Introduction – Shock absorption during walking is of concern in lower-limb prosthesis users. The loss of anatomical structures due to the amputation affects the body’s ability to readily attenuate shock. The implementation of a prosthetic gel liner may increase shock absorption by deforming under body weight, thereby dissipating or absorbing impact forces. This deformation, contributing to system compliance, may help regulate pressure through the residuum (Lin et al., 2004, Silver-Thorn and Childress, 1996). We hypothesized that a thick gel liner would increase compliance at the limb-socket interface and create a more uniform distribution of peak pressure across the residual limb. It was also hypothesized that this increased compliance would allow subjects to walk at a faster self-selected speed and alter other gait parameters, such as ground reaction force profiles and kinematics.

Materials and Methods – Subjects: Persons with a unilateral transtibial amputation were recruited for this study. Research Tools: Each subject participated in two data collections that involved a gait analysis, a loading protocol, and a questionnaire. Procedures: Subjects were provided with a custom-fabricated experimental prosthesis including a 3mm Ohio Willow Wood Alpha liner. They were given a minimum of two weeks to accommodate to the prosthesis. The gait analysis was performed at normal, slow and fast self-selected walking speeds. Pressure data on the residual limb were monitored in five locations (patellar tendon - PT, distal anterior tibia - DT, fibular head - FH, medial gastrocnemius - MG, and distal end of the tibia - DE) using capacitive pressure sensors. Next, the subjects participated in a loading protocol, where the prosthetic foot was replaced with an experimental foot plate designed to control the point of loading. Subjects were asked to load their prosthesis by stepping in place as marker position data and ground reaction forces were recorded. Following the data collection, subjects filled out a questionnaire about the liner, and were fit with a second prosthesis that included a 9mm Alpha liner. Subjects repeated the protocol on the second liner two weeks later. Data Analysis: Motion data were collected and filtered using EVa RealTime software; joint kinematics, ground reaction forces, and temporal-spatial data were calculated using OrthoTrak software (Motion Analysis Co., Santa Rosa, CA). Compliance was determined using a linear spring model that incorporated socket displacement from the residual limb and ground reaction force data. All data were averaged and plotted in MATLAB. A 2x3 repeated measures ANOVA was performed using SPSS statistical software.

Results – Eleven subjects participated in this study. Subjects’ residual limbs were categorized as bony (n=5), average (n=1), or padded (n=5) based upon residual-limb soft tissue coverage. Subjects with bony residual limbs (BRL) and padded residual limbs (PRL) were analyzed as groups. At greater than 10% of body weight, the 9mm liner displayed a statistically insignificant decrease in stiffness (88.04 N/mm to 80.00 N/mm). BRL subjects experienced a decrease in peak pressure at the PT, DT, and FH with the 9mm liner, while PRL subjects found a decrease in peak pressure at the FH, an increase at the DT, and no change at the PT with the 9mm liner. The decrease in pressure at the fibular head was significant for all subjects (p = 0.01). However, when compared to uniform normal pressure estimates, the 9mm liner created a more uniform distribution of pressure at the limb-socket interface for all subjects. The PRL group experienced a small increase in walking speed (p = 0.04) with the 9mm liner, and all subjects had a larger vertical ground reaction force weight-acceptance peak on the prosthetic side (p = 0.02) with the 9mm liner. No other kinematic or kinetic variables were altered with the thicker gel liner. Questionnaire data indicated that BRL subjects found the 9mm liner much more comfortable than the 3mm liner, while PRL subjects had more divided opinions on the two liners.

Discussion – Statistical significance was difficult to determine for many of the analyzed variables owing to small sample sizes and high variability between subjects. Despite these limitations, some evidence to support the hypotheses was found. At loads greater than 10% body weight, the 9mm liner demonstrated greater compliance than the 3mm liner. Additionally, we found that the 9mm liner created a more uniform normal pressure distribution at the limb-socket interface, as suggested by Lin et al. (2004) and Silver-Thorn and Childress (1996). Finally, although small increases in walking speed and vertical ground reaction force peaks were found with the 9mm liner, no clinically significant changes in gait were observed. Even so, many subjects – particularly those in the BRL group – perceived the 9mm liner to be more comfortable. Therefore, the prescription of a thicker prosthetic gel liner may be appropriate for many transtibial amputees with reduced soft tissue on their residual limb, while thicker gel liners may be too hot and bulky for many amputees with more residual-limb soft tissue.
