A Computational Tool to Enhance Liner Selection

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INTRODUCTION

With over 60 prosthetic liners available, it can be challenging for a practitioner to choose the best liner for each patient. Previous research has investigated six distinct mechanical properties of 25 prosthetic liners (Cagle, 2015), however, it is unclear how these materials respond to the compound loading experienced in normal use. The purpose of this research was to create an accurate Finite Element Model (FEM) to estimate how different liner materials influenced load transmission to a residual limb.

METHOD

Magnetic Resonance Images (MRI) were taken of a residual limb within a prosthetic socket. From these images, a FEM was created that included the distal third of the thigh and the residual limb. Components included skin plus muscle, patellar tendon, liner, and socket. Material data for the soft tissues and prosthetic socket were taken from the scientific literature. Force data reflected pylon loads collected during the weight-acceptance phase of gait.

Three different liner materials were modeled. Liner property data were from material tests collected in the lab and then fit to a non-linear hyperelastic material model. The liners chosen represented extremes of available liner properties – hard-slick, soft-slick, and soft-sticky. Frictional slipping and surface separation was modeled both between the liner-socket and the limb-liner interfaces.

Load transmission was evaluated by comparing slipping, pressure, and frictional shear stresses at the limb-liner interface for the three liner materials.

RESULTS

Slipping was more pronounced between the limb and liner than the liner and socket, particularly over the lateral wall and the tibia. Slip between the limb and liner over the tibia was 1.2mm, 1.1mm, and <0.1mm for hard-slick, soft-slick, and soft-sticky liners, respectively.

Each liner tended to distribute socket loads in a unique manner. The hard-slick liner transmitted loads through focused pressures in targeted regions such as the patellar tendon. The soft-slick liner transmitted loads through pressures over a more distributed area (Figure 1). The soft-slick liner experienced the greatest deformation and thinning under high loads. Peak stresses were not as well distributed compared to the hard-slick or soft-sticky liners, and skin contact pressures were increased in regions where loads were typically undesirable, most notably around the fibular head and distal tibia.

The soft-sticky liner shifted load transmission compared to the slick liners. Peak pressures were decreased by 19% in target loading areas (e.g., the patellar tendon), while no increase was seen in non-targeted regions. Loads were transmitted through frictional shear stresses more evenly distributed over the limb compared with the slick liners (Figure 2).

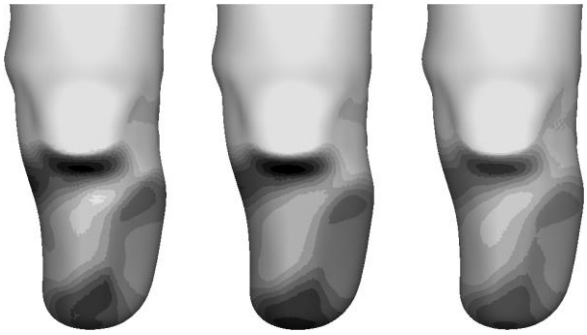

Figure 1: Pressures for hard-slick (left), soft-slick (middle), and soft-sticky (right) liners

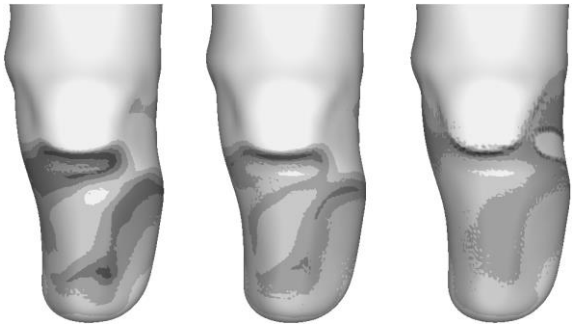

Figure 2: Frictional shear stresses for hard-slick (left), soft-slick (middle), and soft-sticky (right) liners

DISCUSSION

Limb-liner interface stress distributions can be manipulated by adjusting liner material properties. Desirable loading is best achieved when stiffness and friction are complimentary (stiff-slick or soft-sticky). Further research should investigate how results change with heat and friction due to sweat.

CLINICAL APPLICATIONS

Liner selection can be improved by tailoring a liner's method of transmitting ambulatory loads to an individual user's residual limb. This model will be used to evaluate all 25 prosthetic liners measured to date and integrated with a free online tool, the Prosthetic Liner Assistant (www.LinerAssist.org).

REFERENCES

Cagle. Proc ISPO 2015 World Congress, p170

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