Quatro Prosthetic Socket Analysis

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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 will help to reduce rubbing, irritation, and formation of sores on the limb.[1]

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%.[3]
- 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: \[P_1V_1 = P_2V_2\]

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].

Future Work
- Expand iterations of panels
- 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)

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References