Rotational instability of the knee: Internal tibial rotation under a simulated pivot shift test

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Introduction: Aim of the present study was to provide more insight into the resulting knee kinematics of the human knee under anterior tibial and rotational forces. To accomplish this, a robotic/UFS testing system was used to record knee kinematics of the intact and ACL deficient knee under a simulated KT-1000 and pivot shift tests. We hypothesized that ACL deficiency leads to increased internal tibial rotation under a simulated pivot shift test. Furthermore, we hypothesized that anatomic single bundle ACL reconstruction significantly reduces internal tibial rotation under a simulated pivot shift test when compared to the ACL deficient knee.

Methods: In seven fresh-frozen human cadaveric knees (range 62 to 78 years) the knee kinematics were examined using robotic/UFS testing system (KR 125, KUKA Robots, Augsburg, Germany). First, the robotic/UFS testing system found the positions of the knee that minimized all external forces and moments applied to the joint from 0° to 90° in 5° increments of flexion. For external loading conditions, an anterior tibial load of 134 N (to simulate a clinical KT-1000 test) and a combined rotatory load of 10 N/m valgus and 4 N/m internal tibial torque (to simulate a pivot shift test) were applied at 0°, 30°, 60°, and 90° of knee flexion. Within the same specimen the knee kinematics under simulated pivot shift and KT 1000 test were determined in different conditions: intact, ACL-deficient, and single bundle ACL reconstructed using a medial portal technique. Statistical analyses were performed using a two-factor repeated-measures analysis of variance (ANOVA, p < 0.05).

Results: Under 134 N anterior tibial load, anterior tibial translation (ATT) of the intact knee was a mean of (± standard deviation) 5.4 (± 2.3) mm, 12.4 (± 4.6) mm, 11.2 (± 4.1) mm, and 9.5 (± 3.4) mm at 0°, 30°, 60°, and 90° of knee flexion, respectively. After the ACL was sectioned, the translations increased significantly at all flexion angles tested (p<0.05). The resulting ATT was a mean of 13.4 (±4.7) mm, 22.8 (±8.1) mm, 17.8 (±6.6) mm, and 14.7 (±5.7) mm at 0°, 30°, 60°, and 90° of knee flexion, respectively. ACL reconstruction reduced the anterior tibial translation significantly from the ACL-deficient condition (p<0.05). After single bundle ACL reconstruction, the ATT was a mean of 8.1 (±4.1) mm at full extension, 16.9 (±6.5) mm at 30°, 13.5 (±4.4) mm at 60°, and 11.1 (±3.4) mm at 90° of knee flexion. There was a statistical significant difference to the intact knee at 30° of knee flexion.

In response to a combined rotatory load, the ATT for the intact knee was 2.3 (±1.2) mm, 10.3 (±4.4) mm, 9.5 (±3.8) mm, and 9.3 (±3.4) mm for 0°, 30°, 60°, and 90° of knee flexion, respectively. The values increased after sectioning of the ACL to 6.6 (±2.4) mm at 0°, 15.5 (±6.1) mm at 30°, 11.3 (±4.8) mm at 60°, and 10.0 (±4.0) mm at 90°. The increase in ATT was statistical significant at all flexion angles tested (p<0.05). After single bundle ACL reconstruction, ATT was a mean of 4.3 (±2.1) mm, 12.0 (±5.3) mm, 10.3 (±4.2) mm and 9.3 (±3.1) mm at full extension, 30°, 60° and 90°, respectively. [Figure 1] There were no significant differences in ATT when compared to the intact knee. In response to a combined rotatory load, the internal tibial rotation for the intact knee was 7.5 (±2.8)°, 19.9 (±6.9)°, 16.5 (±5.8)°, and 7.7 (±4.8)° for 0°, 30°, 60°, and 90° of knee flexion, respectively. The values increased after sectioning of the ACL to 26.6 (±2.4)° at 0°, 52.0 (±6.1)° at 30°, 22.3 (±7.8)° at 60°, and 17.9 (±6.2)° at 90°. There were no significant differences in internal tibial rotation when compared to the intact knee. After single bundle ACL reconstruction, the internal tibial rotation was a mean of 9.7 (±4.2)°, 22.4 (±7.9)°, 17.6 (±6.7)° and 8.0 (±5.8)° at full extension, 30°, 60° and 90°, respectively. There were no significant differences in internal tibial rotation when compared to the intact or the ACL deficient knee.

Discussion: The subjective instability of a patient suffering ACL insufficiency can be distinguished into anterior tibial instability and rotational instability. Clinical tests to quantify this instability are Lachman and pivot shift test. The quantification of the pivot shift test however seems to be strongly subjective. The pivot shift phenomenon is in the spotlight of basic and clinical research again. The results of the current study show that the internal tibial rotation of the knee joint under a simulated pivot shift is not significantly influenced by the integrity of the ACL. After resection of the ACL there was no significant increase in internal tibial rotation under pivot shift forces. For the clinical setting this basic science data is extremely important. To assess the rotational instability of the knee joint during the clinical examination, the observer needs to quantify rather the anterior tibial translation of the tibia than the internal tibial rotation of the tibial head. Several authors have recommended instrumental knee laxity measurements for the rotational instability of the ACL deficient knee and the first experimental results of new testing devices were presented. These devices apply internal/external tibial rotational forces at the foot and record the range of motion. The current data raises concerns that these strategies may not be able to detect any significant difference in internal/external tibial rotation due to the fact that the results of this study show no significant difference of the ACL deficient knee compared to the intact knee.