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Title
Effect of Socket Fit, Cadence, and Suspension on Multiaxial In-Socket Movement of the Residual Limb

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Summary
The purpose of this study is to: 1) measure pistoning and horizontal motion (transverse plane) of the limb inside the socket using an inductive proximity sensor; 2) measure changes in the movement due to socket fit; 3) determine relationship to elevated vacuum pressure fluctuation during gait.

Introduction
Existing literature investigating motion between the socket and residual limb mostly considers pistoning (Board, 2001; Darter, 2016; Gerschutz, 2015). Although other types of movement have been measured using imaging technologies (Kahle, 2013), these imaging modalities somewhat restrict user movement to the capture workspace. Previous work explored the use of elevated vacuum pressure profiles to quantify socket fit (Wernke 2016) and early evidence suggests these profiles are sensitive to both global and local differences in fit as well as different types of movement. Another benefit of using vacuum pressure profiles is this information can be collected without limiting the users' movement. The purpose of this study is to: 1) measure pistoning and horizontal motion (transverse plane) of the limb inside the socket using an inductive proximity sensor; 2) measure changes in the movement due to socket fit; 3) determine relationship to elevated vacuum pressure fluctuation during gait.

Methods
Twenty lower-extremity prosthesis users participated. Inductive coils were placed around the socket to measure vertical and horizontal movement of the limb within the socket. Magnetic targets were adhered to the outer liner surface in areas that corresponded to the inductive coils

embedded in the socket. The LimbLogic Vacuum System was used to generate and monitor elevated vacuum pressure inside the socket.
Limb shape was captured wearing a 6mm uniform Alpha liner and the shape digitally modified with an appropriate reduction (Normal). Two more sockets were fabricated with -1.5% (Tight) and +1.5% (Loose) modifications from the Normal socket shape. Liner variations were made with Alpha design liners by thinning the gel thickness to 3mm in certain locations. Participants completed short walking trials with specific socket and liner combinations and at different vacuum settings while inductive sensor and vacuum pressure data were collected. Data for 10 consecutive steps were analyzed.

Results

Pistoning and horizontal movement were dependent on socket fit as well as the vacuum pressure setting. The loose socket condition with lower vacuum pressure settings generally resulted in the most horizontal movement and the tight socket condition with lower vacuum pressure settings resulted in the most distal movement. The movement decreased as the vacuum pressure setting was increased and with the normal (well-fit) socket condition. Interestingly, horizontal movement still occurred with the tight socket condition, perhaps due to the limb not fully reaching the distal end of the socket. Transfemoral subjects tended to have more horizontal motion than transtibial subjects, likely due to anatomy of the residual limb. Horizontal motion generally attributed 20-50% of the total motion depending on socket fit condition, suggesting poorer biomechanical performance through a decreased transmission of motion between the user and prosthesis. Increases in cadence led to increases in movement occurring at the socket interface measured by both the vacuum pressure profile and inductive sensor array. The relationship of cadence on movement was impacted by socket fit. Vacuum pressure data had a positive correlation to the inductive sensor data, indicating it can detect global and local changes in fit.

Conclusion

This study provides new insight into socket interface movement and its relationship to socket fit and vacuum pressure. This study quantifies the impact of global and local differences in socket fit and how fit impacts movement of the limb inside the prosthesis. The vacuum pressure profiles correlated positively with the data, suggesting it can be a clinically useful for the assessment of socket fit. This information can in part help define optimal socket fit and suspension metrics which currently do not exist. The limitation of this work is that it only approaches the problem from a mechanical perspective, and does not include the impact of movement on limb health. Previously our group found physiological differences based on suspension method, however there are no studies to evaluate the physiological impact of motion within the socket. Here the data shows that for a well fit socket, motion can be eliminated at vacuum pressure settings below the maximum setting. Therefore, could damage to the limb tissue occur by applying additional pressure? Alternatively should we eliminate all motion or is some beneficial from a physiological perspective? Current work focuses on addressing this gap. Through a better understanding of socket interface movement, how this movement relates to socket fit, and creating ways to quantify these movements will enable better evidence based practice surrounding the socket and interface designs and modifications.

References

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