Determination of Elastic Properties of Articular Cartilage

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INTRODUCTION

High resolution MR-images of knee joints show a multilaminar appearance, reflecting the zonal different anisotropy of collagen network organisation. In case of femoral and tibial cartilage of adult knee joints we only find one anisotropic zone of preferred radially oriented collagen fibres. In earlier works we could show, that the network orientation and hence the MR-visualisation is sensitively influenced by mechanical load (1). Aim of the presented study is to demonstrate the potential of pressure-dependent, high resolution MRI to determine biomechanical properties of the cartilage and to calculate the spatial load distribution within the tissue.

METHOD

Cartilage-bone plugs (∅ 16mm) of adult sheep femoral condyles were statically loaded (stepwise up to 1.6 MPa) against a flat surface using a self-made hydraulic device. T_2-weighted MR-images were taken (TE=20ms, TR=500ms, slice thickness 1mm, in-plane resolution 78µm) at 7T using a Bruker Avance 300WB spectrometer. Multi-echo experiments were performed to determine the T_2-distribution and to deduce the arrangement of the collagen fibres. By knowing the intensity change upon load, applying neural nets and finite element simulations, the spatial load distribution as well as Youngs modulus in zonal dependency were calculated. The method was adapted to clinical conditions (Siemens Vision 1.5 T).

RESULTS AND DISCUSSION

In T_2-weighted MR-images within the pressure influenced region of cartilage having radially orientated collagenous network, we measure rising intensity with increasing load (Fig.1). The intensity behaviour can be fitted by a linear function in its rising part; at higher pressure values we observe saturation (Fig.2), depending on the zonal varying grade of isotropy (cf. Fig.1a). Depending on the distance of the cartilage zone from the subchondral bone, we observe an increase of the intensity rise with load; the saturation is reached earlier and the relative intensity change itself is higher.

CONCLUSIONS

The zonal varying changes of MR-intensity with load originate from the grade of anisotropy of the collagen fibres. Measuring the influence of mechanical load on the MR-visualisation of the joint cartilage it is possible to calculate the spatial load distribution (Fig. 3)
and Youngs modulus of the cartilage. Based on that abnormal changes or lesions of collagen network could be detected.

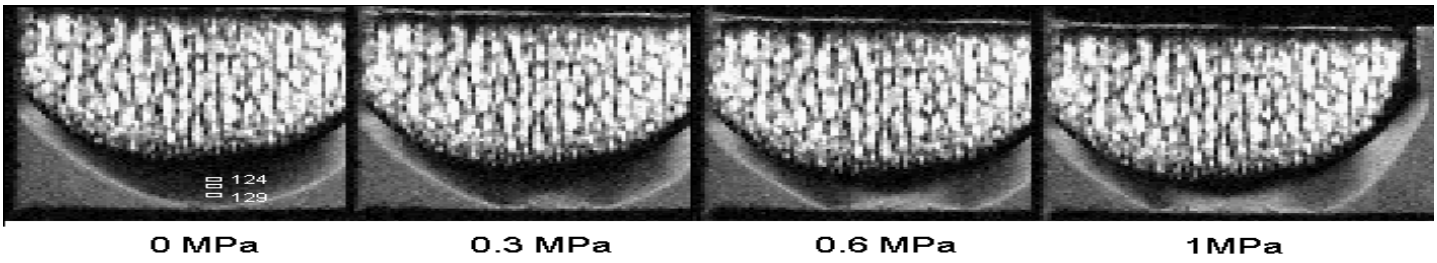


Fig. 1: T_2-weighted microimages of sheep femoral condyle under the influence of rising pressure

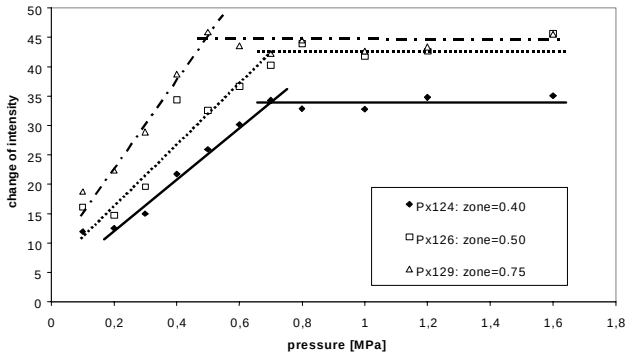
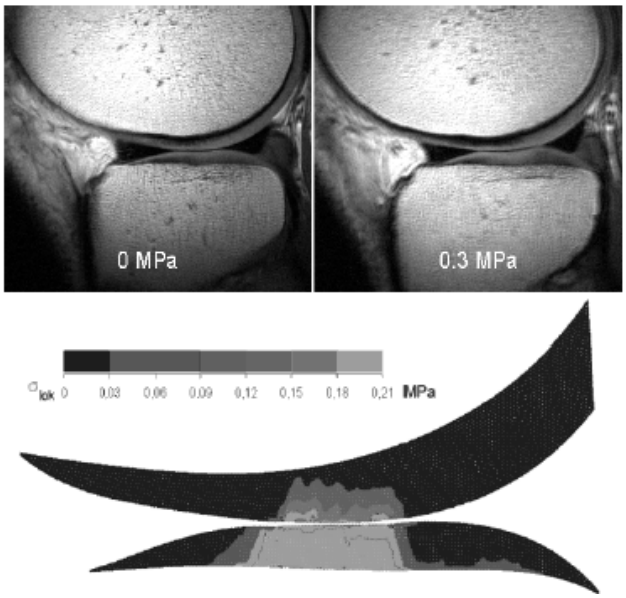


Fig. 2: Relative changes of MR signal intensity in different cartilage zones of sheep femoral condyle as function of the applied static pressure.



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