DEVELOPMENT OF AN FE MODEL OF UNI-COMPARTMENTAL KNEE REPLACEMENT

[1] Andrew R Hopkins, [1] Mark Taylor, [1] Sara Checa Esteban, [1] Andrew New and [2] Lorin P Maletsky
[1] Bioengineering Science Research Group, University of Southampton.
[2] Department of Mechanical Engineering, University of Kansas.
E-Mail: a.r.hopkins@soton.ac.uk,
Web: http://www.ses.soton.ac.uk/projects/Bioengineering_Sciences/bioengineering_sciences.html

INTRODUCTION

Uni-compartmental replacement of the knee is recognized as a suitable treatment for localized damage of the tibiofemoral joint, whilst often allowing for later revision to a total knee replacement [1]. Several clinical studies have followed the progress of this implant device, however to date there have been very few computational studies [2]. The purpose of this project is the development of a Finite Element testing suite for the uni-compartmental knee, and its validation against existing clinical data. This paper will consider the steps involved in the development of such a model.

METHODS AND MATERIALS

Loading of the knee has been applied using data gathered from the Kansas Knee Simulator. This device uses five axes of dynamic control to apply loads to the components of the total knee replacement during activities such as walking and squatting. The loading profile consists of a vertical component applied to the centre of rotation of the hip, a prescribed rotation of the femur during walking (12-37° flexion), an applied quadriceps loading, tibial torque and abduction-adduction of the tibia. An FE model of one of the tested component sets was developed from CAD data (Fig. 1). The femur, tibia and patella were modeled as rigid bodies for this analysis, with the quadriceps modeled as a 2D membrane. Following successful application of the Explicit Finite Element time-stepping scheme to the analysis of total knee kinematics with the Stanmore simulator [3], all analyses were conducted in the Explicit FE solver PAMCRASH (ESI Software). The femur was free to rotate and translate relative to the vertical axis. The tibia was permitted to rotate around the ankle centre, but not to translate in the vertical axis. The resulting unconstrained movement of the knee components was recorded during these different activities and compared to the experimental findings.

Figure 1 – FE models of TKR used to validate loading configuration.

Using the software package AMIRA (TGS Software) it is possible to extract surface representations of the anatomy of the lower extremity. Surface meshes of the osseous geometry have been developed from this data (Fig. 2), and in the first instance a model of the intact knee has been developed, inclusive of cartilage and ligaments. Following successful modeling of this configuration, a uni-compartmental knee device will be developed from CAD data and introduced to the lateral and medial compartments in separate analyses.

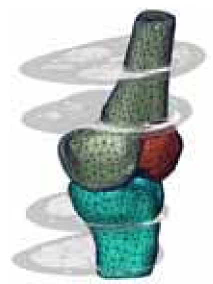

Figure 2 – Surface meshes of femur, tibia and patella developed from CT

RESULTS AND DISCUSSION

Displacements of the patella, tibia and femur were recorded during loading and compared with experimental data. The FE model managed to reproduce predicted kinematics to within 8% for all three components. Time-step size was not found to influence kinematics, however due to the large ranged of movement in the unconstrained knee system mass and inertial forces were found to be of critical relevance. The model was extremely sensitive to misalignment of the components.

The surface meshes of the tibia, femur and patella have been introduced to the finite element model of the total knee replacement. Initial results suggest that precise positioning of these osseous geometries and the inclusion of accurate inertial qualities of the mesh will influence the kinematics of the intact knee.

REFERENCES

1. Marmor L, *Clin Orthop Rel Res* **94**, 242-248, 1973.
2. Iseaka K, et al. *J Biomech* **35**, 969-974, 2002.
3. Godest A-C, et al. *J Biomech* **33**, 435-442, 2000.

ACKNOWLEDGEMENTS

This work has been funded jointly by EPSRC and DePuy International.