OPTIMIZATION OF MUSCLE ATTACHMENT LOCATIONS FOR A MORE PHYSIOLOGICAL FEMUR MODEL

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Introduction

Boundary and loading conditions applied in pre-clinical testing of intact and/or implanted femur change widely. It was shown that only physiological joint constraints (at the hip and knee) could produce physiological deflection of femur [Speirs, 2007]. However, a non-physiological “residual reaction force”, (RRF) develops at the femoral head due to the constrained motion of this joint [Simoes, 2000, Paul, 2001]. This residual force is probably due to the imbalance of externally applied (muscle and joint) forces in the model. Although the hip contact force (HCF) is well documented, the boundary and loading conditions at the knee are not. Also, there is an ambiguity in the muscle attachment locations.
In this study, it is proposed that this residual reaction force is minimized via optimization.

Methods

A rigid body-model was employed to realize the static equilibrium of the femur, taking into account the loads (HCF, abductor+tensor fascia latae, and vastus lateralis muscles) at the instance of maximum *in vivo* hip contact force during a gait cycle as proposed in the reduced muscle loading model of [Heller, 2005]. In order to achieve a more realistic model, improvement of boundary and loading conditions at the knee joint as well as optimization of the muscle attachment locations, are necessary. The optimization objective is to minimize the RFF, where the muscle attachment locations are varied within search regions via a genetic optimization algorithm. The initial attachment points are determined from [Heller, 2005].
The proper constraining and loading of the femur at the knee joint, including the patella-femoral contact force is within the scope of this study, towards the achievement of which progress is under way.

Results

In order to illustrate the viability of an optimization study, we have obtained some preliminary results that reflect the sensitivity of the RRF to muscle attachment locations. As shown in Fig. 1, a search region with local x, y coordinates were attached to the attachment point of vastus lateralis. The search plane is oriented such that its normal is also normal to the femoral surface. It was observed that an 8-mm shift in the y-direction produced a 4% reduction (from 280 to 255 N) in the RRF. Similarly, a 5% was obtained for the combination of abductor and tensor fascia latae muscles.

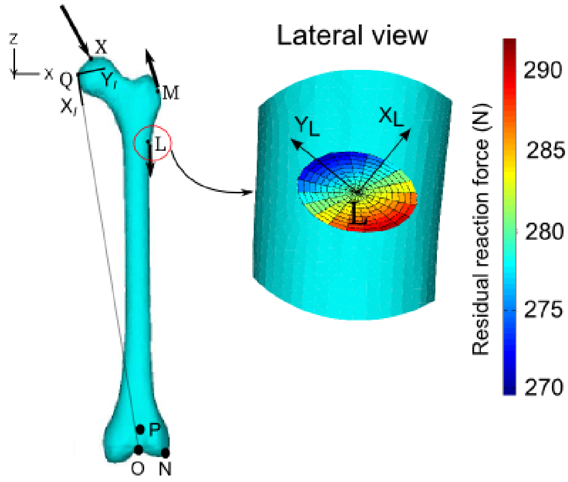

Figure 1 Rigid body-model of the intact femur (left), and the variance of RRP in the close neighbourhood of the vastus lateralis muscle (right)

Discussion

Application of reduced muscle loading and joint constraints creates a non-balanced force and moment system, which results in RRF at the femoral head. It was seen that reduction of this excess force was possible within small search regions around the muscles’ cross sections. As improvement in the knee joint modeling and optimization of muscle attachment locations will be held within the scope of this study, it will be possible to obtain a more realistic femur model.

References

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