INTRODUCTION:
Anterior cruciate ligament (ACL) tear is a common injury of the knee. It can lead to mechanical instability of the joint such as excessive anterior translation and internal rotation of the tibia. It is also believed that the instability after ACL tear is associated with degenerative changes of the knee. To understand the biomechanical mechanism of joint degeneration, it is important to determine the kinematic changes in the ACL-deficient knee joint, especially during walking – the most frequently performed daily activity. However, the kinematics of the knee during gait, such as internal/external rotation, abduction/adduction, or mediolateral translation, has not been reported in literature. In this study we utilized a validated dual fluoroscopic imaging system (DFIS) technique to investigate the six-degree-of-freedom (6DOF) kinematics of normal and ACL deficient knees during the stance phase of treadmill gait. We hypothesized that the three-dimensional tibiofemoral kinematics of ACL-deficient knees would be altered even under low demand activity such as slow speed walking.

METHODS:
Eight subjects (six men and two women) with unilateral ACL rupture and healthy contralateral knees participated in this study. Each patient signed an IRB approved consent form. Magnetic resonance images of both the normal and injured knees of each subject were used to create 3-dimensional model of the knee. Next, the DFIS was used to capture knee kinematics during the stance phase of gait. Each subject performed the gait on the treadmill at a speed of 2.5 miles per hour (MPH) i.e. 1.12 m/s (Fig 1). Two thin pressure sensors were fixed to the bottom of each shoe, which recorded the heel strike and toe-off of the stance phase. The model and fluoroscopic images were used to reproduce the motion of the knee. The 6DOF kinematics of normal and injured knees during the stance phase of gait were analyzed. The differences between the normal and injured knee at a specific point of the gait were compared using a paired t-test. The level of significance was set at \( P < 0.05 \).

RESULTS:
The predominant motion of the knee during the stance phase of gait occurred in the sagittal plane. Both the normal and ACL-deficient knees demonstrated a similar flexion pattern with a first flexion peak at loading response (12.6±11.8° in normal and 12.15±7.7° in deficient knees) and the other at toe-off (41.5±10.9° in normal and 38.8±16.3° in deficient knees) (Fig 2A). The injured knees on average flexed more during midstance and terminal stance \( (P>0.05) \) in the normal gait patterns of this study were similar to those reported in our previous study. However, the kinematics measured in ACL-deficient knees deviated from the normal gait patterns. In the ACL-deficient knees the femur consistently tended to shift more posterior, and lateral during certain instances of the stance phase of gait. These are in agreement with previous studies of knee kinematics during weight bearing flexion. Such kinematic alterations were linked to increased contact deformation on the medial tibial plateau near the medial tibial spine. Previous clinical reports also demonstrated a development of osteophytes adjacent to the medial tibial spine in ACL-deficient knees. Surgical reconstruction restoring the normal knee kinematics and homeostasis could potentially prevent increased stresses in the cartilage and delay the onset of degeneration.

In summary, using the new DFIS technique, we could examine the subtle kinematic changes during the stance phase of gait. After ACL tear, the femur tends to shift more posterior in relation to the tibia during push off. It also experiences greater valgus rotation and lateral shift during single-leg support. Surgical reconstruction aimed at correcting these abnormalities is warranted to prevent further degenerative process.

REFERENCES:
4. Van de Velde et al; Arthritis & Rheumatism; 2009; 60(12): 3693-3702

Tibiofemoral Kinematics during the Stance Phase of Gait in the Normal and ACL Deficient Knees

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DISCUSSION:
This study quantified the tibiofemoral 6DOF kinematics in the normal and ACL-deficient knees during the stance phase of gait. There are few reports on 6DOF knee motion during gait in literature. The normal gait patterns of this study were similar to those reported in our previous study. However, the kinematics measured in ACL-deficient knees deviated from the normal gait patterns. In the ACL-deficient knees the femur consistently tended to shift more posterior, and lateral during range of motion change. Such kinematic alterations were linked to increased contact deformation on the medial tibial plateau near the medial tibial spine. Previous clinical reports also demonstrated a development of osteophytes adjacent to the medial tibial spine in ACL-deficient knees. Surgical reconstruction restoring the normal knee kinematics and homeostasis could potentially prevent increased stresses in the cartilage and delay the onset of degeneration.

In summary, using the new DFIS technique, we could examine the subtle kinematic changes during the stance phase of gait. After ACL tear, the femur tends to shift more posterior in relation to the tibia during push off. It also experiences greater valgus rotation and lateral shift during single-leg support. Surgical reconstruction aimed at correcting these abnormalities is warranted to prevent further degenerative process.

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