Quantitative Assessment Of The Pivot-shift Test For Anterior Cruciate Ligament Injuries Using A Gyroscope

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Introduction: The pivot-shift test has been defined as a combination of valgus stress and tibial internal rotation during limb flexion. This test is commonly used for patients with suspected anterior cruciate ligament (ACL) deficit to evaluate knee stability. However, this test is evaluated by surgeons subjectively, and lacks a quantitative measurement. Recently several authors have reported the importance of quantitative evaluation of the pivot-shift test. A gyroscope can detect acceleration and rotational angular velocity in three-dimensional directions. The purpose of this study was to clinically confirm the utility of a gyroscope for quantitative assessment during a pivot-shift test, and to clarify the details of the pivot-shift test when using a gyroscope. ACL deficient knees increase anteroposterior instability and rotational knee instability, therefore we hypothesized that ACL deficient knees might significantly increase both peak acceleration and maximum rotational angular velocity in comparison with ACL intact contralateral knees.

Methods: 25 consecutive patients with isolated anterior cruciate ligament (ACL) unilateral deficiency were involved in this study between 2013 and 2014. The gyroscope was fixed on the tibial tuberosity with an exclusive strap and a single examiner performed the pivot-shift test on bilateral knees under general anesthesia before ACL reconstruction. These patients included 13 females and 12 males with a mean age of 27.1 ± 12.3 years (range 16-52 years). For the gyroscope, we defined the medio-lateral axis of the tibial axis as the x-direction, the supero-inferior axis as the y-direction, and the antero-posterior axis as the z-direction, respectively. The three axis acceleration and the three axis rotational angular velocity were repeatedly measured with a gyroscope during the pivot-shift test. Initial and final measurements were deleted and in total an average of three measurements were used. Statistical analysis for differences between the two groups were performed using the Wilcoxon T test. Statistical significance was defined as p < 0.05.

Results: The maximum tibial flexural angular velocity in the x-direction on average was 169.2 ± 49.8 deg/s in ACL deficient knees and 143.2 ± 36.0 deg/s in contralateral knees, respectively. There was no significant difference between ACL deficient knees and contralateral knees with respect to the maximum tibial flexural angular velocity. With regard to acceleration, there was a high spike wave during the pivot-shift for the ACL deficient knee, however, for the contralateral knees, there was no high spike wave during the pivot-shift. The difference between positive and negative peak values of acceleration in ACL deficient knees was significantly higher than in contralateral intact knees. (P=0.0002) The mean difference value in the z-direction was 12.1 ± 6.7 m/s2 in ACL deficient knees and 1.5 ± 2.2 m/s2 in contralateral knees. (Fig.2) When the tibia was relocated during pivot-shift test, the angle of tibial inclination in ACL deficient knees...
when the peak of the acceleration was lowest was 12.6 ± 5.5° on average, and when highest it was 15.2 ± 5.1° on average. The angle of tibial inclination in contralateral knees when the peak of the acceleration was lowest was 13.7 ± 3.8° on average, and when highest it was 15.8 ± 3.3° on average. The maximum tibial external angular velocity in the y-direction on average was 135.3 ± 72.4 deg/s in ACL deficient knees and 58.6 ± 49.4 deg/s in contralateral knees, respectively. The maximum tibial external angular velocity of ACL deficient knees was significantly higher than that of contralateral knees (p = 0.002). The angle of tibial inclination at maximum tibial external angular velocity was 16.8 ± 4.5° on average in ACL deficient knees and 16.7 ± 3.1° on average in contralateral knees, respectively. (Fig.3)

Discussion: Recently several studies have reported on quantitative assessment of dynamic rotational knee instability using such means as electromagnetic devices, navigation and triaxial accelerometry. Our study evaluated anteroposterior instability and rotational knee instability by acceleration and angular velocity using a gyroscope. We hypothesized that the gyroscope could identify rotational knee instability of ACL deficient knees. Although there was no difference with respect to flexural angular velocity, because ACL deficient knees have anteroposterior instability and rotational instability, substantial acceleration and external angular velocity were produced when tibial subluxation was reduced during pivot-shift. The results of this study support our initial hypothesis.

When tibia was inclined 12.6° on average during pivot-shift, maximum tibial posterior acceleration was produced. At the moment at which the tibia is reduced from subluxation, the tibial acceleration turned in the opposite direction and substantial anterior acceleration was induced. The tibial inclination at peak anterior acceleration had a mean value of 13.7°. The tibial external angular velocity reached maximum value at 16.8° of tibial inclination after reduction.

There are some limitations in this study: The gyroscope was skin-fixed, therefore soft tissue artifacts may have influenced the result. In addition, our study did not evaluate the quantity of power gained against knees by the examiner during the pivot-shift test.

Significance: Regarding clinical relevance, these findings may help to improve preoperative or postoperative quantitative measurement in ACL deficient patients. In conclusion, ACL deficient knees significantly increased the difference between positive and negative peak values of acceleration and maximum rotational angular velocity in comparison with ACL intact contralateral knees. Our study indicates that the gyroscope may indeed be useful for quantifying the pivot-shift test.
A gyroscope was fixed on the tibial tuberosity with an exclusive strap. The gyroscope can detect acceleration and rotational angular velocity in three-dimensional directions.

**Fig. 1**

**Acceleration during a pivot-shift for the ACL deficient knees and the contralateral knees**

![Graphs showing acceleration](image)

- **Positive peak**
- **Negative peak**
- **No peak**

The dotted line shows angle of tibial inclination.
The black line shows acceleration in z-direction.

**Fig. 2**
Angular velocity during a pivot-shift for the ACL deficient knees and the contralateral knees

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**Fig. 3**

*The dotted line shows angle of tibial inclination.*
*The double gray line shows angular velocity in y-direction.*

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