INTRODUCTION

A lower-limb prosthesis is often used to restore appearance and lost function to individuals with limb amputation. The soft tissues of the residual limb are not well suitable for load bearing. A quantitative understanding of the relationship between a designed socket and load transfer property at the residual limb/ prosthetic socket interface is the fundament for an optimal design.

Finite element (FE) methods have been widely used in prosthesis design during past 30 years. Several models have been developed to study the interface mechanics between the prosthetic socket and residual limb. However, all models reported so far are static by applying static forces/moments to simulate a single or more phases of gait. A dynamic model should be developed to consider not only variable external loads, but also material inertial effects during gait.

Before establish a full dynamic model, it is useful to estimate how much the material inertia will influence the load transfer property during walking. The aim of this paper is to study the effects of inertial loads on knee joint load calculation and interface stress distribution between residual limb and prosthetic socket during a whole gait cycle.

METHODS

Based on the 3D free body diagram shown in Figure 1, equivalent forces and moments applied at the knee joint were calculated with consideration of variable ground reaction forces, weights of residual limb and prosthetic components, and material inertial loads. The kinematic and kinetic data needed for the calculation were obtained using Vicon motion analysis system and ATMI force platform.

Figure 1: 3D model for load calculation at the knee joint

A 3D nonlinear FE model was built, using actual geometry of residual limb and bones from magnetic resonance images and modified PTB socket. The material properties in FE model were assumed to be linear, homogeneous and isotropic. Automated surface-to-surface contact with friction (COF=0.5) was defined to simulate friction/ slip boundary conditions at the interface of residual limb and prosthetic socket. Relative slip was allowed. The outer surface of liner was fixed assuming the hard socket would offer a rigid support. The equivalent dynamic loads were applied at the knee joint. The FE model was analyzed using the ABAQUS finite element package.

RESULTS AND DISCUSSION

Interface pressure and shear stress between residual limb and prosthetic liner were predicted during walking. One example (interface pressure at middle patella tendon) of the results with or without inertia effects was compared in Figure 2. It can be found the curves in two cases have similar double-peaked waveform in stance phase, while there is significant change in swing phase. The average difference in both interface pressure and shear stress prediction is 8.4% during stance phase and up to 20.1% during swing phase.

Figure 2: Interface pressure at patella tendon during gait cycle with or without consideration of material inertia

Although the FE model presented here is not a full dynamic model, the inertial effects on the prediction of interface stress distribution were investigated during walking. One example (interface pressure at middle patella tendon) of the results with or without inertia effects was compared in Figure 2. It can be found the curves in two cases have similar double-peaked waveform in stance phase, while there is significant change in swing phase. The average difference in both interface pressure and shear stress prediction is 8.4% during stance phase and up to 20.1% during swing phase.

SUMMARY

The effects of material inertia on the load transfer property at residual limb/ prosthetic socket interface were studied. The findings will be significant for improving techniques of prosthesis design.

REFERENCES