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Common Problems with Prosthetic Sockets

- Poor fit/function of socket leads to: ulcers, lesions, poor circulation.^[1]
- Prosthetic abandonment rate: 25-57%^[1]
- Socket comfort affected by two major variables: pressure and volume change
- Standard socket designs are static and limit activities



The Quatro Socket

A revolutionary transfemoral socket design that will allow amputees to be more active and have less fitting problems than before. Through patient testimonials, the Quatro is said to be the most comfortable and secure socket experienced by its user.

- 3 independently adjusting zones
 - Consist of 4 panels along residual limb that allow for control of volume and compression
- 3 RevoFit™ dials adjust panels
 - Highest level of adjustability
 - Rapid donning and doffing



Have: Qualitative data → Need: Quantitative data

Goal

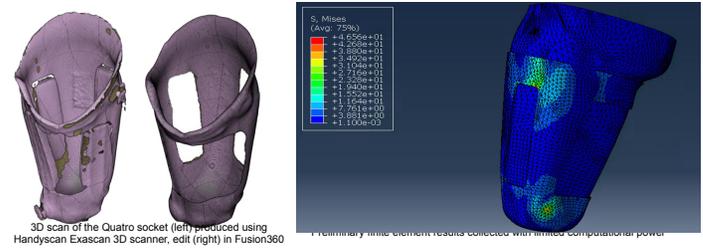
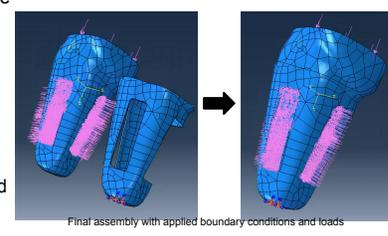
Collect quantitative data that relates pressure points and percent volume change to a comfort measure of a prosthetic socket. Comparing the Quatro Socket to standard sockets on the market through engineering testing and techniques.

Objectives

- Create FEA model via 3D scan
- Validate FEA model with benchtop testing mechanics
- Full failure analysis of the socket
- Collect data for volumetric and pressure changes within the socket
- Easily transferable between patients

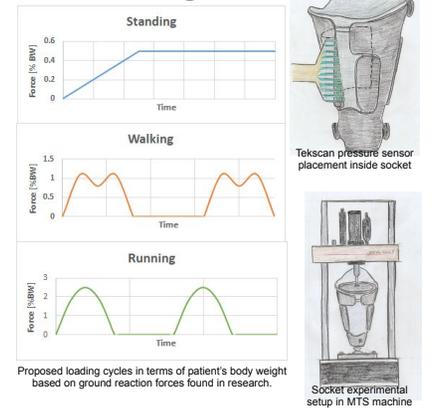
Finite Element Analysis

- Socket 3D scanned and edited to create solid model.
- Assembly of limb and socket were created and imported into Abaqus.
- Load of 80lb applied as distributed pressure of 1.6psi on top of model of residual limb.
- Boundary condition of fixed rotation and movement at bottom of model applied.
- Finite element analysis results must be validated via benchtop testing.



Pressure Testing

- Pressure has been found to have a direct correlation to comfort.^[4] Therefore pressure distribution throughout the Quatro socket can be found via benchtop testing.
1. Socket lined with pressure sensors
 2. Load model limb with an axial force
 3. Iterations of gait scenarios
 4. Iterations of panels loose to panels tight



Volumetric Testing

- Amputees experience change in volume of residual limb throughout the day, ranging from -11% to 7%^[2]
- Testing was conducted to determine the volumetric change capabilities of the Quatro based on changes in pressure within an air bladder as panels were tightened using Boyle's law: $P_1 V_1 = P_2 V_2$

Mean (% ΔV)	Standard Deviation
12.095%	0.85%

Results of volume testing concluded that the Quatro has significant volume change capabilities, which can compensate for residual limb volume changes, and in turn, help to reduce rubbing, irritation, and formation of sores on the limb^[1].



Redesign

- Add more panels (N=4 → N=10)
- Change shape of the panels.
- Change materials used (carbon fiber vs nylon 3D printed)
- FEA can be made specific to different patients (range of patient sizes)

Limitations

Due to the COVID-19 pandemic we were unable to conduct further benchtop testing. Restrictions placed on university provided resources also limited the capabilities to run sophisticated FEA simulations.

Conclusion

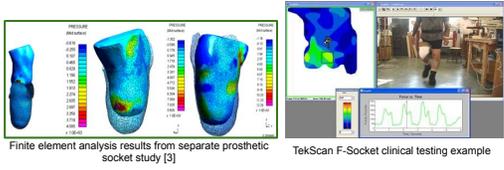
This preliminary data is the foundation for justification of this advanced socket design. We predict the results from the developed methods will provide the needed data that can justify that this design is an improvement on traditional sockets on the market. The volume data will support the Quatro system's claim to allow for macro/micro adjustments. The FEA model will aid in the optimization of discovery and design of successful patient specific fittings that will have a reduced lead time and longer product lifespan. The benchtop pressure data can be used to verify and validate the FEA results and techniques.

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Future Work

- Validate FEA
- Increase Sophistication
- Clinical testing
- Analysis of 3D Printed Quatro
- Complete Failure Analysis



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