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Articular cartilage friction and wear in a unicompartmental hemi-arthroplasty of the knee tested in an anatomic simulator: the effect of tibial plate conformity and stress

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Purpose: An understanding of articular cartilage (AC) tribology could provide possible explanations for the premature failure of spacer/hemiarthroplasty devices used to treat arthritic patients. The purpose of this study was to develop a medial unicompartmental knee model for tribological testing of AC in an anatomic simulator, in particular, the examination of tibial counterface conformity and stress on AC friction and wear.
Methods and Materials: Tests were conducted in a pendulum friction simulator (SimSol, UK). Sagittal sections of the medial condyle of a bovine femur was made to articulate against conforming metallic tibial counterface (R=50mm and 100mm). Physiological knee loading profiles, representing low and high stress conditions were applied, the lubricant was 25% bovine serum and AC wear was determined through 3D surface profiling (Talysurf, TaylorHobson, UK). AC friction and wear of the conforming bearings were compared to an AC-AC negative control and AC-flat counterface positive control.
Results: The conforming bearings showed similar AC friction to the negative control AC bearing (μ=0.022–0.04), but showed significantly lower friction and negligible wear (R~a~=0.136–0.145μm) compared to the positive control flat bearing (μ=0.078, R~a~=2.70μm), at low stress levels. However, under higher, more physiological stress conditions, AC friction, increased significantly (μ=0.2) with rapid and severe wear, in the conforming and flat bearings.
Conclusions: This study has shown that conforming knee bearings produce minimal AC friction and wear, attributed largely to the low stresses experienced. However, under physiologic load levels, the higher stresses rather than the friction would appear to be an important factor in predicting AC degeneration in hemiarthroplasties.

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3D in vitro model for testing drug potency on cytokine –mediated inflammation in disc cells.

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Purpose: To establish three-dimensional in-vitro annulus fibrosis (AF) and nucleus pulposus (NP) models to investigate proteoglycan modulation and changes in gene expression in response to inflammatory cytokines such as Interleukin-1 (IL-1B) and potential therapeutic agents such as growth and differentiation factor (GDF-5), and P38 Kinase Inhibitor.
Methods and Materials: AF and NP cells from bovine caudal discs were isolated by enzymatic digestion and seeded (2x10^{6}cells/cm~2~) onto Millipore CM filters coated with Collagen Type II and cultured in DMEM/20% heat-inactivated FBS/100 ug/ml ascorbic acid and 5 ng/ml TGFβ1. After 3 weeks in culture, medium was changed to DMEM/ITSx (insulin, transferring, selenium) and 10 ng/ml IL-IB was added to the cultures (4 days). Finally, rhGDF-5 (200 ng/ml) and-/or P38 kinase inhibitor at 1 μM was added to the cells. Results were evaluated by histology, GAG/DNA assay and Taqman analysis.
Results: Following P38 Kinase Inhibitor and/or rhGDF-5 restored the amount of GAG in the tissue and gene expression of Agg and Col 2 close to control levels.
Conclusions: This data suggests that our in vitro culture system can be used to model IL-1 induced degeneration (i.e. loss of proteoglycan) and the effects of potential therapeutic agents to reverse the effects of this inflammatory cytokine.

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Chondroitin sulfate: An effective joint lubricant for articular cartilage.

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Purpose: Glycosaminoglycans(GAGs) play an important role in the tribological properties of articular cartilage. Chondroitin sulphate(CS) is the most abundant GAG found in articular cartilage. Oral intake of CS supplements has been suggested to have therapeutic effect. In the current study CS was evaluated as a joint lubricant in an in vitro cartilage sliding against cartilage model.
Methods and Materials: A pin-on-plate tribological system was utilized to study the effect of CS dissolved in PBS (10mg/ml, 50mg/ml) as the lubricant on the static and dynamic friction properties of bovine cartilage under 25N load. For each cartilage couple, pin (9mm diameter) and plate (20mmX15mm) the baseline friction levels were determined in PBS initially. PBS was then replaced with CS solution and the tests repeated to study its lubricating ability. The samples were then soaked in fresh CS solution for 24 hours at 4°C and the friction tests repeated again with PBS as the lubricant.
Results: In dynamic tests, when the intrinsic biphasic lubrication of cartilage was effective, CS solution at either concentration did not have any effect on the already low friction values(~0.02). In static tests, where boundary lubrication was active, replacing PBS with CS solution reduced the start-up friction levels by 15% and 45% for 10mg/ml and 50mg/ml respectively. Soaking the cartilage samples for 24 hours in CS solution reduced the start-up friction levels by 20% and only at 50mg/ml concentration.
Conclusions: The results indicate tribological potential of CS solutions as joint lubricants. Future work will investigate the effect of CS solutions on GAG depleted cartilage samples.

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Effects of reduced oxygen tension and long-term mechanical stimulation on chondrocytes-polymer constructs

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Purpose: This study investigates the influence of long-term confined dynamic compression and surface motion under low oxygen tension on tissue engineered cell-scaffold constructs.
Methods and Materials: Porous polyurethane scaffolds (8mm x 4mm) were seeded with bovine articular chondrocytes and cultured under normoxic (21% O~2~) or hypoxic (5% O~2~) conditions for up to 4 weeks. Using our joint simulating bioreactor, cyclic axial compression (10-20%, 0.5 Hz) was applied for one hour daily with a ceramic ball, which simultaneously oscillated over the construct surface (±25°, 0.5 Hz).
Results: Culture under reduced oxygen tension resulted in an increase in mRNA levels of type II collagen and aggrecan, while the expression of type I collagen was down-regulated. Furthermore, increased glycosaminoglycan contents were found in hypoxic compared to normoxic constructs. Immunohistochemical analysis showed more intensive type II and weaker type I collagen staining in hypoxic than normoxic cultures. Type II collagen gene expression was up-regulated after short-term loading, while aggrecan gene expression was consistently up-regulated in loaded compared to unloaded samples over 28 days of loading at either oxygen tension. Importantly, the combination of loading and low oxygen tension resulted in a further down-regulation of collagen type I mRNA expression, contributing to the stabilization of the chondrocytic phenotype. Histology results confirmed the beneficial effect of mechanical loading on chondrocyte matrix synthesis.
Conclusions: Mechanical stimulation combined with low oxygen tension is an effective tool for modulating the chondrocytic phenotype. This may be considered when chondrocytes or mesenchymal stem cells are cultured and differentiated with the aim to generate cartilage-like tissue in vitro.