Osteochondral Defects in the Human Knee with Evaluation of Defect Size on Cartilage Rim Stress: In-Situ Study for Finite Element Model Validation

*Papapantoniou, G; #Demetrioupolos, C; #Gueitler, J; #Jurist, K; *Fyhrle, D; *Tashman, S; *Yang, K

*Bone and Joint Center, Henry Ford Health System, Detroit, MI, #Biomechanics and Implant Analysis William Beaumont Hospital, Royal Oak, MI, +Bioengineering Center Wayne State University, Detroit, MI

Introduction

The purpose of this study was to determine the effects of various defect sizes on rim stress and pressure distribution in a human cadaveric knee. Subsequent finite element (FE) computer modeling of these defects was designed to determine the deformation of the underlying cartilage and to further analyze the development of rim stress.

Methods

Eight fresh frozen cadaveric knees were used to study the rim stresses around osteochondral defects of the femoral condyles. Knees were mounted in 30 degrees of flexion on an Instron materials tester (Instron Corporation, Canton, MA). A K-Scan pressure sensor (Tekscan Corporation, South Boston, MA) was inserted between the femoral condyles and the meniscus to dynamically measure pressure distribution during loading. Each intact knee was loaded to a maximum value of 700 N under load control. Maximum load was maintained for 5 seconds prior to unloading of the specimen. Loading and pressure mapping history were recorded for analysis. Following the testing of the intact knee, full thickness circular defects were created (Fig 1) using a friction coefficient of 0.001. We input the 3D kinematics on part of the skeleton, for the surface interaction in the knee joint with friction formulation and surface tangential contact algorithm (ABAQUS/standard) was applied for the defect size of 12 mm.

Results

Experimental results demonstrated that pressure distribution around defect sizes 8 mm and smaller were dominated by the effects of the meniscus. However, when defects of 10 mm and greater were created, a peak rim stress was observed at an average distance of 2.64 mm +/- 1.63 mm on the medial condyle and 2.90 mm +/- 1.51 mm on the lateral condyle. The model predicted the rim stress topology but overestimated the maximum pressure magnitude by about 10% (fig 2).

Discussion

Combining high-quality static 3D imaging, and a knee FE model with experimental kinematics allowed prediction of the effect that different defect sizes have on cartilage rim stress and pressure distribution in a human cadaveric knee. The model overestimates slightly maximum pressure due to its generic nature. Co-registration of multiple imaging modalities should be implemented for increased topological and geometric model fidelity. We also concluded that, even in a very controlled uniaxial compression loading condition, pressure distribution around defect sizes 8 mm and smaller were dominated by the effects of the meniscus. We are now acquiring all of the elements required for a patient specific modeling approach (e.g. CT, MRI, dynamic RSA). Thus, this validated method will enable prediction of patient specific in vivo articular stress in the effort to estimate defects on cartilage continuity.

References