# Innovative Technology for Knee Laxity Evaluation

## Clinical Applicability and Reliability of Inertial Sensors for Quantitative Analysis of the Pivot-Shift Test

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**KEYWORDS**

• Knee kinematics • Anterior cruciate ligament injury • Dynamic instability • Pivot-shift test • Acceleration

**KEY POINTS**

- There has been an increased interest in the quantification of the knee laxity secondary to anterior cruciate ligament (ACL) injury. In clinical practice, the diagnosis is performed by clinical examination and magnetic resonance imaging analysis and confirmed arthroscopically under anesthesia.
- The pivot-shift (PS) phenomenon has been identified as one of the essential signs of functional ACL insufficiency.
- During the preoperative phase, the importance of the PS test for a complete evaluation of the injury is well acknowledged. Moreover, PS is the test that correlates with functional instability and patient outcomes better than does any other physical examination test. Thus, a reliable system to adequately assess patients with ACL injury, quantifying the PS test outcome, is needed to determine the efficacy of such reconstructions and aid in managing patient recovery.
- Several studies have been conducted in this regard using navigation systems, electromagnetic sensors, or other devices. Unfortunately, because of various problems, the proposed methods remain confined to a research area.
- The goal of this article is to summarize the actual knowledge and current concepts with respect to the use of acceleration as a quantitative parameter in the assessment of the dynamic knee movement during the PS test.

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## INTRODUCTION

Instability of the tibiofemoral joint secondary to an anterior cruciate ligament (ACL) injury is considered a critical issue and relates to the concept of joint *laxity*.[1] By definition, laxity is the displacement, or the rotation, produced in response to an applied load or moment. Moreover, it is defined as *static* laxity when only one degree of freedom is involved and *dynamic* when more than two are considered.[2]

Because the ACL represents the primary restraint to tibia anteroposterior (AP) displacement,[3] historically, the first approach to the evaluation of the tibiofemoral joint laxity involved the measurement of joint AP translation. From this point of view, Lachman and drawer tests are still the most commonly used tests to quantify the static laxity of the knee joint.

Although the previous tests are useful in the detection of a large part of ACL injuries, they do not provide information about rotational and dynamic laxity of the joint. Moreover, analyzing solely static laxity makes it difficult to isolate the injured ligament because of the different structures involved in the restraining phenomenon.[4] Thus, additional stress tests have been introduced.

The pivot-shift (PS) phenomenon is commonly described as the anterior subluxation of the lateral tibial plateau followed by its sudden reduction during combined stresses.[2,5] This pathway has been widely identified to be one of the essential signs of functional ACL insufficiency[6,7]; thus, clinicians have been trying to mimic it by means of a combination of valgus stress and tibial internal rotation during limb flexion.[5,7]

Lachman and PS are the two clinical tests most commonly used to assess knee laxity.[8] Although the PS test could be considered the most specific test in detecting ACL injury,[4,9,10] the Lachman test, involving only one knee grade of freedom, remains more easily quantifiable and sensitive.

Moreover, literature reported that PS grade more closely correlates with instability symptoms,[11] reduced sport activity,[12] articular cartilage damage, and meniscal damage[13] with respect to the standard clinical examinations addressing only static joint laxity (ie, Lachman and drawer tests).[14]

The major problem using PS test lays in the complexity of the maneuver itself, which provokes a large variability both between testers and patients and making it a highly surgeon-subjective clinical examination.[15–17] Furthermore, given that the test itself is a combined stress, PS test lacks a generally recognized quantitative and overall measurement.

In the past years, several studies proposed a quantification of this phenomenon, promoting different kinematic parameters.

The goal of this article is to summarize the actual knowledge and current concepts about the quantification of PS test and, above all, about the use of acceleration as a quantitative parameter in the assessment of the dynamic knee movement during the test. The authors specifically reported the performed in vitro and in vivo validations in the use of an inertial sensor (ie, accelerometer) to quantify PS test.

## QUANTITATIVE EVALUATION OF THE PS TEST

During the past decade, several systems and methods have been developed and proposed to quantify knee dynamic laxity level because of ligament injuries, providing a standardized approach as a basis for the clinical examination. The importance of any grading system lies in how helpful it can be in making decisions concerning diagnosis, treatment and recovery phase after surgery. A quantification of knee laxity can be valuable during the course of the diagnosis assessment and preoperative planning to determine *if* and *what* surgery is required, as well as during the postoperative