Introduction: Although surgical reconstruction of the anterior cruciate ligament (ACL) leads to clinically satisfactory restoration of knee stability, recent data suggest that ACL reconstruction does not prevent early onset of knee osteoarthritis (OA) [1]. It is possible that abnormal knee kinematics alter the normal mechanical environment in the articular cartilage and subchondral bone in the knee even after ACL reconstruction, leading to cartilage degeneration and OA. To determine whether three-dimensional (3D) knee kinematics are altered after ACL reconstruction, we used a loading device to simulate partial weight bearing during MRI in reconstructed and normal, contralateral knees when moving from extension to flexion.

Materials and Methods: Five patients (3 male, 2 female, average age = 29 years) who had previously undergone unilateral ACL reconstruction were recruited from the UCSF Sports Medicine Center by physician referral. Four of the patients had hamstrings tendon autografts, and one patient had an Achilles tendon allograft. Mean time since surgery at the time of imaging was 10 months.

Images were obtained with a SIGNA 3T echo-speed system (GE Medical Systems, Waukesha, WI) and a dual phased-array coil (USA Instruments, Cleveland, OH). Images of both knees in each patient were obtained in full extension and in flexion while the patient pushed on a foot plate that applied a load of 13 kg. Images were obtained using a fast spin echo sequence (FSE) with TR of 3700 ms, TE of 9.7 ms, echo train length = 16, 512 x 512 pixels over 16-cm field of view (in-plane resolution of 0.3 mm), and 1.5 mm thick sections with zero spacing. The receiver bandwidth was 62.5 kHz. Sixty-six sagittal slices were obtained, resulting in a scan time of approximately 10 minutes.

For each set of images, the femur, tibia, and contact area were segmented using an in-house gradient edge detection program. MATLAB (Mathworks, Natick, MA) software was used to determine the translations of the centers of the medial and lateral femoral condyles relative to the tibia between the flexed and extended positions. Rotations were calculated based on the positions of the femoral condyles relative to the tibia. The angle of knee flexion was determined by defining the tibial and femoral shaft axes on a central sagittal image. Points defining regions of cartilage-on-cartilage contact in each tibiofemoral compartment were joined with a set of triangles, and the total three-dimensional contact area and contact centroid were computed for the medial and lateral contact patches defined by the triangles. Student t-tests (α = 0.05) were used to determine significant differences between normal and ACL-reconstructed knees. Significant translations or rotations occurred only in reconstructed knees. No significant differences in centroid translation were detected between normal and reconstructed knees. In both normal and reconstructed knees, movement from extension to flexion led to a significant decrease in medial compartment cartilage-on-cartilage contact area. Contact area in the lateral compartment of normal knees also decreased significantly when moving from extension to flexion, while reconstructed knees did not demonstrate a significant decrease in lateral contact area when moving from extension to flexion.

Results: Movement from extension to an average of 45° of flexion produced significant translation of the medial femoral condyle relative to the tibia in both normal and ACL-reconstructed knees (Figure 1). Significant internal tibial rotation of was detected only in reconstructed knees. No significant differences in tibiofemoral kinematics were detected between the normal and reconstructed knees.

Discussion: This study provided a 3D characterization of tibiofemoral kinematics during flexion. The results did not demonstrate statistically significant differences between normal and ACL-reconstructed knees. However, there is significant internal tibial rotation observed in the ACL reconstructed group. We anticipate that analysis of additional subjects will allow us to determine whether the kinematic changes produced by ACL injury are successfully corrected by surgical ACL reconstruction.

Our observed decrease in medial contact area when moving into flexion is consistent with a previous study using a 0.2 T open MRI system without weight bearing [2]. However, the decrease in lateral contact area that we observed in normal knees is not consistent with the results of that study. The loading device used in our study provided a simulation of partial weight bearing, and the presence of a higher load in our study may explain the observed decrease in lateral contact area during 45° of knee flexion. We did not observe a significant change in lateral contact area in reconstructed knees when moving from extension to flexion. This difference may point to an important difference between normal and ACL-reconstructed knees, because the contact area affects the magnitude of the contact stresses in the articular cartilage.

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