High resolution diffusion tensor imaging of bovine articular cartilage

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Introduction

Hyaline articular cartilage is an anisotropic structure of various zones, defined mainly by the arrangement of the collagenous fibers. Changes within this fiber network are regarded to be a hallmark of early degeneration in cartilage subject to osteoarthritis (1). It has been shown that DTI is a useful tool in analyzing structural anisotropy in white matter and also in intervertebral disc tissue (2,5). However, no data are available about DTI of hyaline articular cartilage. Therefore, this work presents a first investigation of hyaline articular cartilage using DTI

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Materials & Methods

The measurements were performed in cartilage-on-bone samples of bovine patellae (cylindrical, 14mm diameter) in pseudo-physiological conditions. These samples were tested both unloaded and under local compressive strain through a solid and not porous indentor (maximum strain about 60%). The DTI data were acquired on an Bruker Microimaging Systems with 750MHz. The maximum gradient strength was 1T/m, we obtained a resolution of 62×62µm² (Matrix 128×256, FOV 8×16mm², slice thickness of 1.5mm) with 40 averages, b-value of 1100 s/mm², TR/TE=1000ms/12ms, Δ=5.5 ms, δ=2.5 ms. 6 different diffusion gradient directions were applied.

Data analysis was performed with a self developed software package based on the visualization system AVS. We determined the diffusion tensor eigenvalues and eigenvectors and visualized the results as trace and anisotropy maps, the latter based on different anisotropy definitions (3,4), eigenvalue maps, and the eigenvectors using color map.

Results

The mean diffusivity map (Figure 1) shows zonal variations with values between 1.38×10^{-3} mm²/s in the tangential zone and 0.2×10^{-3} mm²/s at the tide mark. The fractional anisotropy varies between 0 and 0.2. The color map of the largest eigenvector direction (Figure 2) shows that the main diffusivity is oriented in different directions at the cartilage surface and deeper in the tissue. There are marked changes in distribution of map parameters at the side of the indentor and under the indentor (Figure 3).

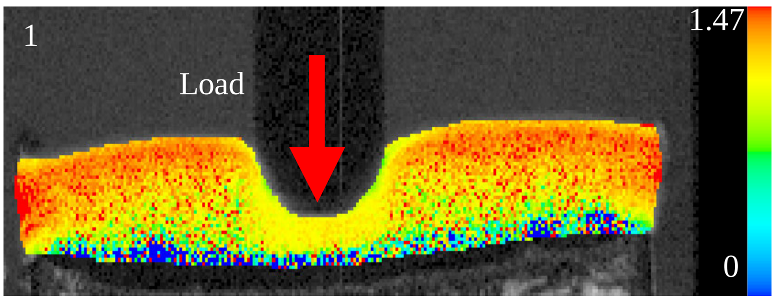

Figure 1: Cartilage under load: mean diffusivity (10^{-3} mm²/s).

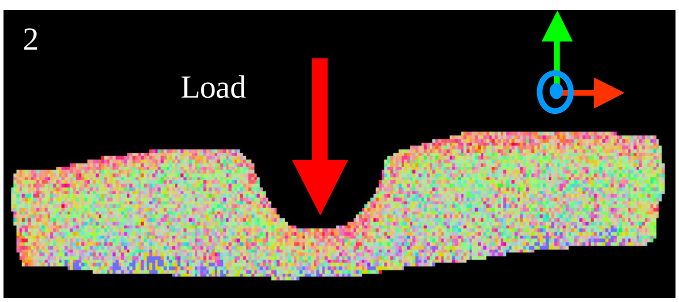

Figure 2: Cartilage under load: largest eigenvector direction as color map.

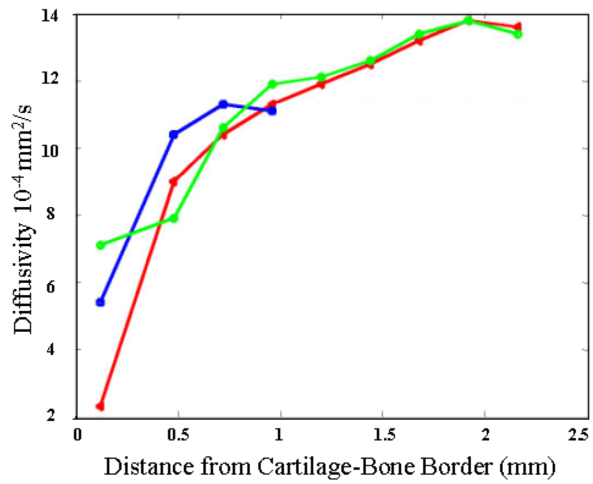

Figure 3: Mean diffusivity of cartilage versus the distance from cartilage-bone border: red and green for the unloaded zones, red left the indentor , green right and blue under the indentor.

Discussion and Conclusion

Our results demonstrate the feasibility of DTI for structural analysis of hyaline articular cartilage. The technique holds high potential for monitoring the zonal arrangement of the cartilage and its change in case of loading. The observed zonal pattern is in good agreement with current literature about the collagenous fiber architecture of cartilage (1).

References

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