Investigation of the Frictional and Mechanical Properties of Tissue Engineered Cartilage

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INTRODUCTION: The main function of articular cartilage is to provide low friction and wear between articular surfaces. Native cartilage is sometimes subject to degradation or trauma, and its natural capacity for regeneration is relatively poor. One aim of regenerative medicine is to develop implantable engineered cartilage which matches the properties of native articular tissue to repair defects. The purpose of this study was to investigate the frictional and mechanical properties of tissue engineered cartilage using bovine chondrocytes seeded on poly(glycolic acid) scaffolds (PGA). In addition, the nature and quantity of debris generated during the friction tests were examined.

METHODS:
Construct synthesis: Articular cartilage slices were harvested from bovine metacarpophalangeal joints. Chondrocytes were isolated via enzymatic digestion and expanded at 37°C in 5% CO_2 - 95% air, in expansion medium[1] until a sufficient number of chondrocytes available. Poly-(Glycolic-Acid) scaffolds (Ø 6mm × 2mm) were seeded at 112×10^6 cells per cm^3, enclosed in an agarose gel plug and cultured in differentiation medium[1] for 33 days. *Friction tests*: The engineered constructs were attached to metal backing pins and loaded on to a reciprocating stainless steel plate in a bath of lubricant (PBS). A piezoelectric force transducer was used to measure the frictional force between the pin and the counterface during sliding. A normal load of 13.2 N (contact stresses of 0.3 MPa) was applied on the pins and a sliding speed of 4 mm/s was adopted. Startup friction measurements were recorded after 5 s, 30 s, 2 min, 5 min, 10 min and 20 min of static loading. Between each measurement a load removal period, at least equal to the time of loading, was applied. During this interval, the constructs were immersed in lubricant to recover. Additionally, dynamic friction tests involving one hour of continuous reciprocating sliding between the constructs and the plate under load were carried out and friction measurements taken at 5 s, 30 s, 2 min, 5 min, 10 min and every ten minutes thereafter. Native cartilage and the unseeded material scaffold were used as controls. *Biochemical analysis*: Histology, scanning electron microscopy (SEM) observations and glycosaminoglycan (GAG) quantification were performed on the constructs to compare the structure, composition and properties before and after the mechanical tests. The lubricant and debris generated were harvested in order to examine their composition (histology and GAG assay).

RESULTS: All the constructs tested exhibited a time-dependent increase in the coefficient of friction and reached an equilibrium final value. While this phenomenon is similar to native cartilage, the values are different: $\mu_{\text{start-up eq}}=0.120$ and $\mu_{\text{dynamic eq}}=0.175$ for the engineered constructs, $\mu_{\text{start-up eq}}=0.240$ and $\mu_{\text{dynamic eq}}=0.038$ for the native cartilage.

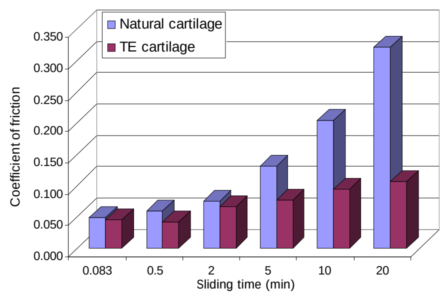

Fig. 1: Initial coefficient of friction vs. sliding time for tissue engineered and native cartilage.

DISCUSSION & CONCLUSIONS: Our conclusion was that engineered cartilage shared similar frictional behaviour to native tissue, although the precise mechanism may differ. More advanced constructs, with properties closer to those of native cartilage, should however be developed for further investigation and clinical use.

REFERENCES: [1] A. P. Hollander, P. V. Hatton *Biopolymer Methods in Tissue Engineering*. Humana Press (2004).

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