3D FE MODEL OF THE PATELLOFEMORAL JOINT CONTACT

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INTRODUCTION

The problem of joint contact mechanics in articular cartilage can be studied theoretically with an exact solution only for small displacements and 2-D or axi-symmetric geometries (Wu et al., 1997). When studying a real joint geometry, a numerical analysis is necessary. In this study, we implemented the biphasic model proposed by Holmes and Mow (1990) into the commercially available FE software ABAQUS 6.3, in order to simulate the 3-D patella and femoral groove contact problem. The cartilage surface geometry was based on laser scanning experimental data of cat knee joints obtained in our laboratory. The main purpose of this study was to investigate the relationship between joint alignment and cartilage contact stress in a real 3-D model of diarthrodial joint.

METHODS

The 3-D FE model of the femoral groove and the patella was based on laser digitized surface scanning data. The 3-D FE mesh model was created by TrueGRID, and ABAQUS 6.3 was used to perform a large displacement contact analysis. In this analysis, articular cartilage was assumed to be biphasic: the solid phase was assumed linearly elastic and incompressible, and the fluid phase was taken as incompressible and with a deformation-dependent permeability (Holmes et. al., 1990). The articular cartilage surface was assumed to be permeable, in order to allow for fluid flow. Cartilage thickness on the femur and patella was taken as 0.3 *mm* and 0.5 *mm* respectively; the thickness was assumed to be uniform, and each cartilage layer was mounted on a cortical bone support. In order to compare different alignment conditions, the patella was shifted laterally by 0.5 *mm* and 1.0 *mm*, and the reference alignment position was assumed to be a 70 degree knee angle position (Hasler and Herzog, 1998). A 0 to 3 *N* ramp load was applied over 120 *s* to the patella, and then kept at 3*N* until a steady-state was reached, where the steady-state was defined by the time derivative of the pore pressure (less than 10^{-3} *MPa/s*) .

RESULTS AND CONCLUSION

As the patella was shifted laterally, the contact area was decreased, peak contact pressure was increased and time to steady-state was increased (Figure 1 and 2). Therefore, a small displacement of the patella relative to femur may cause a great change in its local joint loading that may cause degenerative responses. Specifically, a 1mm lateral displacement increases the peak contact pressure by a factor of two for a given patellofemoral contact load. These results indicate the potential importance of bone alignment to the mechanics of diarthorodial joint.

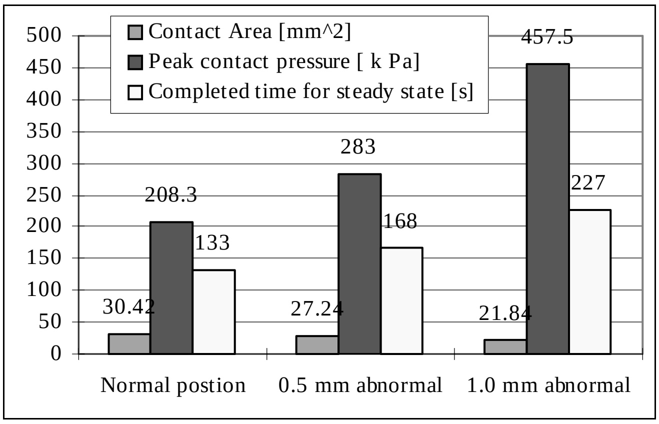

Figure 1. Comparison between the normal and abnormal alignment of patella relative to femur

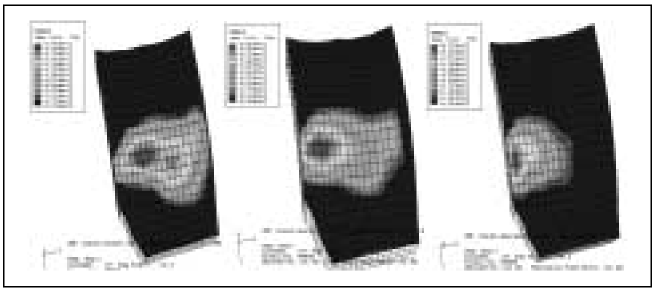

Figure 2. Contact pressure plots for normal and abnormal alignment for the patella relative to the femur

Here, we showed that a small misalignment of the patella relative to the femur changes the joint contact mechanics for a given external load. Therefore, understanding of the contact mechanics requires a very accurate, 3-D geometry of the articular cartilage surface and the corresponding bone alignment and orientation. This is a problem that has not been solved adequately for in vivo diarthrodial joints. Thus, contact models and simulations remain, at present, the best source for estimating the in vivo contact mechanics of real joints.

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