Author
Leboucher, Julien (None DE) | PhD
Heidelberg University Hospital - Orthopedics and Trauma Surgery

Title
Study of the residual limb and socket interactions using a poly-instrumented prosthesis in a population of transfemoral amputees during gait

Coauthors
Heitzmann DWW, Block J, Salami F, Alimusaj M, Wolf SI

Summary
Goal of this project is to monitor the residual limb-socket interactions during walking activities including electromyography (EMG), ultrasound (US), socket pressure, and kinematics and kinetics in order to provide a better understanding of how transfemoral amputees control their prosthesis.

Introduction
The loss of leg due to a trauma, a tumor or diabetes-related amputation is a serious loss for the affected person. This fact combined to that, in Germany, more than 40,000 major amputations of the lower extremities are performed each year [1], make the study of residual limb and socket interactions a topic of great importance.
Indeed, prosthetic biomechanics is a topic that has been described as "one of the most challenging area in the field of biomechanics" [2]. This challenge is partly maintained because, despite advances in technology and miniaturization, measurements in this field continue to be rather delicate.
The goal of this study is to allow for a finer biomechanical modeling of users and to provide answers on how the prosthesis fulfills its three-fold objectives that are: allowing for the transmission of axial forces in providing support; transferring of horizontally directed forces for stabilization; and adhering to the residual limb for suspension during the swing phase

Methods
Instrumented prostheses will be designed to study the kinematics and the kinetics of the residual limb. The prosthesis will include a number of sensors (EMG, US, pressure sensors) for monitoring as accurately as possible how the user controls his/her prosthesis.

The purpose of this sensors is to record remaining muscles activity (EMG), to track the residual bone position within the soft tissue and the socket (navigated US probes) while recording kinematics and kinetics of the prosthesis user.
The goal is to initially evaluate the experimental protocol on three users. The first part of the protocol will consist of measuring patients isometric hip torques using a dedicated device [3] before asking them to perform gait-related tasks. The protocol will then be extended to 5 to 7 patients in a validation stage. Experimental data will also be used to feed a model of the artificial joint between the residual limb and the socket, which almost all biomechanical models ignore.

Results

As a first step, retrospective medical imaging data (CT or MRI) will be used to obtain knowledge of patients anatomy (muscle position and remaining bone shape). This will allow finding the most appropriate positioning of EMG electrodes and US probes.
In order to allow experiments to be performed, patient-specific sockets including all sensors will be designed. This patient specific design is mandatory due to the variety of bone cuts and soft tissue suturing.
Special care will be given to ensure the fitting of the socket while including the sensors in contact with the residual limbs (US probes, EMG electrodes, pressure sensors).
The activation of muscles will be first evaluated on the hip torque measurement device (i.e. without the prosthesis) in order to obtain the maximum voluntary contraction. Bone motion will also be tracked using femoral contours semi-automatically segmented from US images from the navigated probes.
The next and final step will consist of running all sensors while the patient walks with the prosthesis. This will allow us to obtain precise kinematics and kinetics of the impaired limb up to the hip joint as well as muscle activation during specific tasks (stairs ascent and descent, and level and non-level walking), pressure data on specific areas and bone position in the socket.

Conclusion

This study will allow getting a better comprehension of how forces are transferred from the hip joint and residual limb to the socket and the prosthesis for body support and patient stability during gait. It will also shed light on how muscles contractions contribute to this transfer and to the adherence of the prosthesis out of stance phase.

The instrumented prosthesis will allow as well for a better understanding of the residual limb and prosthesis socket interactions. This will be achieved thanks to the recorded biomechanical data and to the residual limb-socket pseudo-joint model fed with experimental data. These data will help to improve socket designs based on objective knowledge that will complement designers professional experience.

References

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