INTRODUCTION
Meniscal injuries frequently occur in combination with anterior cruciate ligament (ACL) tears. Tears in the meniscus that occur acutely with ACL injury are located either medial or lateral, but in ACL deficient knees chronic instability most commonly leads to meniscal tears in the posterior horn of medial meniscus [1]. These chronic tears are believed to be related to the increasingly important role of the menisci in restraining anterior tibial displacement after ACL deficiency. Treatment of meniscal tears with partial or complete meniscectomies may also alter knee stability. Previous biomechanical studies infer the role of the meniscus through measurements of alterations in forces or knee motions, however no studies have provided clear images of the motion or deformation of the meniscus itself. The objective of this study was to investigate the effects of anterior cruciate ligament resection, as well as partial and complete meniscectomies on knee kinematics in response to anterior loading. Application of loads during magnetic resonance (MR) imaging allows us to visualize the motion and deformation of the menisci, and therefore obtain a more clear understanding of its role in knee stability.

METHODS
Seven fresh frozen human cadaveric knees were used (age: 67 ± 9) in this study. A loading device was designed to apply anterior load to the tibia when the knee was positioned at 0°, 30°, 60° or 90° degrees of flexion during MR scanning. MR images were acquired using 3D gradient recalled echo (GRE) fast sequence (TE: 3.6 ms, TR: 8.7 ms, 1 NEX, Flip angle: 35°, Scanning time: 2.05 min) in sagittal plane, with in plane resolution of 66.4 µm² or 70.3 µm² and 1.5 mm slice thickness. Using a controlled approach along the medial collateral ligament, surgeries were performed to transect ACL followed by partial and complete medial meniscectomy. Each knee was scanned with different injury conditions (normal, ACL-deficient, ACL-deficient plus 20%, 50% or 100% medial meniscectomy), at different flexion angles (0, 30, 60 or 90 degrees) and under different loading conditions (unloaded or anteriorly loaded with 107 N). To track the bone motion, four plastic markers with a spherical hole (5.71 mm in diameter) filled with Vaseline were screwed firmly in each bone close to the joint center (Fig 3). Marker centroid locations were recorded using NIH image software in each image volume. Translations of tibia and femur in the anterior loading direction were calculated for each injury condition at different flexion angles. A repeated measures two-way ANOVA statistical analysis was used to assess the effects of knee flexion angle and injury on the anterior tibial translation (absolute and in relation to the femur).

RESULTS
Progressive knee injuries caused significant increase of absolute anterior tibial translation at 30°, 60°, and 90° of flexion (not shown). The average value was largest at 30°. However, ACL deficiency with or without medial meniscectomy caused significant increase of the anterior translation of tibia relative to femur at 60° and 90° of flexion. In both cases no significant difference was found among different conditions of the medial meniscus.

DISCUSSION
Our study confirmed that ACL is the primary restraint to anterior tibial translation. In the ACL deficient knees, the absolute anterior tibial translation increased with progressive medial meniscectomy. However there is no significant difference among various medial meniscal conditions in ACL deficient knees. In contrast to similar previous studies [2-4], the MR images not only allow the calculation of relative bone motion, but also provide clear visualization of the deformation and motion of the menisci during loading. We observed that for the loaded ACL deficient knee the posterior inferior edge of the medial meniscus wrapped around the posterior edge of tibia plateau, suggesting the mechanisms for meniscal degeneration. In the knees with both ACL and medial meniscus transected, lateral meniscus shows large posterior translation in the loaded knee. In 2 out of 7 knees, significant joint distraction was found when anterior load was applied. The loss of contact between menisci and cartilage might limit meniscal function in restraining anterior tibial translation, therefore further studies will consider the application of a combined axial and anterior load.

REFERENCES

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**Department of Orthopaedics, University of Rochester Medical Center, Rochester, NY.

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