INTRODUCTION
The biomechanical characteristics and associated pathologies of articular cartilage have recently attracted researchers’ attention. It is believed that following knee injury, abnormal joint kinematics and the consequent abnormal loading within the joint contribute to the development of osteoarthritis [1]. Anterior cruciate ligament (ACL) injury is among the most common of such knee injuries. Although contact behavior of articular cartilage in ACL-deficient patients has been investigated [2,3], the effects of meniscus injury on the kinematics of the knee joint are still not clear. In the present study, we hypothesized that among ACL-deficient patients, those with a medial meniscus tear would exhibit different contact behavior in the knee joint articular cartilage than those with a lateral meniscus tear.

METHODS
Fourteen patients with unilateral ACL-deficiency combined with meniscus injury were recruited, with half of the patients with a medial meniscus injury and the other half with a lateral meniscus injury. Tibiofemoral kinematics of both the injured and contralateral healthy knees of each subject were determined during an ascending stair exercise using a combination of magnetic resonance imaging (MRI), dual fluoroscopic imaging and advanced computer modeling. Three-dimensional MRI-based bony models were matched to the bony outlines on the pair of fluoroscopic images captured by two orthogonally oriented fluoroscopes during the ascending stair exercise. To measure the kinematics of articular cartilage contact points, a tibial coordinate system was constructed using anatomical landmarks. The surface model of each cartilage was mapped onto the corresponding bone model and the contact area of the intersecting femoral and tibial cartilage surfaces was determined (figure 1). The location of the center of the contact area at every 10% of the step-up exercise was determined in both anteroposterior (AP) and mediolateral (ML) directions. The data in AP (ML) direction was normalized to the width of the tibial plateau in sagittal (coronal) plane. These normalized data from medial meniscus injured patients were compared with those from lateral meniscus injured patients. In addition, data from the injured knees were compared to those from the contralateral healthy knees. A paired Student T-Test was used for statistical analysis with the level of significance set at p<0.05. The study was approved by the institutional review board and informed consent forms were collected prior to the study.

RESULTS
In the group with lateral meniscus injury, the articular cartilage contact points shifted anteriorly and laterally in the medial compartment (figure 2A). Statistical significance was found only at 50% progress of the step-up activity in the ML direction. In the lateral compartment, the contact points shifted posteriorly.
In the group with medial meniscus injury, the cartilage contact points shifted posteriorly in the medial compartment, although no statistically significant differences were found (figure 2B). In the lateral compartment, the cartilage contact points did not shift significantly between injured and healthy knees.

DISCUSSION
The articular cartilage contact points of the tibiofemoral joint were investigated in ACL-deficient patients with either medial or lateral meniscus injuries. The results indicated that during step-up exercise, the tibia shifted anteriorly and rotated internally in patients with lateral meniscus injury. However, in patients with medial meniscus injury, the tibia rotated externally.
It has been reported that the contact behavior of articular cartilage is activity dependent [4]. These findings showed that in ACL-deficient patients, the side of meniscus injury may also play a role in the articular cartilage contact behavior.

SIGNIFICANCE
This study implies that in patients with ACL deficiency combined with meniscus injury, the knee joint kinematics and articular cartilage contact behavior depend on the side of meniscus injury.

ACKNOWLEDGEMENTS
This study was financially supported by a grant from the National Institutes of Health (R01 AR055612).

REFERENCES