Team 03 - 3D Printed Titanium FDL Tendon Fixation Screw

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Background

Posterior Tibial Tendon Dysfunction (PTTD)

- Tendon that supports the arch of the foot becomes inflamed, torn, or overstretched
- Arch Collapse → Adult Acquired Flat Feet

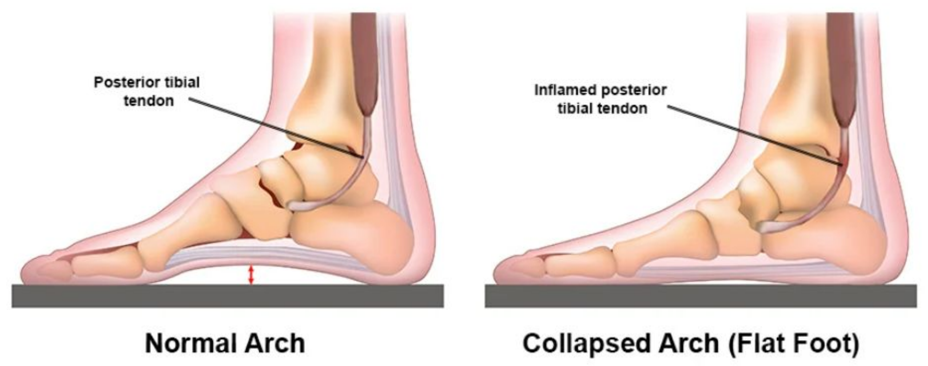

Figure 1: Normal arch of foot vs. flat foot. Over 300,000 patients suffer with PTTD [1].

FDL Transfer

- Flexor Digitorum Longus (FDL) tendon is adjacent to the afflicted tendon & has a similar function
- Restores arch stability

Simple Procedure

1. Dissect and measure tendon
2. Drill and tap hole into navicular bone
3. Pull tendon through hole
4. Securely insert fixation screw

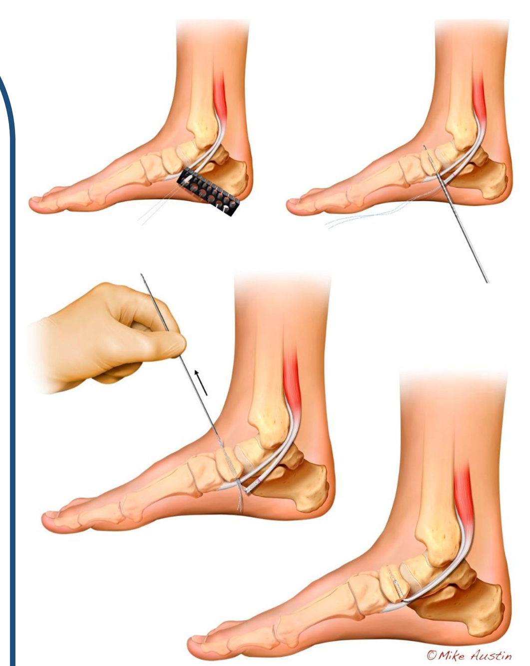

Figure 2: Procedure of FDL transfer surgery [2].

Objectives

Problem Statement: Current tendon fixation procedures for FDL transfers often utilize solid, rigid interference screws that cause stress shielding and disorganized scar tissue formation that compromise long-term recovery outcomes, as well as being limited to only specific, standardized sizing.

Figure 3: Example of current, plastic fixation screws made by injection molding [3].

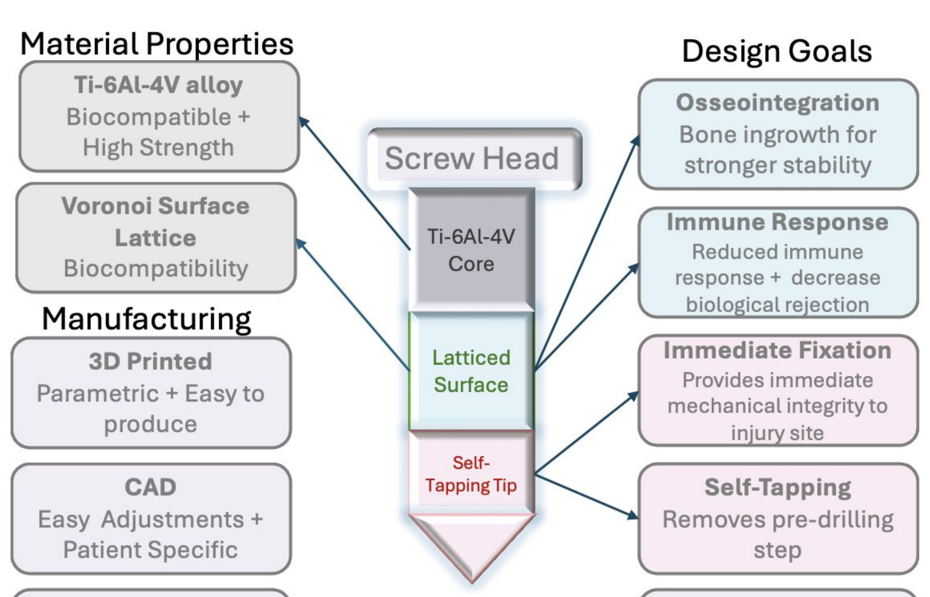

Figure 4: Goals for improved fixation screw.

Experimental Design & Testing

Version 1 - Initial Prototyping

- Designed three geometries in CAD (Self-Tapping, Buttress, Cylinder) to compare to current competitors.
- Fabricated initial plastic (PLA) prototypes

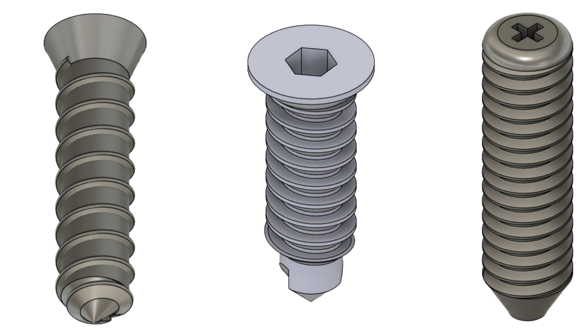

Figure 5: CAD models of initial iterations: Self-tapping (left), Buttress (middle), Cylinder (right).

Version 1 - Informal Testing

- Benchtop pull out testing using bone block and paracord
- Low pull out strength and lacerated paracord upon insertion

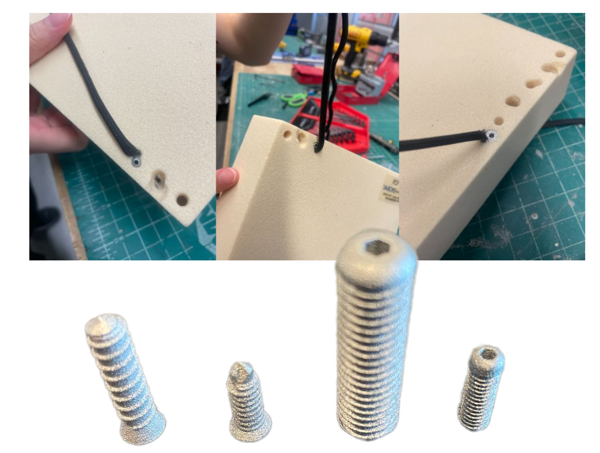

Figure 6: Paracord flush against screws in bone block simulating surgery. Bottom shows titanium initial prototypes.

Version 2 - Design Edits

- Incorporated lattice
  - Cylinder: Surface lattice
  - Self-Tapping: Surface lattice
  - Buttress: Middle body
- Standardized loop hole for Mark-10 testing
- Rounded out threads

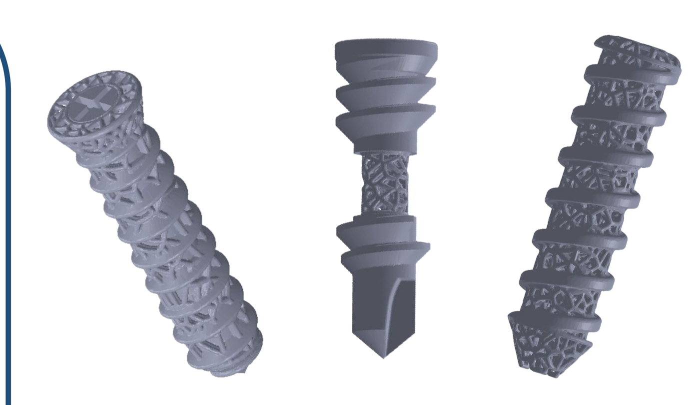

Figure 7: Version 2 CAD models after incorporation of lattice: Self-tapping (left), Buttress (middle), Cylinder (right).

Version 2 - Testing

- FEA: Simulated physiological pull-out forces (~104N)
- Mark-10 Pull-Out: Conducted static axial pull-out testing in 15 PCF Sawbones foam

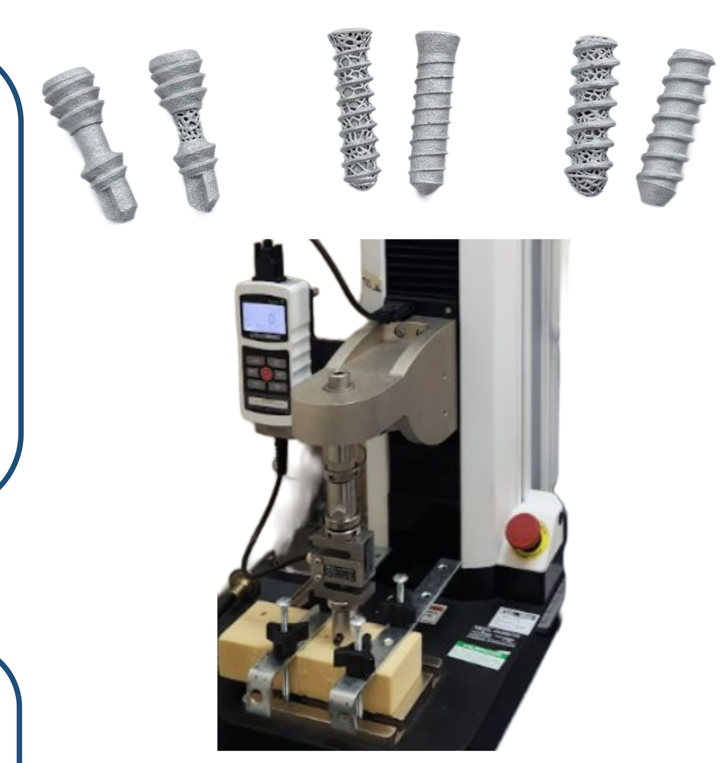

Figure 8: Version 2 titanium screws (top). Mark-10 setup testing screws in bone block (bottom).

Final Design

- Self-Tapping Screw: Increased thread size, Hex driver, Limited sharp edges, Editable CAD dimensions

Results

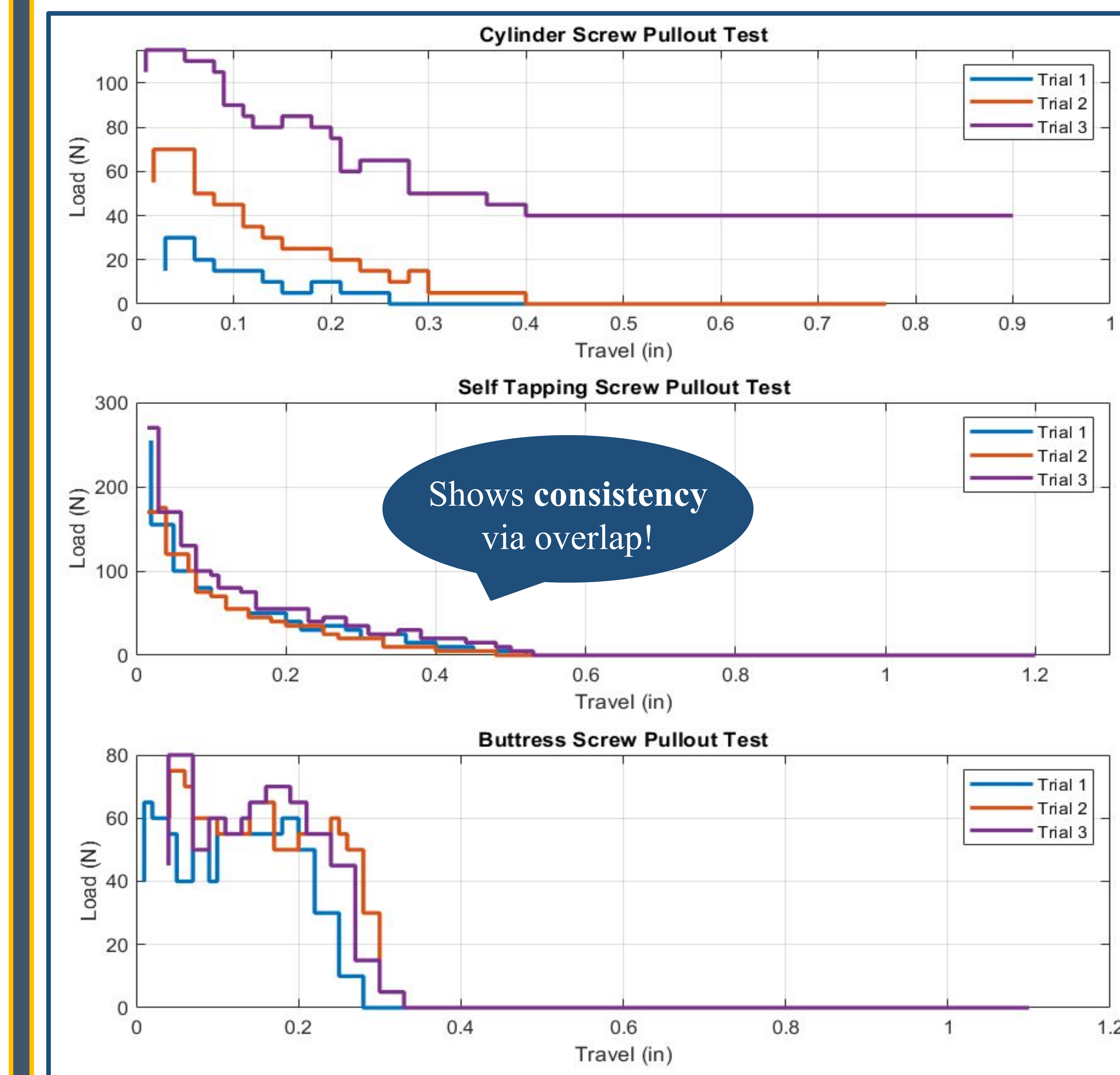

Figure 9: Mark-10 pull-out results: 3 trials per screw design.

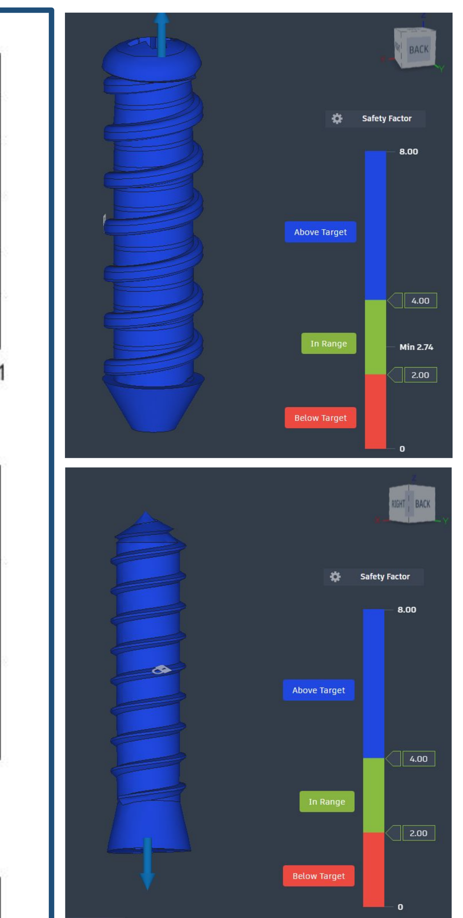

Figure 10: Cylinder FEA with a FOS of 2.74 (top). Self-tapping FEA with a FOS of 13.24 (bottom).

Screw Type	Cylinder	Self-Tapping	Buttress
Max Loads (3 Trials)	30N / 70N / 115N	175N / 270N / 255N	65N / 75N / 80N
Average	71.67N	233.33N	73.33N

Table 1: Maximum loads from Mark-10 pull-out test results.

Conclusions and Future Directions

Figure 11: Final screw design; CAD model showing improvement over current fixation screws from success in testing.

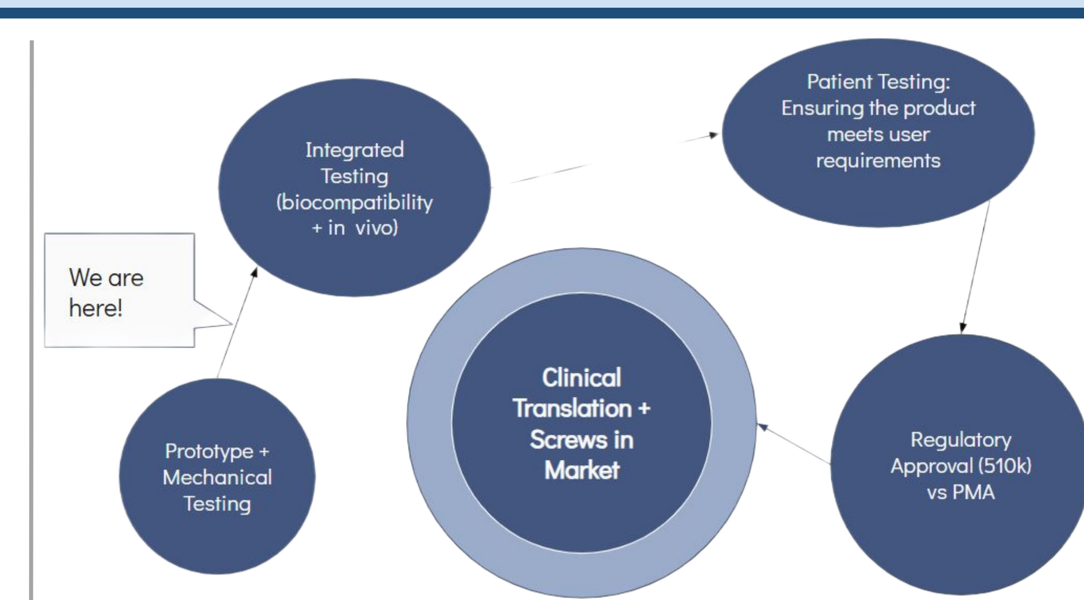

Figure 12: Project timeline. Extensive future evaluation, like in vivo and cyclic testing is required prior to clinical translation.

Acknowledgements & References

Special thanks to **Jeff Brittan** and **David Hart** for supporting this project and providing input every step of the way. Also thank you to **Iris**, **Dr. Taylor**, and **the teaching team** for not only allowing this project to happen but also for providing guidance throughout the project.

References