A biomimetic 'sensate' uni-condylar replacement scaffold for knee joint resurfacing

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Introduction: Osteoarthritis is a debilitating disease affecting millions of people worldwide. The pain associated with cartilage degradation leads to decreased quality of life and mobility. Current treatment modalities all have drawbacks, which has prompted development of alternative therapies. One such treatment is to use a condyle replacement scaffold to anchor autologous adipose derived stem cells, which are differentiated to chondrocytes, to resurface the articular cartilage surface. In addition to anchoring the cells within the joint space, this scaffold is designed to measure joint loading in the axial, anterior-posterior (AP) and medial-lateral (ML) direction, which will provide measurements for rehabilitation protocols and can be utilized as a patient warning device. The purpose of this study was to design and test a condyle replacement scaffold that could be used in subsequent *in vivo* studies.

Methods: A Scanco μCT 20 scanner was used to collect a CT data set of the femoral medial condyle from a canine stifle. This data set was then manipulated using Solidworks and Quickslice to develop a rapid prototyping file. The rapid prototyping file consisted of a femoral condyle attached to a cylindrical stem that was 10 mm in diameter (Figure 1). The stem was made from with an outer jacket and stabilizing flanges to provide mechanical strength and a porous interior that was made from an inverted set of CT scans of canine trabecular bone. Polybutylene terephthalate (PBT) was extruded through a Stratasys 1650 Fused Deposition Modeler. Once built, strain gauges were placed along the AP and ML direction within the condyle replacement and an axial gauge was placed along the stem to measure axial compression. The scaffold was calibrated by press fitting the scaffold into Darofoam, which simulated the support provided by trabecular bone, and was loaded in the three principle directions with a material testing system. These custom calibration curves were used to calculate loads from the strain values recorded from the senstate scaffold.

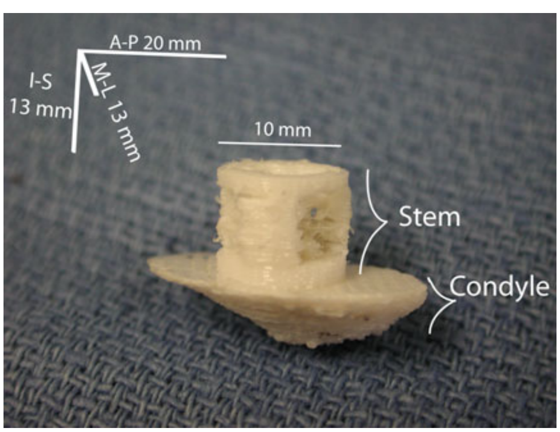

Figure 1: Condyle replacement scaffold. A-P is anterior-posterior, M-L is medial-lateral, I-S is inferior-superior.

Following calibration, the scaffold was implanted into a cadaveric canine stifle by removing the native medial condylar surface, reaming a 10 mm hole and then press fitting the condyle replacement into place (Figure 2). Following implantation the cadaveric stifle was tested in axial compression at 30, 50 and 70 degrees of flexion as well as during passive flexion/extension, varus/valgus flexion and internal/external rotation.

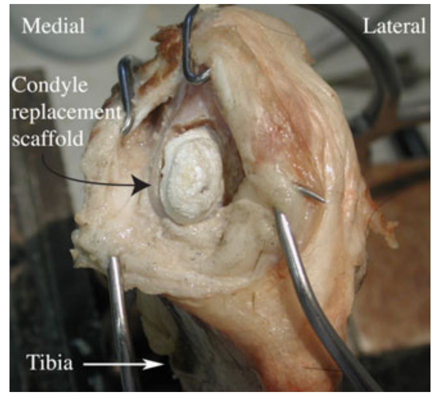

Figure 2: Condyle implanted into stifle joint

Results: A linear elastic curve was measured for each of the strain gauges. Axial compression of the stifle joint at 30, 50 and 70 degrees of flexion illustrated that loads measured by the implanted condyle replacement were greatest at 30 degrees of flexion and least at 70 degrees of flexion. Passive flexion/extension of the joint demonstrated AP shear forces of 36.9±2.6 N. External rotation resulted in AP shear loads of 33.5±0.32 N, which increased to 75.4±8.0 N during internal rotation. ML shear loads during internal and external rotation were much less than AP loads ranging from 3.76 to 7.80 N.

Conclusions: The results showed that a condyle replacement scaffold made of PBT polymer in conjunction with strain gauges can be utilized to measure joint forces during a variety of physiological activities. The observed linear elastic calibration curves are in agreement with previous results from polymer scaffolds used to treat focal chondral defects. Decreasing axial loads with increasing joint flexion angles was expected as the axial gauge was positioned to be co-linear with the loading axis of the femur at 30° flexion. This is also in agreement with previous studies utilizing strain-gauged scaffolds for focal defect repair. The results of this bench-top study demonstrate that a condyle replacement can be effectively utilized to resurface the canine stifle and to measure joint loads. In the future this sensate scaffold will be utilized to anchor adipose derived stem cells in the joint space to facilitate cartilage regeneration.

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