INTRODUCTION:

Magnetic resonance imaging (MRI) can be used to characterize structural constituents of articular cartilage, i.e. proteoglycans (PGs) [1] and collagen [2] as well as to predict tissue compressive stiffness [3], property that is sensitively impaired in early cartilage degeneration [4]. In a preliminary study, MRI parameters of normal and spontaneously degenerated bovine cartilage (n=2) indicated similar features as mechanical parameters of fibril-reinforced poroviscoelastic (FRPVE) model [5]. In the present study we characterized more extensively interrelationships between the structural and mechanical properties of articular cartilage from different species using quantitative MRI and FRPVE analyses. FRPVE model includes realistically characteristic structural features of cartilage [6]. We believe that this kind of approach may further help to develop non-invasive MRI methods to assess mechanical properties of articular cartilage.

METHODS:

Cylindrical bovine (n=11) and human (n=11), approval of National Authority of Medicolegal Affairs (1781/32/200/01), patellar cartilage samples were prepared for MRI-analyses and mechanical testing [7]. T2 (collagen specific) and dGEMRIC (PG specific) imaging was performed using a SMIS console and an Oxford 400NMR vertical magnet (9.4T), as described before [7]. Stepwise (2x5% strain, strain rate 1μm/s) stress-relaxation tests in unconfined compression were performed. Collagen orientation in different zones (superficial, middle and deep) for each sample was determined using spatial variation curve of T2-anisotropy (Fig.1). FRPVE model with realistic collagen architecture was fitted to stress-relaxation curves (Fig. 2) to determine model parameters, i.e., initial (E0) and strain-dependent (E1) fibril network modulus, equilibrium Young’s modulus (Eeq) and permeability (k=keq.s). Viscelastic damping coefficient and Poisson’s ratio were assumed to be constant (=1062MPa/s and ν=0.15, respectively) [6]. Finally, the interrelations between the MRI-parameters (T1, T2-relaxation times, T1 at the presence of Gd-DTPA (T1,Gd)) and mechanical properties were assessed.

RESULTS:

Significant linear correlations were found between the MRI- and mechanical parameters of cartilage (Table 1, Fig.3), i.e. between E0 and T1 as well as between E1 or k and T1. T1,Gd had no significant linear correlation with the modeled parameters. M showed no significant relationships with the MRI parameters.

DISCUSSION:

Results of the present study suggest that some quantitative MRI parameters are indicative to mechanical characteristics of articular cartilage. Since early degeneration of cartilage is detected sensitively through the changes in the mechanical properties of the tissue [4], MRI as a non-invasive method could be a simple way to estimate those changes and improve the diagnosis of osteoarthritis. However, the number of samples was rather small (n=22) and further investigations with larger material are needed to confirm the interrelationships between the MRI-parameters and model-determined mechanical properties and, especially, to demonstrate potential species-specific differences in relationships.

REFERENCES:


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