The Effect of Lateral Meniscal Root Injuries on the Stability of the Anterior Cruciate Ligament Deficient Knee

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Introduction: Prior research has demonstrated that the anterior cruciate ligament acts as a restraint to anterior tibial translation as well as providing rotational stability. In addition to the ACL, the medial and lateral menisci have been shown to be secondary stabilizers and play an even larger stabilizing role in the ACL-deficient knee. Lateral meniscus injuries seen in conjunction with ACL-deficient knees are commonly radial type tears to the posterior horn of the lateral meniscus or root avulsion type injuries to the posterior horn of the lateral meniscus. In this study we sought to evaluate the effect of a root avulsion of the posterior horn of the lateral meniscus in the ACL-deficient knee using a simulated pivot shift maneuver as well as a simulated Lachman maneuver.

Methods: Eight fresh-frozen cadaveric lower extremities were harvested from male and female donors (mean age 44 years, range 25-63 years). The knees were evaluated arthroscopically to rule out any ligamentous, meniscal pathology or previous surgeries. Both the tibia and the femur were sectioned 30.5cm from the joint line and potted in cylinders using a casting resin (Smooth-On, Easton, PA). The cylinders were aligned parallel to the axis of each respective bone. All overlying soft tissues were removed 18cm distal and proximal from the joint line. Flags were rigidly fastened onto the potted femur and tibia. The flag system consisted of two, four marker arrays of 11.5mm passive photo-reflective spheres in different, asymmetric patterns and provided spatial reference for solid models. Computed tomography (CT) scans (0.625mm slices) were then taken of the flagged knee and 3D solid models were created from the scans using specialized image processing software (Materialize, Belgium) with a dimensional accuracy of 0.2mm.

For kinematic testing, each knee was secured in a custom-made Activity Simulator designed to allow 6 degrees of freedom at the knee during each intended test. A six axis load cell (AMTI, Watertown, MA) in-line with the tibia measured specimen forces and moments applied during testing. For pivot shift testing, a pneumatic cylinder (SMC, Noblesville IN) with an in-line force transducer (Futek, Irvine CA) maintained selected ITB loads. A servo motor (AutomationDirect, Cumming GA) applied the internal rotation moments while an additional pneumatic cylinder (SMC, Noblesville IN) produced the valgus moment. For accuracy and repeatability, a custom LabView program (NI, Austin TX) was written to control the Activity Simulator to recreate a simulated pivot shift test. A pneumatic rotatory actuator (A-T Controls, Cincinnati OH) with feedback from the six axis load cell applied an anterior load to the distal tibial simulating an ATT drawer type test.

Anterior stability tests were performed by applying a 90N anterior force to the tibia at flexion angles of 15°, 30°, 45°, 60°, and 90°. To create a simulated pivot shift, the simulator dynamically loaded each knee from 15° to 90° of flexion with all the permutations of the following: IT band force (50N, 75N, 100N, 125N, 150N and 175N), internal rotation moments (1Nm, 2Nm, 3Nm) and valgus moments (5Nm, 7Nm). Anterior tibial translation and rotational displacement were measured and compared for each knee for the following three conditions: ACL intact, ACL deficient and ACL deficient/lateral meniscus posterior root avulsion.

Kinematic measurements of the 3D positions of the tibia and femur were tracked in real-time during testing using the same photo-reflective flag arrays and a high resolution, infrared multi camera motion analysis system (Motion Analysis, Santa Rosa CA). Reference points were created at the centers of the femoral condyles and tibial plateau with respect to the centroids of the flag arrays using reverse engineering software (Rapidform, INUS Technologies, Seoul, Korea). The reference points as well as the camera capture data were imported into analysis software (MATLAB, Mathworks, Natick, MA) and rotations and translations were calculated. All pivot shift translations were measured from the centroid of the lateral tibial plateau while all ATT translations were taken from the center of the knee.

Results: A pivot shift-type phenomenon was noted in the ACL-D and ACL-D/LM. The mean tibial translation of the lateral tibial condyle during the pivot shift maneuver was 2.62 mm for the ACL-I knees, 6.01 mm for the ACL-D knees, and 8.12 mm for the ACL-D/LM knees. There was a statistically significant difference between the ACL-I vs. ACL-D (p-value 0.0005) and ACL-D/LM (p-value <0.0001). There was a statistically significant difference increased translation of ACL-D/LM vs. ACL-D (p-value .0146). Presented in Figure 1 is a plot of the average pivot shift testing results of the three knee conditions.

There was increased anterior tibial translation with a Lachman simulated maneuver at 30° and 90° of flexion in the ACL-D group.
(p<0.0001) and ACL-D/LM group \( p<0.0001 \) vs. ACL-I group. However, no statistically significant difference was found between the ACL-D and ACL-D/LM at 30° and 90° (\( p= 0.16, p=0.72 \) respectively). Figure 2 is a plot of the average tibial translation for the three knee states tested in this study.

**Discussion:** 1. The presence of a lateral meniscal posterior root injury significantly destabilizes the ACL-D knee when dynamic rotational loads are applied such as a pivot shift maneuver.
2. Our study shows a trend towards increased instability with lateral meniscal posterior root injury during a Lachman-type maneuver.
3. Injury to the lateral meniscus root alone destabilizes the knee with rotational type loads or stresses.
4. Historically, these injuries have been treated non-operatively or with debridement alone.
5. Results demonstrate role in stability favoring consideration for possible surgical repair.

**Significance:** 1. We have developed a technique to dynamically load the knee to create a pivot shift type phenomenon.
2. The presence of a lateral meniscal posterior root injury further destabilizes the ACL-deficient knee when dynamic rotational loads are applied.

**Acknowledgments:**

**References:** Figure 1 - Presentation of the average pivot shift relative to 60° of flexion for the three knee states (ACL-I, ACL-D, and ACL-LM).
Figure 2 - Average tibial translation recorded for the pivot shift, Lachman (30° of flexion) and anterior draw (90° of flexion) for the three knee states (ACL-I, ACL-D, and ACL-