Study of the Vertical Striations in Articular Cartilage Using Dipolar Anisotropy Fiber Imaging

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Introduction

Magic angle effects in articular cartilage have been studied intensively (1). The layered appearance of articular cartilage with signal decreasing from superficial to deep is seen at the lower end of the femur and in the tibial plateau when patients are examined in a conventional solenoidal cryomaget with B_0 parallel to the long axis of the body. It is largely due to magic angle effects in radial, transitional and tangential fibers. However, equally striking in articular cartilage is the appearance of vertical striations (2,3). These are orthogonal to the layers described above. They are seen in cartilage at the lower end of the femur and in the tibial plateau and have a periodicity of about 0.56 mm (3). The effects have been attributed to fiber structure and differences in T2 but there is no generally accepted explanation for either their cause or distribution. In particular, they have not been commented on in the detailed studies which have identified magic angle effects as the source of layers seen in cartilage (1,4). We have studied femoral condyle and tibial plateau samples using dipolar fiber anisotropy imaging in which cartilage is systematically rotated relative to B_0, images are acquired and registered and then signal intensity and magic angle effects are quantified (5) in order to help understand the origin of the signal seen with vertical striations.

Methods and Materials

Cartilage samples from the lower end of the femur, tibial plateau and patella were studied. 3D isotropic spoiled gradient images were performed at 30° increments relative to B_0, images were registered and both minimum intensity and coefficient of rotation images were obtained.

Results

Striations are well shown at 0°to B_0 (Fig. 1). Images parallel to the cartilage surface showed a linear pattern with generally parallel striations. Marked variation in signal intensity between different striations was seen with change in orientation to B_0 (Fig. 2). High signal striations generally showed less magic angle effect than low signal striations. Fig. 3 shows less regular striations and a meshwork pattern rather than a linear pattern in cross section.

Discussion

The vertical striations are attributable to differences in degree of magic angle effects between layers or leaves or sheets within cartilage. There may be differences in number, order and orientations of fibers between different leaves. The parallel distributions seen correspond to sheets as demonstrated by freeze-fracture technique but the meshwork pattern corresponds to a more random orientation of fibers. The features are particularly well seen in the uncovered areas of the tibial plateau (i.e. in cartilage not covered with menisci) where the tangential layer of cartilage is absent (6,7). The features are present but to a lesser extent in the cartilage at the lower end of the femur and patella. The detailed effects differ depending on the presence of linear and meshwork pattern with cartilage.

References

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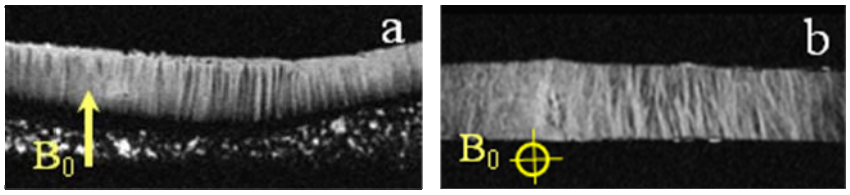

Fig.1 Tibial plateau linear pattern. Sagittal (a) and axial sections (b). Prominent striations are seen in (a) and a linear pattern is seen in (b).

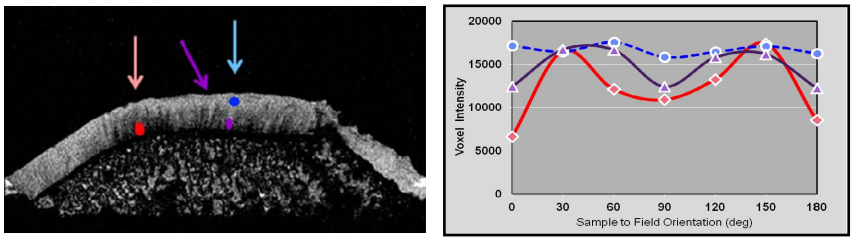

Fig.2 Patella specimen with intensity plots from 3 regions of interest vs. specimen orientation. Dark striations ♦, light striations ▲, and superficial region ● show different degrees of dipolar anisotropy.

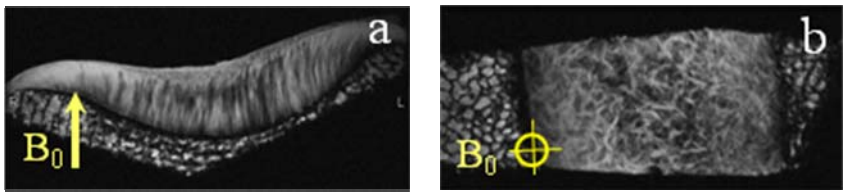

Fig.3 Tibial plateau meshwork pattern. Sagittal (a) and axial (b) images. Striations are again seen in (a), but in a less regular pattern compared with Fig.1a. Instead of the linear pattern as in Fig. 1b, a meshwork is seen if Fig. 3b.