Biomechanical Investigation of Principles of Load Transfer in Transfemoral Sockets: An Innovative Study Design and Preliminary Results

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Introduction

There are different prosthetic socket technologies for the treatment of transfemoral amputees. Within this context, ischium containment socket technologies have established in the past. They differ from other technologies in shape and functionality (Sabolich, Ortiz, Schuch). The main difference is to be found in the proximal functional area that is responsible in different proportions for the force transmission between the residual limb and the bony pelvis structures. Socket technologies without force transmission in the pelvic region are available as well (brimless sockets).
Within the scope of this biomechanical study, a study design has been developed to investigate force transmission principles by main functional elements of a transfemoral prosthetic socket. The study aims at further increasing the understanding of force transmission between residual limb and prosthetic socket.

Methods

To record the forces in the four main socket areas (area of ischium containment, lateral support, frontal support, volume and control area), the sockets are segmented according to these areas and implemented in a CFK frame. Between frame and socket segments, load sensors are installed. They are able to record three forces in the corresponding segments and their centres of pressure within a cartesian coordinate system. Using a self-developed data transmission path, the measuring data are transferred via a mobile wireless LAN system to a central PC and triggered synchronically to a stationary gait analysis system (Kistler, Vicon).
Loading between the residual limb and three different sockets (CAT-CAM, MAS, brimless socket) was measured with 5 transfemoral amputees in the following situations: standing with different socket adduction and flexion angles, level walking at three different walking velocities, descending stairs and ramps. For the measurements in standing, the measured socket is tightly installed on a stationary fixture and brought into the different test positions by means of a spherical sliding adapter. For the measurements during movement, a trial prosthesis with a prosthetic knee joint and a prosthetic foot is mounted by analogy with the everyday prosthesis.

Results

First results suggest that the principles of force transmission between a CAT-CAM and MAS socket do not significantly differ from each other - neither in standing position nor during walking. With both socket types, a high degree of axial forces is transferred by the medially located containment area. Furthermore it becomes obvious that the contribution of the lateral support for stabilization between residual limb and socket during the stance phase is very low. With the brimless socket that does not contact the pelvis, differences can be identified, however. They are to be found in the position of the total force running through the socket leading to the conclusion that the force transmission principles are different compared to a ischial containment socket.

Conclusion

In the literature, the force transmission principles of femoral socket technologies have been discussed exclusively on the basis of fitting experiences (Sabolich, Ortiz, Schuch). Theoretical models such as the so-called hydrostatical principle have been used. They have assumed that - also with ischial containment total contact sockets - an axial force can only be transferred by the soft tissue cover of the residual limb. However, clinical observations have not always confirmed this approach. Overloading is often caused in residual limb areas that according to the socket technology used should not transfer any forces. The method described in this study allows for the first time to objectify by comparison which socket areas are involved in force transmission and to what extent.