A longitudinal study of trabecular bone in knees with acute anterior cruciate ligament (ACL) injuries at 3T

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Introduction
Anterior cruciate ligament (ACL) tear is one of the most common ligament injuries of the knee joint, and is a risk factor for post-traumatic osteoarthritis (OA) [1]. Many factors may be involved in the mechanisms of cartilage damage following ACL, including the initial inflammatory response, altered kinematics, abnormal contact stresses, and concomitant injuries to the menisci and subchondral bone bruise. However, little is known about the changes in the underlying trabecular bone following injury. Previous studies [2] have indicated that the volumetric mineral density decreases due to incomplete mineralization of trabecular bone structure in early stages of OA. The aims of this study are to compare bone structure parameters in knees following ACL tears to those of the contralateral, uninjured “control” knee, and to evaluate these parameter changes at one year follow-up using magnetic resonance imaging.

Method
MR images were acquired on a GE 3T MR scanner (General Healthcare, WI) with an eight-channel phased-array knee coil. Twelve patients with ACL injuries in one knee were studied at baseline within 1-3 month of injury and prior to ACL reconstruction (12 ACL-injured knees and 6 contralateral knees were scanned). Among these, 9 patients finished one year follow-up scans (9 ACL-injured knees and 6 contralateral knees were scanned). Axial fully refocused steady state free-precession (SSFP) 3D phase cycle Fast Imaging Employing Steady State Acquisition (3D FIESTA-c) images were acquired to quantify the trabecular bone structure parameters. The sequence parameters were: repetition time (TR)/echo time (TE) =11/4.2 ms, acquisition matrix = 512×384, flip angle =60°, field-of-view (FOV) =10cm, slice thickness = 1mm, 86 slices, approximately 10 min scan time. The analysis of trabecular bone structure parameters were performed using an in-house-developed image analysis software programmed in Matlab (Sterling, VA). Four different compartments (Fig. 1) were defined for trabecular bone analysis: femur (FM), lateral and medial femoral condyle (LFC/MFC) and tibia (TB). Bone enhanced fuzzy C-means clustering (BE-FCM) [3], which captures more bone structure while being less affected by partial volume effects, noise, and intensity inhomogeneities, was applied to obtain bone and marrow components from the image and to quantitatively conventional bone structure parameters. Among these, acquisition matrix = 512×384, flip angle =60°, field-of-view (FOV) =10cm, slice thickness = 1mm, 86 slices, approximately 10 min scan time. All statistical analysis was performed using JMP (SAS Institute, Cary, NC, USA). The differences in trabecular bone structure parameters between ACL-injured knees and contralateral knees were assessed using mixed-effect models with subject-specific random effects to account for multiple compartments measured within one subject. The statistical results were adjusted for gender, age and body mass index (BMI).

Results
Significant differences were found in 2 or more compartments for all 4 bone structure parameters in ACL-injured knee between baseline and 1-year follow-up, no significant differences were found in compartments in contralateral knees (Table 1). However, similar trends (decrease in Tb. BV/TV, Tb. Th and increase in Tb. Sp.) were found in contralateral knees (representative examples of Tb. BV/TV are shown in Figure. 2).

Discussion
This study evaluated bone structure changes in knee joint after ACL injury at baseline and 1-year follow-up. Significant differences in trabecular bone structures were found in at least two compartments in ACL-injured knees from baseline to 1-year follow-up. Although no significant differences were found between ACL-injured knees and contralateral knees, even after 1-year follow-up, our preliminary data suggested a decreasing trend of the bone structure in the injured knees compared to the uninjured knees. These results suggest bone loss might occur after ACL injury and reconstruction. The relationship between cartilage and bone were reported previously in OA knees [4]. Future studies will investigate the potential interaction between cartilage and bone in ACL-injured and reconstructed knees.

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References