The Comparison Between Static And Dynamic Evaluation Of Pivot Shift Phenomenon.

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Disclosures:

Introduction: Rotational instability remains unsolved despite the progress of anterior cruciate ligament (ACL) reconstruction. Primary reason for this is its dynamism and complexity of the rotational instability which inhibit appropriate quantitative evaluation. This instability is clinically evaluated as pivot shift phenomenon reproduced by the manual pivot shift test, which is very subjective and hard to be quantified. Many studies have attempted to evaluate the pivot shift test by displacement or angular change against some fixed external loading, which are conceptually related to static joint laxity, even though the rotational instability could contain dynamic essence. Some studies reported that the acceleration during the pivot shift test is a good indicator of rotational instability which could be reflected in dynamism of the pivot shift phenomenon. However, there is no study to compare between static and dynamic evaluation of pivot shift phenomenon. Thus, the purpose of this study was to compare the data from the accelerometer with that from the robotic system. We hypothesized that there is correlation between the data from accelerometer and the robotic system.

Methods: Fifteen fresh-frozen human cadaveric knees (n=15) (from donors with a mean age and SD of 58.8 ± 5.6 years at the time of death; 11 males and 4 females) were tested using a robotic/UFS testing system and triaxial-accelerometer. The femur and tibia were then cut approximately 20 cm from the joint line, and the surrounding skin and muscles that were more than 10 cm away from the joint line were removed to expose the bone.

Robotic/UFS Testing System A CASPAR Stäubli RX90 robot (Orto MAQUET, Germany) was used to manipulate the joint. A universal force/moment sensor (UFS-Model 4015; JR3 Inc. Woodland, CA) was used to measure the forces and moments for 6-degrees-of-freedom (DOF). The robotic system was capable of controlling the displacement and the force/moment applied to the knee in all 6 DOF based on a mathematical description of knee kinematics and kinetics. For this study, a simulated pivot shift test with a combined 7 N-m valgus and 5 N-m internal tibial torque was applied to the specimen at 15°, 30° and 45° of knee flexion. Anterior tibial translation (ATT) (mm) was measured before and after ACL transection.

Triaxial accelerometer Specimens underwent pivot shift test, which can reproduce the dislocation phase of the pivot shift phenomenon from flexion to extension, performed manually by the same examiner. An accelerometer (Kistler, Winterthur, Switzerland) was used to record triaxial acceleration during the pivot shift evaluation (x-axis: anteroposterior; y-axis: mediolateral; z-axis: superoinferior). A sensor was attached over the tibial tuberosity with a bone screw attachment. Signals from the sensor were recorded as digital data through an analog/digital board at a sampling rate of 10 kHz, while the waveforms were displayed on a computer screen during pivot shift test. The acceleration in each direction was then collected and the overall magnitude of acceleration was also calculated with use of the formula |a| = √(a^2 + a^2 + a^2). The overall magnitude of acceleration during the pivot shift in each condition was compared with that of intact knees.

Statistical Analysis We compared the data between the overall magnitude of acceleration and the value of ATT from robotic system. Pearson’s product-moment correlation coefficient (r) was used to study the relationship between overall magnitude of acceleration and the value of ATT. The statistical significance level of these analyses was 5%. A simple linear regression analysis showed that a study of 15 knees should provide at least a 95% chance of detecting a correlation between overall magnitude of acceleration and the value of ATT, accepting an r value of 0.30 and a p value of <0.05. All statistical data were calculated using a statistical software package (SPSS version 17.0).

Results: The value of ATT were 5.44±2.28 mm (at 15°), 4.01±2.45 mm (at 30°), 2.71±1.85 mm (at 45°). The overall magnitude of acceleration was 1.55±0.29. Pearson’s correlation coefficient analysis showed no correlation between the overall magnitude of
acceleration and ATT ($p = 0.3241$; $r = -0.277$ at $15^\circ$, $p = 0.6458$; $r = 0.132$ at $30^\circ$, $p = 0.2499$; $r = -0.320$ at $45^\circ$).

Discussion: Rotational instability which affects subjective knee functions is a valuable clinical outcome measure after ACL injury and reconstruction. Clinically performed manual pivot shift test has often analyzed for establishing quantitative measurement of the rotational instability, but most of them evaluated static parameter, such as displacement or angular change, which might reflect more joint laxity. Bignozzi et al found that there were no significant correlations between joint static laxity measured by a navigation system. They further concluded that the dynamic evaluation of a pivot shift is better able to describe dynamic rotational instability. Hoshino et al and Lane et al measured a dynamic parameter, namely acceleration, during pivot shift test but only in anteroposterior direction, even though the pivot shift phenomenon is a multi-directional motion. Therefore, we investigated the pivot shift phenomenon in multiple planes by use of a triaxial accelerometer, which was previously used for the detecting the pivot shift phenomenon. We demonstrated the increase of the acceleration and ATT during pivot shift phenomenon or simulated pivot shift movement using a ACL cutting model, which supposedly developed rotational instability along with the damage of the ACL. In this study, there was no correlation between the ATT and the acceleration. The evaluation of load-displacement at fixed angle such as ATT form robotic study can detect the just only the stability of ligament. The ATT may evaluate the stability of ACL purely. However, the pivot shift phenomenon is affected with various factors such as meniscus, bone morphology and ITT band etc. We consider that the pivot shift phenomenon is better indicator to evaluate the ACL insufficient knee comprehensively. Thus, the evaluation of acceleration of pivot shift phenomenon is useful for the ACL insufficient knee. There is limitation to consider in this study. Manual measurements like the pivot shift are not performed in a blind manner, which may influence the results, and such tests are highly dependent on the experience and skills of the examiners. To exclude such effects, we performed this study by one well-experienced examiner and confirmed the repeatability.

Significance: We compared the data from the accelerometer (acceleration) with that from the robotic system (ATT). There was no correlation between the ATT and the acceleration.

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