Prosthetics is a clinical field in need of further investigation for the improvement of patient care. Engineering principles can be used in collaboration with clinical expertise to quantify key mechanical issues occurring at the residual limb to prosthetic socket interface. Deep penetrating ulcers can form on the residual limb within the socket and the formation is not understood in the current research regarding interface mechanics. Quantitative data on limb motion within the socket, shear forces at the interface, and propagation of these loads to the skin level and deeper tissues are all lacking in current literature. The broad goal of this research was to understand the interface mechanics of the gel liner on the residual limb relative to the prosthetic socket to improve our understanding of displacements, loads and gel liner slip or no slip conditions.

This work consisted of four aims. Objective 1: Develop a quantitative method for assessing motions between the prosthetic device and gel liner on the residual limb for patients with transtibial amputation. Objective 2: Determine limb displacements, strains, relative socket to limb displacements and angular rotations of transtibial limbs within a prosthetic socket during gait. Objective 3: Quantify normal and shear force within the prosthetic socket for use in modeling. Objective 4: Determine the level of tissue stresses within a layered finite element model including gel liner interactions, constrained with experimental conditions of displacement and normal force.

First, a method to obtain kinematics within a socket was developed using motion capture thin-disc markers beneath the surface of a clear prosthetic socket. Results comparing motion capture with gold standard measurements statistically supported the use of this method. Secondly, the newly developed method was used to obtain limb displacements, strains, relative socket to limb displacements and angular rotations within a prosthetic socket during gait from eight participants. Reflective markers with motion capture were used to track displacements of the gel liner located within the clear prosthetic socket device. Results provide the most comprehensive data set of interface kinematics in a transtibial amputee population and significantly contribute to knowledge of interface mechanics which are a direct predictor of ulcer formation.

Thirdly, a single transtibial prosthetic socket was instrumented with a two axis load cell to measure kinetics at the internal socket wall. The participant walked in three conditions: gel liner, three ply sock and a hole cut through the liner to measure forces at the skin. Shear and normal force data were obtained during walking for these three conditions.
Lastly, simulations of tissue layers in transtibial amputees were modeled with Finite Element Methods in FEBio. The gel liner to skin interface was modeled for two situations 1) gel liner slips on the skin or 2) does not slip relative to the skin. Kinematic and kinetic conditions obtained in earlier objective served as boundary conditions. The purpose was to further understand tissue stresses that may lead to pressure ulcer development and evaluate the influence of various liner stiffness and thicknesses on underlying tissue stresses.

The presented research benefits the biomechanical community by addressing multiple gaps in the literature and our understanding of the interface mechanics associated with prosthetics. These data also further our understanding of how pressure ulcer formation may progress due to internal resulting stresses.

Persons with disabilities please contact the Mechanical Engineering office at 517-355-5131 to request accommodations.