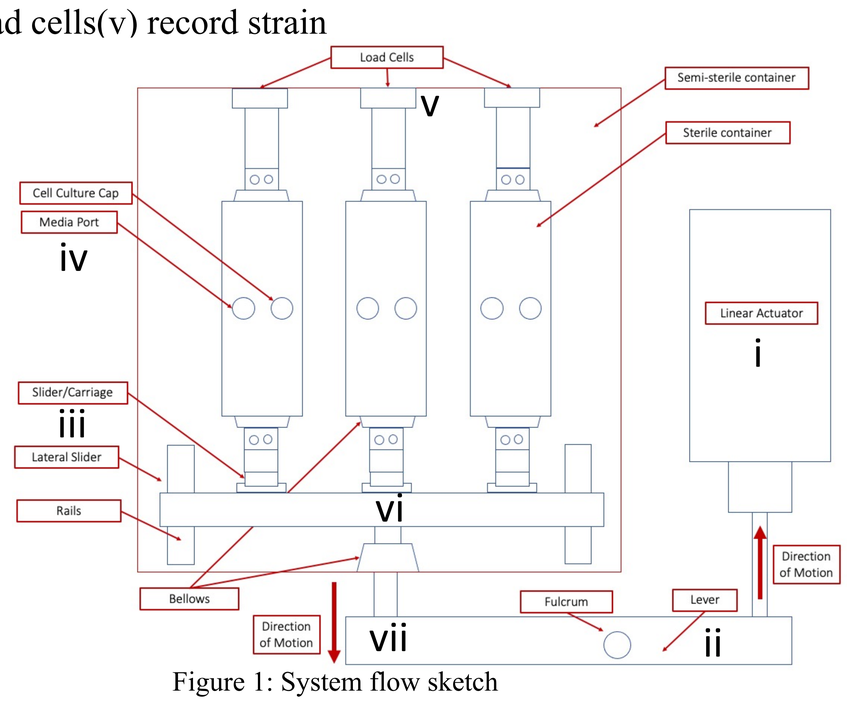

Figure 1: System flow sketch

Stress and Deformation Analysis

- ANSYS simulation on steel lever(vi) performed using maximum forces of 3600N
- Lever will withstand stresses without significant deformation
- Maximum stress occurs at fulcrum
- Maximum displacement occurs at cross bar interface(vii)

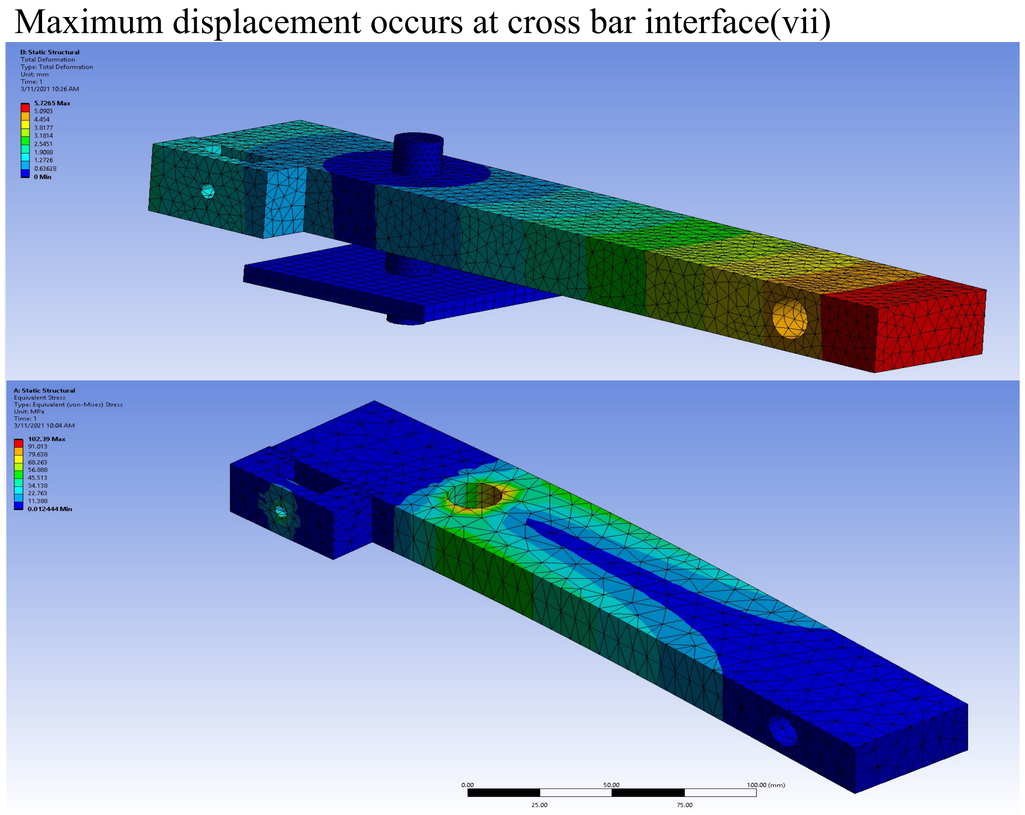

Figure 2: ANSYS simulation of stress and deformation of the lever arm

Scaffold container design

- Arm (i) allows interface between scaffold and actuator while maintaining sterility
- Frame (ii) holds scaffold and allows it to be directly printed onto the frame
- Container (iii) holds media and scaffold and is sealed for sterility

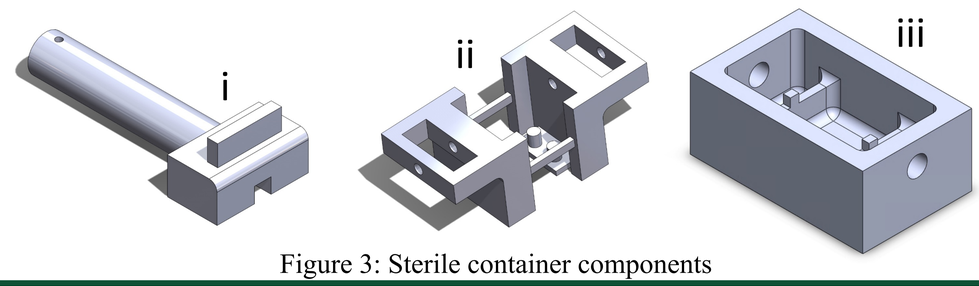

Figure 3: Sterile container components

Results

Fabrication and Controls (Figure 4)

- Sterile container prototypes 3D printed(i)
- Bellows to maintain sterility integrated(ii)
- Semi-sterile container machined and sealed(iii)
- Actuator interface through lever arm and fulcrum integrated(iv)
- Sliders to ensure uniaxial strain attached(v)
- Threaded heat-set press inserts installed to allow for frequent and easy lid removal(vi)
- Cell culture cap used to influx the incubator environment integrated into the lids(not pictured)
- Footprint machined to combine all system components(vii)
- Custom LabVIEW code created for load cells (Figure 5)
- Amplifiers and shunt cal will be integrated to facilitate accurate data from load cells

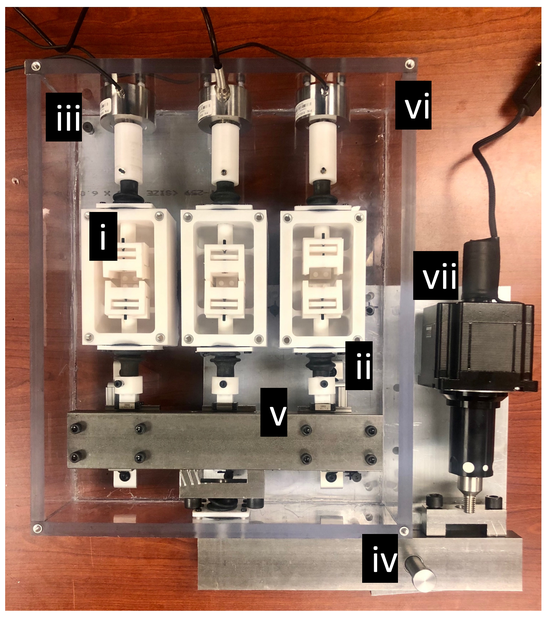

Figure 4: Physical System

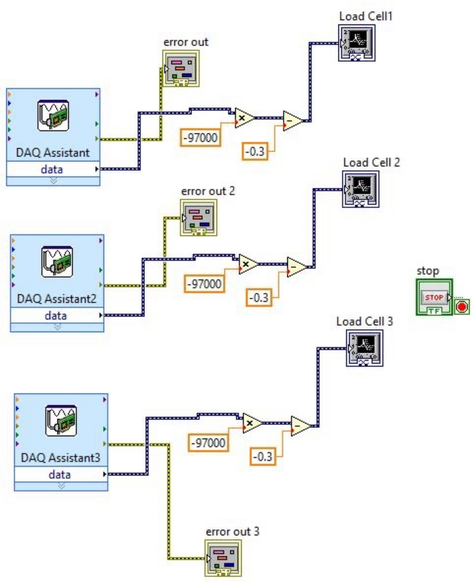

Figure 5: LabVIEW code

Conclusion

- **The system does not facilitate uniaxial strain as hoped**
- **The original constraints, as well as flaws in the design, have resulted in this outcome**
- Coding and electric components need to be integrated
- The ease of use and assembly of the system should be improved
- 3D printed prototypes should be machined out of stainless steel in a later phase of the project
- **Ultimately, the system requires some adjustments but meets several aims of the project**

References

1. McCormack, R. A., Shreve, M. & Strauss, E. J. Biologic augmentation in rotator cuff repair--should we do it, who should get it, and has it worked? *Bull. Hosp. Jt. Dis. 2013* **72**, 89–96 (2014).
2. Prabhath, A., Vernekar, V. N., Sanchez, E. & Laurencin, C. T. Growth factor delivery strategies for rotator cuff repair and regeneration. *Int. J. Pharm.* **544**, 358–371 (2018).

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