INTRODUCTION: Patients who undergo anterior cruciate ligament (ACL) reconstruction are at greater risk for early osteoarthritis (OA). The use of quantitative MRI (qMRI; measurements of cartilage volume or thickness after segmentation of MR images using a cartilage-specific pulse sequence) to evaluate temporal changes in articular cartilage structure could provide significant insight into the mechanisms of OA in this patient population. However, the ACL graft is typically fixed with titanium interference screws that could create magnetic susceptibility artifacts and reduce the accuracy and precision of qMRI (1). Gradient echo pulse sequences are often used for qMRI (2) and may exacerbate artifacts. The 3T magnetic field strength for qMRI has theoretical advantages over 1.5T because of the greater resolution and signal-to-noise ratio (3). Unfortunately, magnetic susceptibility artifact would also be amplified on a 3T magnet. The objectives of this study were to assess the affects of interference screws on cartilage volume measurements, and to compare qMRI of articular cartilage at 1.5 and 3T. We hypothesize that there will be no significant differences in tibiofemoral cartilage volume measurements with and without interference screws, and that the cartilage volumes will be similar between the two magnet field strengths.

MATERIALS & METHODS: 5 intact fresh frozen human cadaver knees from the right limb (mean age = 56 (range 51-59) years; 3 male/2 female) were utilized. The knees were thawed to room temperature prior to MR scanning.

MR images were performed on both a 1.5T (Siemens Symphony; Erlangen Germany) and a 3.0T (Siemens Trio; Erlangen Germany) magnet using knee surface coils. In a preliminary evaluation of several sequences, we found that the T1-weighted WE-3D FLASH sequence (water-excitation three-dimensional fast low-angle shot: 20/7.6 [TR msec/TE msec]; 12° [flip angle]; 160 mm [field of view, FOV]; 1.5 mm/0 [slice thickness/inter-slice gap]; 80 slices per slab; 130 hz/pixel [bandwidth, BW]; 512x512 [matrix]; right/left [phase encoding axis]; one average of two excitations) minimized image distortion and maximized image contrast when using the 3T magnet. A modification of this sequence employing a 2 mm slice thickness was used on the 1.5T magnet.

Two 9x20 mm titanium interference screws (Arthrex, Inc; Naples FL) were placed in the tibia and femur with the aid of an arthroscope and a commercial drill guide system for ACL reconstruction (Arthrex, Inc; Naples FL). The screw locations were selected to duplicate those used to fix a graft in the knee during surgery. A complete ACL reconstruction procedure was not performed.

All knees were scanned on 1.5T and 3.0T magnets with and without the interference screws implanted in the knee. The scans were performed with the knees in full extension. The test order was block randomized to minimize measurement bias. The articular cartilage of the distal tibia and proximal femur was segmented from the sagittal slices (Analyze 6.1; Mayo Clinic, Rochester MN). The segmented images were aligned to generate 3-D meshes to represent the volumetric shape of the tibial and femoral condyles. The volumes were then quantified by the numerical integration of the number of voxels contained within the segmented regions of the tibia and femur (Geomagic 6.0; Durham NC).

A 2-way repeated measures analysis of variance was performed to compare the cartilage volumes of the proximal tibia and distal femur due to screw condition (screws versus no screws) and magnet strength (1.5T versus 3.0T). Each specimen served as its own control.

RESULTS: For the femoral articular cartilage volume, there was no significant difference due to the presence of the screws (p=0.80), or the increase in magnet field strength (p=0.98) (Fig. 1). No significant interaction was found between these two parameters (p=0.40). The percent change in volume due to either the magnet or the screw (relative to the volume of cartilage for the 1.5T, no magnet condition) was less than 4% (Fig. 1).

For the tibial articular cartilage volume, there was no difference due to the presence of the screws (p=0.79), and no interaction between the presence of the screw and magnet strength (p=0.51). The percent change due to the presences of screws was less than 3.6%. However, there was a strong trend (p=0.06) indicating that the tibial articular cartilage volumes from the images reconstructed from the 3T magnet were 10% greater, on average, than the 1.5T magnet. The trend was consistent with and without the screws inserted.

DISCUSSION: Prior to initiating this study we evaluated several cartilage sensitive pulse sequences including FS-TSE intermediate weighted and T1-weighted WE-3D FLASH sequences. We subjectively found that the WE-3D FLASH sequence minimized image distortion in the vicinity of the interference screws while maximizing image contrast. Furthermore the fat saturation pulse sequences tended to increase magnetic susceptibility artifacts. Thus, the T1-weighted WE-3D FLASH sequence was selected for this study. Our data demonstrated that measurements of tibiofemoral cartilage volume were not affected by the presence of titanium interference screws. The T1-weighted WE-3D FLASH sequence has already been shown to be effective in tracking structural changes in articular cartilage for patients with OA (2). Our study showed that qMRI using this sequence can be used to track longitudinal changes in cartilage volume in patients before and after ACL reconstruction. In addition, these data suggest that there may be no distinct advantage in performing qMRI on the 3T magnet for the femur because the mean articular cartilage volume and variability were similar to those obtained from the 1.5T magnet. Similarly, Kornaat et al found no significant differences in mean femoral cartilage thickness between healthy knees scanned on 1.5T and 3T magnets using a sagittal 3D fat-suppressed intermediate-weighted spin echo or 3D spoiled gradient recall echo sequences (3). However, in our study there was a strong trend suggesting that an increase in tibial cartilage volume occurred with an increase in magnet strength. Fortunately, this effect was not dependent on the presence of the screw. In conclusion, qMRI with the T1-weighted WE-3D FLASH sequence can be used to document changes in knee articular cartilage volume before or after ACL reconstruction on either a 1.5T or 3.0T magnet. However, the strong trend relating magnet strength with tibial cartilage volume indicates that it would be prudent to use the same magnetic field strength when tracking longitudinal changes in tibial cartilage volume within a patient.


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**Department of Biostatistics, University of Vermont, Burlington VT.

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**Fleming, B C; Tung, G A; Trafton, T G; Badger, G J; Fadale, P D; Hulstyn, M J
**Brown Medical School/Rhode Island Hospital, Providence, RI

Braden_Fleming@brown.edu

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