Heterogeneity of Cartilage Laminae in MRI

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Introduction

In MRI studies of cartilage, it has been known that normal articular cartilage appears laminated when placed at certain orientations with respect to the external magnetic field (the magic angle effect) [1-4]. Bi- or tri-laminar appearances of cartilage tissue were observed in MR images. The number and the relative intensity of the cartilage laminae varied in different studies. Several recent studies [5-7] addressed the orientational dependence of $T_2$ in cartilage at 14 $\mu$m resolution using Microscopic MRI ($\mu$MRI). The results have shown that the $T_2$ anisotropy is the origin for laminated appearance of cartilage in MRI.

In this study, the heterogeneity of cartilage laminae is investigated. The results show that (a) there are various patterns of cartilage laminae for tissues from different areas in a joint surface: bi-laminae, tri-laminae, and even multi-laminae; (b) this heterogeneity of cartilage laminae corresponds to the areas from which the tissue is harvested (and hence the difference in tissue loading conditions).

Materials and Methods

Full-depth cartilage-bone plugs were harvested from several areas (weight-bearing, intermediate, peripheral) of the two humeral heads of the shoulder joints of young beagles. The plugs were bathed in physiological saline solution and sealed in glass tubes.

$\mu$MRI experiments were performed on a Bruker AMX 300 NMR spectrometer equipped with a 7-Tesla/89-mm-bore magnet and micro-imaging accessory. The magnetization prepared pulse sequence was used to acquire a series of images under different $T_2$-weightings [7]. The TE in the imaging segment of the pulse sequence was 8.86 ms; the TR of the experiment was 2 seconds. The in-plane resolution was 14 $\mu$m and the slice thickness was 1 mm.

Results and Discussions

$\mu$MRI experiments using identical parameters were carried out for different cartilage-bone plugs at approximately 0° and 55° angles (the angle between the normal direction of the articular surface and the direction of the magnetic field).

For the plugs from the central weight-bearing area of the humerus, a bi-laminar appearance of cartilage was observed at 0°. The $T_2$-weighted proton intensity and quantitative $T_2$ images have similar characteristics as in our previous studies [5-7].

For the plugs from the peripheral area, more complicated and non-bi-laminar appearances of cartilage were observed at 0°. The patterns of appearance range from tri-laminar for the plugs from the greater tubercle side of the peripheral region to 5-laminar for the plugs from the lesser tubercle side of the peripheral region. Figure 1 shows the intensity profile of three cartilage images. The three plugs were acquired from the right half of the left humeral head side-by-side. Evidence for a transition from a bi-laminar appearance at the central-weight-bearing location (Width = 0) to a tri-laminar appearance at the peripheral location (Width = 250) is clear in this figure.

Conclusions

A heterogeneity of cartilage laminae (bi-, tri-, or five-layers) over the 2D joint surface was found in MRI. This finding could explain the controversial over whether the appearance of cartilage in MRI is bi-layered or tri-layered. This result demonstrates the complexity of cartilage laminae and the need for extra cautions in interpreting the MRI cartilage results. It is speculated that this heterogeneity of cartilage laminae is related to the weight-bearing status of the tissue in the joint. The ability to visualize such structural heterogeneity is important because of the direct connection between the collagen structures and the mechanical characteristics of the cartilage tissue.

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References