# Partial Anterior Cruciate Ligament Ruptures: Knee Laxity Measurements and Pivot Shift

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**Abstract**

Partial anterior cruciate ligament (ACL) tears can involve isolated injury to the anteromedial (AM) bundle, the posterolateral (PL) bundle, or ACL remnant healing to the posterior cruciate ligament (PCL). The viability and function of the partial ACL tear is assessed through history, physical examination, including laximetry utilizing new technologies, imaging, and arthroscopy. New treatment algorithms aim at individualizing treatment for partial ACL injuries to ultimately improve clinical outcomes for patients.

## Introduction

Treatment algorithms for injuries of the anterior cruciate ligament (ACL) are rapidly evolving as the best available evidence from higher-level studies develops. With the increased recognition of partial tears of the ACL, new techniques for reconstruction or augmentation are being reported. Further research is defining the role of platelet-rich plasma (PRP), fibrin clot, and other growth factor augmentation techniques (Rodeo et al. 1999; Yeh et al. 2007; Kuang et al. 2010). The treating physician must be aware of the new advances in technique to provide a more complete analysis of the injury, with the aim being restoration of each patient's unique anatomy to achieve the goal of individualized ACL reconstruction.

Ruptures of either the anteromedial (AM) or posterolateral (PL) bundle in isolation have been reported to comprise between 5 % and 28 % of all injuries to the ACL. These partial tears pose new diagnostic challenges to the orthopedic surgeon. Suboptimal outcomes following ACL reconstruction can be related to an inaccurate diagnosis and poor preoperative planning. Improved diagnostic ability is necessary to select the optimal course of treatment for each patient. ACL augmentation procedures, which aim to reconstruct the AM bundle or PL bundle, are increasingly being performed and are showing good results (Ochi et al. 2006; Sonnery-Cottet et al. 2010).

Preservation of the ACL remnants may aid the biological process following an ACL reconstruction or augmentation surgery. The remnants may serve as a mechanical restraint in anterior knee stability (Crain et al. 2005). Histological studies revealed improved healing potential due to the vascular support provided by the epiligamentous tissue (Howell et al. 1995). Also, the remnants may provide a proprioceptive function due to the presence of neural mechanoreceptors (Ochi et al. 1999; Georgoulis et al. 2001; Adachi et al. 2002).

Clinical examination remains one of the most important steps when evaluating the injured knee. Ligamentous laxity is difficult to quantify and is currently graded subjectively by the examiner (Noyes et al. 1991; Kuroda et al. 2012). Hole et al. found that clinical evaluation is unreliable in the differentiation of a 75 % sectioned ligament from a completely sectioned ligament (Hole et al. 1996). To minimize this problem, objective instrumented laxity methods have been developed. The KT-1000 (MEDmetric Corp., San Diego, CA, USA) and the Rolimeter (Aircast, Vista, CA) are commonly used to quantify the Lachman test but with the limitation of measuring only anterior tibial translation. Instrumented anteroposterior laxity does not correlate with postoperative outcomes or development of osteoarthritis (Kocher et al. 2002).

The pivot shift is the most specific test for the diagnosis of an ACL rupture. It is also the most reliable test for the diagnosis of partial lesions (DeFranco and Bach 2009). It is manifested clinically by the complaint of "giving way" and as a physical sign that can be detected (Galway and MacIntosh 1980). The presence of a pivot shift has been correlated with poor subjective and objective knee scores, with rates of return to the same level of play and with the development of degenerative changes (Jonsson et al. 2004; Leitze et al. 2005). Thus, the goal of ACL reconstruction is elimination of the pivot shift.

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**Fig. 1** Oblique coronal PD/TSE MR image showing a right knee with a partial ACL tear. The AM bundle is intact (*arrow*)

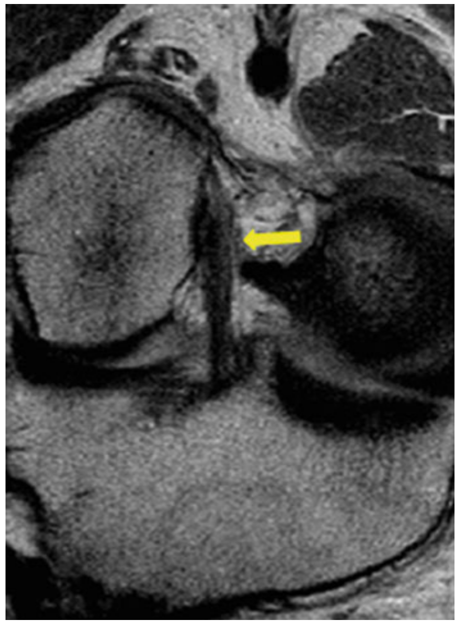

**Fig. 2** Oblique coronal PD/TSE MR image showing a right knee with a partial ACL tear. The PL bundle is intact (*arrow*)

## Partial Tears

### Definition and Classification

A partial ACL rupture is defined as either an isolated lesion of the AM bundle or the PL bundle. The diagnosis is made by a combination of history, physical examination, advanced imaging, and arthroscopy. An isolated rupture of the AM bundle with a competent PL bundle is characterized as "PL intact" (Fig. 1). The converse is called "AM intact" (Fig. 2). The remnant of the ACL may adhere to the PCL which is called "PCL healing" (Bach and Warren 1989).

In terms of surgical versus nonsurgical treatment, it is necessary to distinguish whether the partial rupture is "functional" or "nonfunctional." Preserved bundles, which can develop tension on probing during arthroscopy, are classified as functional. If the preserved bundle shows abnormal laxity, it is classified as a "nonfunctional" partial rupture Dejour et al. (2013) (Fig. 3).

### How Can the Clinical Examination Help with the Diagnosis?

Several devices are currently used to aid the clinician in the diagnosis of either a complete or a partial ACL tear. Siebold and Fu demonstrated that PL bundle ruptures showed 1–3 mm of increased laxity on KT-1000 measurements. For AM tears, the translation was greater, with a difference between 2 and 4 mm (Siebold and Fu 2008). Dejour et al. used Telos stress tests and bilateral stress radiographs and found complete tears to have a median of 9 mm of translation, 6 mm in all nonfunctional partial tears, and 4 mm in functional partial tears (Dejour et al. 2013). They were unable to differentiate between the anatomic patterns of the partial tear, i.e., AM versus PL tear. Panisset et al. studied the differences between complete and partial tears using the Rolimeter and the Telos device. The Rolimeter showed a mean side-to-side difference (SSD) of 5.3 mm for complete tears and 2.6 mm for partial tears, and the Telos device showed 7.4 mm and 4.0 mm, respectively. A threshold value of 5 mm

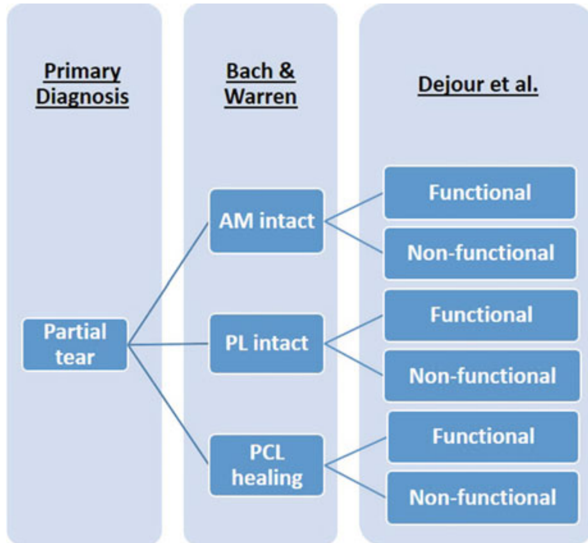


**Fig. 3** Flowchart showing the classifications of partial tears according to Bach and Warren (1989) and Dejour et al. (2013)

of SSD demonstrated by the Telos device was strongly associated with the differential diagnosis of complete and partial tears of the ACL (sensitivity 80.9 %, specificity 81.8 %) (Panisset et al. 2012).

## The Pivot-Shift Test

### Historical Review

In 1972, Galway and MacIntosh characterized the pivot shift as anterior subluxation of the lateral tibial plateau on the femoral condyle as the knee approaches extension with spontaneous reduction in flexion (Galway and MacIntosh 1980). Losee, in 1982, stated that for the pivot shift to occur, the ACL, lateral, and posterolateral portions of the capsule have to be deficient (Losee 1982).

Many descriptions of the maneuver have been proposed. The classic description by Galway and MacIntosh is internal rotation of the foot, valgus moment on the knee by the upper hand, and during the flexion of the knee the displaced tibial plateau reduces (Galway and MacIntosh 1979). Bach et al. described a modified maneuver with the foot in external rotation, as an option to increase the sensitivity of the test. In addition, the position of the hip may influence the amount of translation during the maneuver. Placing the hip in abduction with tibial external rotation yielded the highest pivot-shift grade when compared to the hip in adduction and the tibia in external or internal rotation (Bach et al. 1988).

In 1987, Jakob and Stäubli created a method of grading the pivot shift. In their method, the maneuver is carried out with the patient's foot in three different rotations: internal, neutral, and external rotation. The system consists of three different grades: (I) the pivot shift occurs only in internal rotation with a small, gentle sliding reduction; (II) a "clunk" is felt when rotating the tibia in the neutral but mainly in internal rotation; and (III) a pronounced "clunk" occurs in neutral and external rotation, being less obvious in internal rotation. According to this method, increased grades represent involvement of different compartments of the knee, from mild anterolateral laxity in grade I through marked shift and translation in both compartments in grade III (Jakob et al. 1987).

As seen, there is a lack of agreement for the execution of the pivot-shift test. The maneuver can be executed with different speeds and forces and its grade is based on the clinician's subjective feel of the phenomenon while performing the test. Clinical grading of the pivot-shift test has low interobserver reliability (Noyes et al. 1991). In an effort to increase consistency between examiners, Musahl et al. attempted to obtain agreement on a standardized pivot-shift technique between

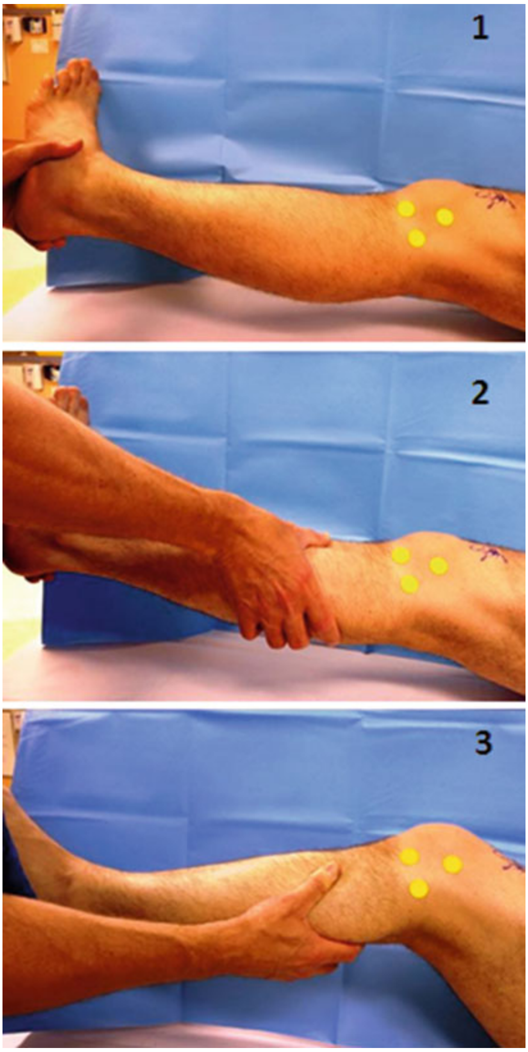


**Fig. 4** Standardized technique for the pivot-shift test in three steps (Hoshino et al 2012a). The test is shown for a left knee. (1) Internal rotation applied by examiners' left hand (*top*). (2) Valgus stress applied by examiners' right hand (*middle*). (3) Knee flexion (applied by left hand) with release of the rotational stress and reduction of the tibial plateau (*bottom*)

experts and assess acceptance. The standardized maneuver consists of three steps (example for the left knee examination): (1) left hand holds the heel while internally rotating the leg; (2) with thumb up, the right hand applies a valgus moment just distal to the joint line; and (3) while flexing the knee with the left hand, rotational stress is released and the reduction is felt with the right hand (Fig. 4). Variation of acceleration between 12 expert examiners was significantly reduced when performing the standardized technique, yielding improved consistency for the test. Also, 87 % of the surgeons tested easily acquired the standardized test after instruction (Hoshino et al. 2012a).

## Rotatory Knee Laxity and Pivot Shift

A major limitation of the pivot-shift test is that it is a non-weight-bearing examination and cannot mimic the true effect of rotatory knee laxity in dynamic weight-bearing conditions. The importance of rotatory knee laxity is increased with the focus on anatomic ACL reconstruction.

For the envelope of laxity of the knee, the ACL performs a primary function in preventing rotatory instability with the collateral ligaments, menisci, and joint capsule performing secondary functions (Bull et al. 2002; Bedi et al. 2010; Suero et al. 2012). The specific contributions of each structure are a point of current debate.

Bony morphology influences knee stability and the pivot-shift test. Musahl et al. described the influence of the femoral condyle and tibial plateau, concluding that smaller lateral tibial plateaus can be related to higher grade pivot-shift test results (Musahl et al. 2010a). Brandon et al. found that a higher pivot-shift grade is associated with an increased degree of posterior-inferior tibial slope (Brandon et al. 2006). Hoshino et al. using 3D-CT data and a dynamic stereo radiographic system, concluded that distal femoral geometry can influence dynamic rotatory laxity (Hoshino et al 2012d).

The function of the AM bundle concerning rotational instability has been rediscovered and increased in importance, despite the fact that the PL bundle was believed to be the primary bundle responsible for controlling rotational stability. Yasuda et al. stated that both bundles are important in both anterior and rotational laxity and the relative contributions of each bundle are dependent on the knee flexion angle (Yasuda et al. 2011). Similar findings have been echoed by other authors (Kato et al. 2013).

## How Can the Pivot-Shift Test Help with the Diagnosis of a Partial Tear?

The pivot-shift test is the most important and useful test to define the extent of injury to the ACL. DeFranco and Bach determined that if damage to the ACL fibers is severe enough to produce a positive pivot-shift test, then the remaining ACL is nonfunctional (DeFranco and Bach 2009). Dejour et al. highlighted the importance of combining results of clinical tests to correctly diagnose partial tears and allowing for adequate preoperative planning. Higher grades (II or III) of pivot-shift laxity were consistent with complete tears, whereas lower grades (0 or I) were related to partial tears (Dejour et al. 2013). Van Eck et al. determined that primarily anterior laxity, but a lower-grade pivot shift, likely has an isolated AM bundle tear. Conversely, a large pivot shift with only a lower-grade Lachman test is more indicative of an isolated PL bundle rupture (Van Eck et al. 2010).

The recent interest in rotatory laxity and the pivot-shift test has made apparent the need for a reliable and noninvasive method to quantify the maneuver. Several devices designed to measure laximetry of the pivot-shift test have been developed. The goal of rotatory knee laxity testing is the development of a noninvasive, user-friendly device that provides accurate and reliable measurements.

## Pivot-Shift Laximetry

There are several devices reported to measure dynamic rotatory knee laxity (Zaffagnini et al. 2006; Musahl et al. 2010b; Colombet et al. 2012; Kuroda et al. 2012; Lopomo et al. 2012; Hoshino et al. 2013). However, the pivot-shift phenomenon is a combination of motions in more than one degree of freedom. The main issue is to obtain relevant data from such a complex movement. Different techniques to analyze aspects of the pivot-shift maneuver such as tibial acceleration (Ahldén et al. 2012), lateral compartment translation (Bedi et al. 2010), velocity of translation (Labbe et al. 2011), and the "angle of p" (Lane et al. 2008) have been attempted.

## Computer-Assisted Surgery and Kinematics

Computer-assisted ACL reconstruction has been used to evaluate tunnel positioning (Nakagawa et al. 2008; Voos et al. 2010). Its use in evaluating knee kinematics and laxity is also valuable. It can provide valuable data on anteroposterior translation and internal and external rotation (Plaweski et al. 2011). This invasive method requires two rigid bodies attached to pins inserted in the distal femur and proximal tibia to provide an intraoperative 3D anatomic model of the patient's knee surface geometry. The accuracy of the navigation system is reported to be $\pm 1$ mm for linear measurements and $\pm 1°$ for angular measurements and is precise in measuring laxity (Colombet et al. 2007; Lane et al. 2008). Limitations include invasiveness, use restricted to the operating room, and lack of comparison with the uninjured side.

## Electromagnetic Tracking Devices

Electromagnetic measurement systems (EMS) are noninvasive and can be used in vivo, allowing six degrees of freedom of knee kinematics. The system works with transmitters attached to the skin that are digitized by a specially made stylus pen. A computer is used to collect and record data.

Hoshino et al., using the EMS, found that acceleration of tibial translation during the pivot-shift test correlated with clinical grading (Hoshino et al. 2007). Araki et al. compared partial and complete tears of the ACL using the EMS and found decreased knee laxity in patients with partial tears during the Lachman test and the pivot-shift test. Mean acceleration of tibial reduction was significantly reduced in partial tears when compared with complete tears (Araki et al. 2013).

Further studies documenting validity and accuracy of these devices must be performed prior to widely accepted usage. These devices are also bulky which results in difficulty in performing the examination in the office.

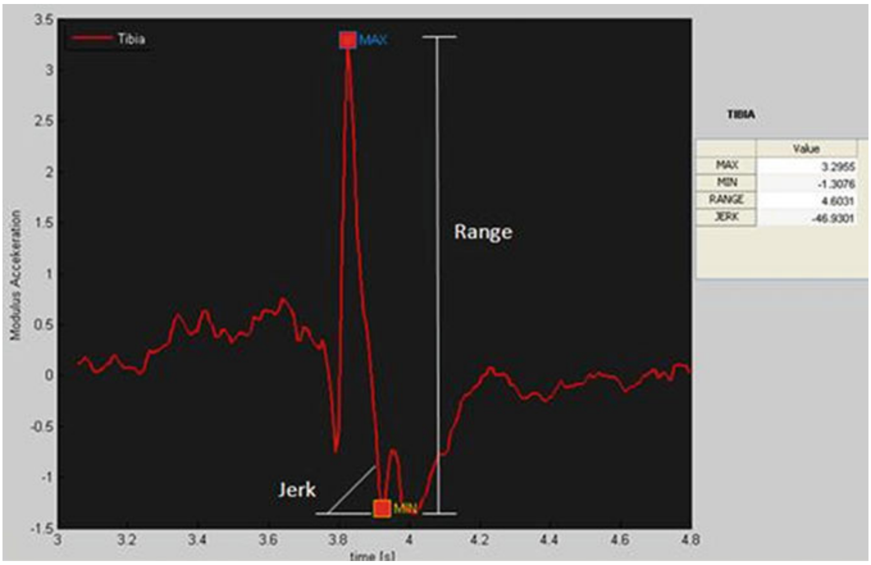


**Fig. 5** Analysis of tibial acceleration by an inertial sensor. The *graph* shows tibial acceleration in m/s$^2$ versus time in seconds. The spike in the curve (at 3.8 s) is produced by the reduction phase of the tibia during the pivot-shift test. The results for the test are shown on the right. Range of acceleration is measured as the difference between the maximum and minimum values of acceleration (in this case 4.6 m/s$^2$). Jerk is a suggestion of the smoothness of the identified phenomenon (Lopomo et al. 2012)

## Triaxial Accelerometer

The triaxial accelerometer for the pivot-shift test is a noninvasive tool consisting of an inertial sensor connected to a computer. The sensor is affixed to the proximal tibia and wirelessly transmits information in real time.

Studies regarding the clinical validation of the accelerometer's use on quantifying the pivot-shift test have been performed. Lopomo et al. found a probability of 70–80 % for diagnosing an ACL-deficient knee using only acceleration parameters (Lopomo et al. 2012) (Fig. 5). Ahldén et al. found that tibial acceleration during the reduction phase of the pivot shift had a good correlation with the clinical grade of the test (Ahldén et al. 2012). Araujo et al. found that the accelerometer had a moderate to good correlation with the electromagnetic system for the acceleration parameter, using the standardized pivot-shift test previously described (Araujo et al. 2012).

Mayema et al., in a sectioning study, demonstrated increased acceleration and rotational instability was observed with increased damage to the ACL (Maeyama et al. 2011). Hoshino et al. highlighted that acceleration during the reduction phase of the pivot shift is a good indicator of rotational instability, which reflects the dynamic behavior of the pivot-shift phenomenon (Hoshino et al. 2012c).

## Image-Based Techniques

### Dynamic Stereo Radiography (DSX)

Radiostereometric analysis (RSA) is a highly precise biplanar radiographic film technique used to obtain 3D information on knee kinematics. It is an invasive method that uses implanted tantalum spheres measuring 1.6 mm diameter in the femur and tibia. This technique is capable of tracking the markers with an accuracy of approximately 0.1 mm (Tashman and Anderst 2003). Using RSA, Tashman et al. demonstrated that rotational instability was not restored by transtibial ACL reconstruction (Tashman 2004).

DSX is a noninvasive method of measuring knee motion. It is a radiographic model-based tracking technique that measures the three-dimensional in vivo motion of the tibiofemoral

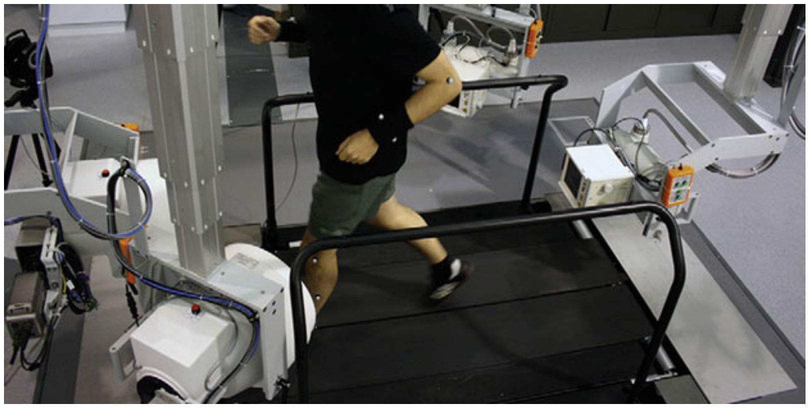

**Fig. 6** A treadmill run test is shown with simultaneous biplane fluoroscopy of the knee (dynamic stereo radiography, DSX) (From Ahlden et al. (2012); **needs permission** from Springer Science and Business Media)

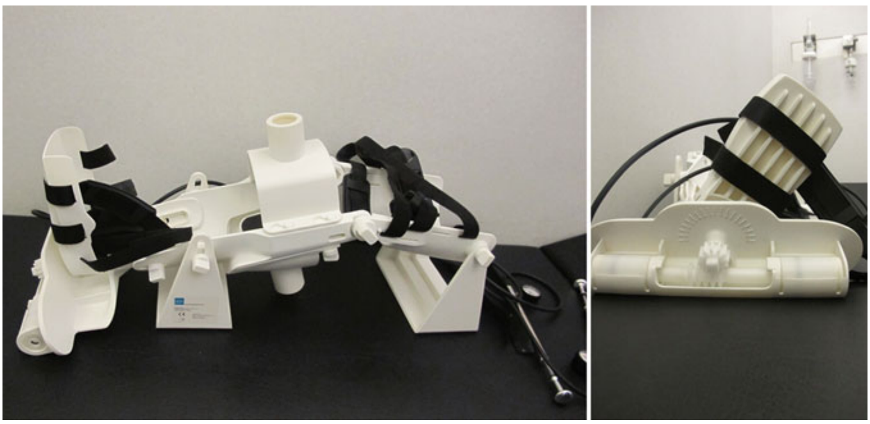

**Fig. 7** Photography of PKTD® currently in clinical application

joint (Fig. 6). Precision of this method was validated when analyzing joint motion during running and was less than 1.0° for rotation and less than 1.0 mm for translation (Anderst et al. 2009). It is considered the gold standard of kinematics evaluation but requires complex tools, is labor intensive, and is expensive.

## Dynamic MRI Evaluation (PKTD)

The Porto-knee testing device (PKTD) (Fig. 7) has proved to be a reliable tool in the quantification of anteroposterior translation (comparing to KT-1000) and rotatory knee laxity (compared to lateral pivot shift under anesthesia). A strong positive correlation has been found between lateral pivot-shift test under anesthesia and the difference between lateral and medial tibial translation of ACL-deficient knees (threshold level for 2+/3+ is 3.5 mm) (Espregueira-Mendes et al. 2012).

PKTD is built in polyurethane, enabling it to be used during MRI (or CT scans). The tibia is put under stress caused by the inflation of cuffs which have a standardized pressure of 46.7 kPa (load per unit area), applied in the posterior proximal calf region. It can be adjusted to different degrees of knee flexion and different degrees of external/internal rotation inflicted by the footplate. Measurements are taken considering only fix bony landmarks (Fig. 8) to overcome inherent bias of considering soft tissue (less precise) for quantification.

Partial ACL ruptures (Ochi et al. 2006; Sonnery-Cottet et al. 2010) have been recognized as difficult to identify by preoperative MRI (Van Dyck P et al. 2012). Furthermore, it is even

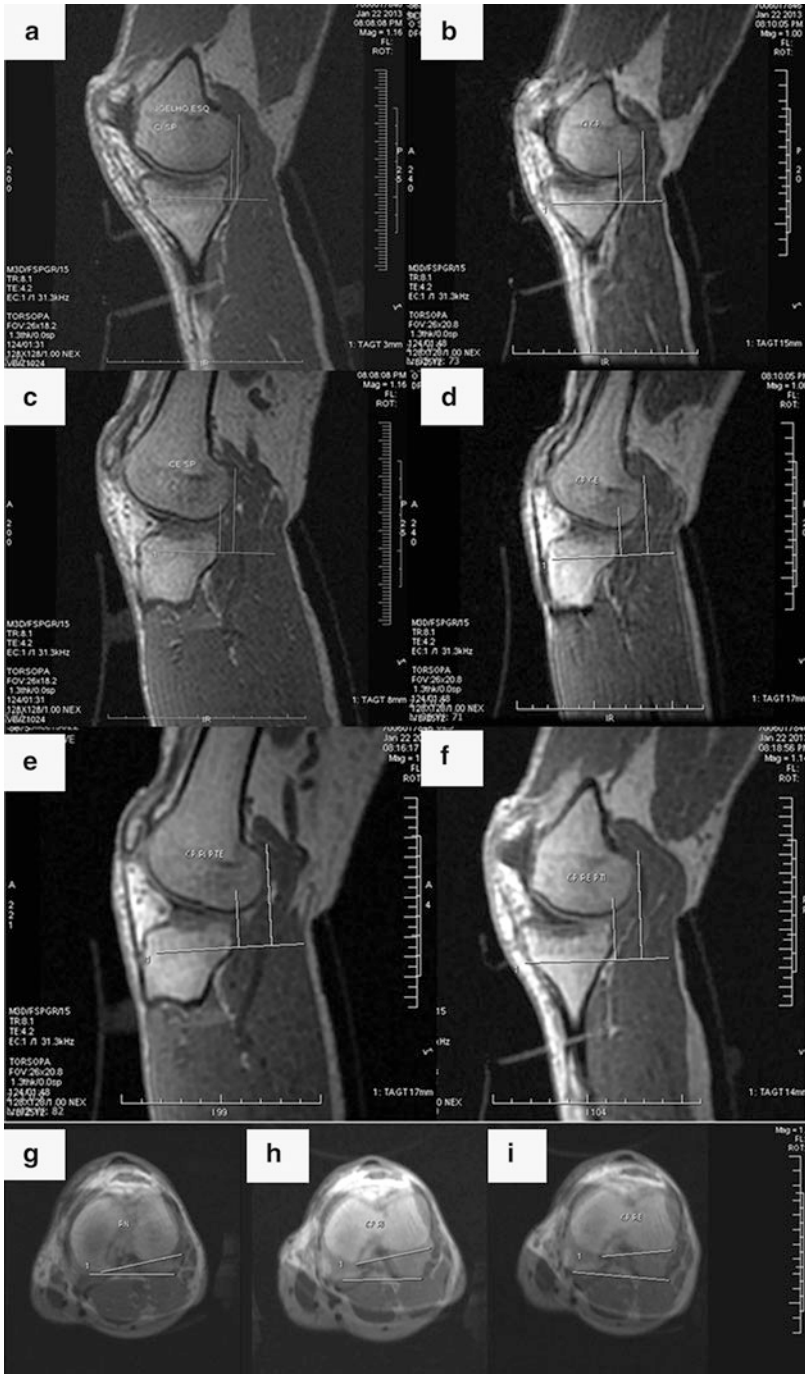


**Fig. 8** Standard protocol evaluation of a case initially classified as having partial ACL rupture corresponding to AM bundle. Sagittal view with foot in neutral position without load application correspondent to medial (**a**) and lateral compartments (**c**). Result after load applications correspondent to medial (**b**) and lateral compartments (**d**). In this case the differential would be respectively of 12 mm and 9 mm. Image correspondent to load after maximum internal foot rotation in lateral compartment (**e**) and after maximum external foot rotation in medial compartment (**f**). Evaluation of angular and linear tibial dislocation from axial views: without load (**g**) and with load after internal (**h**) and external foot rotation (**i**). Evaluation confirmed global ACL insufficiency

more difficult to establish the functional behavior of the ligament's remnant. ACL injuries, initially classified by radiologists as "partial ACL ruptures," often present an instability pattern of total rupture (Fig. 8). The possibility of combining functional and anatomic evaluation helps preoperative evaluation. Patients and surgeons might be informed of other surgical options (e.g., augmentation procedure) to be considered in advance.

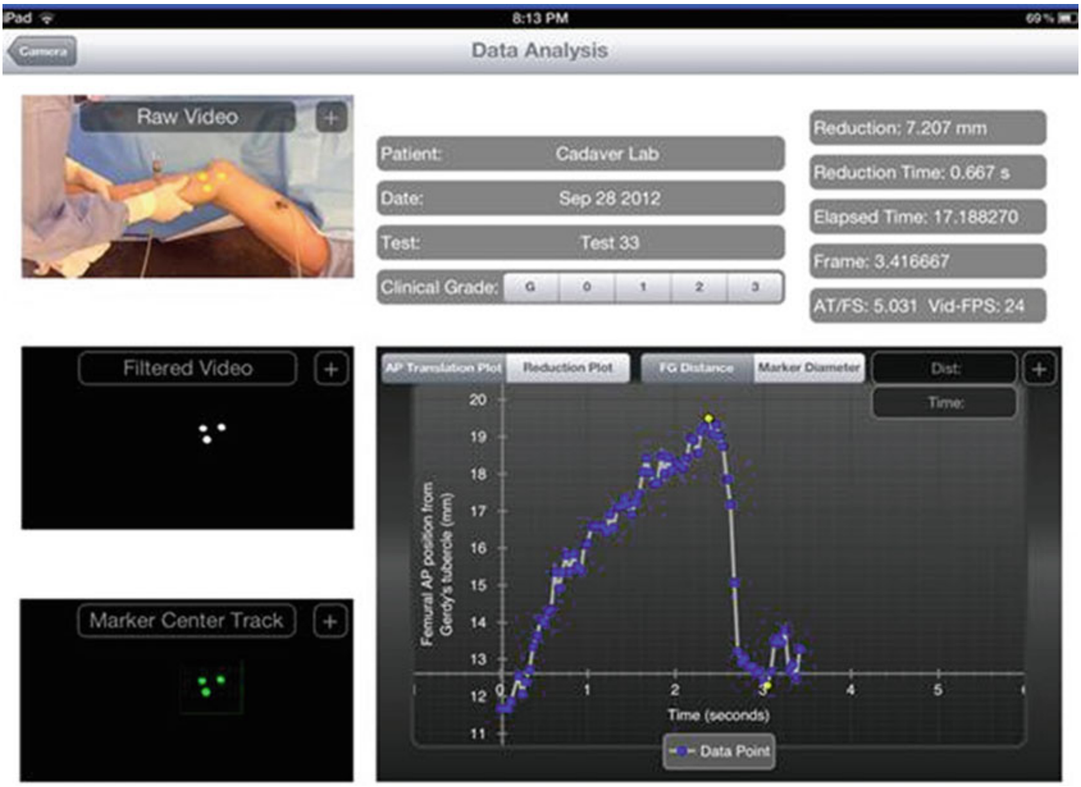


**Fig. 9** The iPad app (PIVOT app) for quantitative analysis of the pivot-shift test. Three stickers are placed on Gerdy's tubercle, fibula head, and lateral epicondyle. The PIVOT app simultaneously records a video of the standardized pivot-shift test (*upper left*), filters the video (*middle left*) to track the center of three markers (*lower left*), and calculates translation (in mm) over time (in seconds; *lower right*). The data analysis is shown on the top of the screen. This example is of a cadaver lab demonstration with transection of the ACL, lateral meniscus, and lateral capsule. The reduction of the tibia during the pivot-shift test occurred at 2.5 s, the reduction time was 0.7 s, and the translation was 7.2 mm (Hoshino et al. KSSTA 2013)

More than the evaluation of the "amount of tibial translation" in a single position of the knee joint, one might test the translation in several positions considering the different kinematic roles of AM and PL bundles. By means of inducing tension on ACL during imaging acquisition, it is possible to rule out the so-called chewing gum effect, testing the mechanical behavior of ruptures initially classified as partial (Sonnery-Cottet and Chambat 2007; Lorenz et al. 2009) (Fig. 8). A flaccid ACL remnant or PCL healing might look like viable in an acceptable position on static imaging but reveal to be functionally unable to resist stress.

Despite being in the early time of its clinical application, PKTD has proved to be a valuable tool. The ability of identifying partial ruptures and the status of the remaining bundle due to its unique feature of combining anatomical and dynamic "clinical" evaluation amplified by the high resolution of MRI places the PKTD in a noticeable spot in the preoperative planning.

## Image Analysis Method (iPad)

Translation of the lateral compartment during the reduction phase of the pivot-shift test can be successfully detected noninvasively using simple image analysis (Hoshino et al. 2012a, b, c). Technological improvements have allowed the development of an iPad (Apple Inc., Cupertino, CA, USA) application, allowing for near real-time image analysis. For image detection by the app, three round yellow stickers are attached to the skin over the lateral epicondyle, Gerdy's tubercle, and fibular head. The data provided generates a graphic showing the relationship between translation and time (Fig. 9).

Hoshino et al. studied 34 patients with unilateral ACL-deficient knees who underwent reconstruction. Using the iPad app, the pivot shift was measured under anesthesia in both knees, using the standardized pivot-shift maneuver described earlier. The image analysis is able to detect an increase in the lateral translation in the ACL-deficient knees compared to the contralateral knees and correlates with grading of the pivot-shift test (Hoshino et al. 2013).

The iPad app is under process of validation. A prospective international multicenter validation of outcome technology study is currently under way (PIVOT study; ISAKOS/OREF research grant). This system might be able to detect partial, complete, and combined ACL injuries. Ultimately, quantitative pivot-shift analysis will help improve the preoperative evaluation and clinical outcomes for patients.

## Clinical Outcomes

Postoperative results following ACL augmentation surgery are promising. In 2000, Adachi et al. compared an augmentation procedure with "traditional" ACL reconstruction with a minimum follow-up of 2 years in 40 patients. They have shown that postoperative anterior translation was significantly less in the augmentation group. Also, the final inaccuracy of joint position sense was significantly less in the augmentation group (Adachi et al. 2000). Similar results were demonstrated by Ochi et al. in a series with 45 patients with a minimum of 2 years of follow-up. They found a significant reduction in anterior translation, measured by the KT-2000, from $3.3 \pm 2.4$ mm in side-to-side difference to a mean of $0.5 \pm 2.7$ mm. Joint position sense inaccuracy was $1.6° \pm 1.8°$, which improved significantly to $0.3° \pm 2.0°$ after surgery (Ochi et al. 2009). In both studies, they highlighted the importance of preserving the remnants as a mechanism to improve proprioception.

Buda et al. analyzed 28 patients who underwent ACL augmentation surgery. Twenty-five patients were rated as excellent, three as fair. Also, a good correlation was shown between clinical results, graft integration, and graft signal on MRI examination. Yoon et al. compared 82 cases of ACL reconstruction, 40 cases of AM augmentation, and 42 cases of PL augmentation. There was no difference between the groups in postoperative measurements including range of motion, Lachman test, pivot-shift test, and KT-1000 arthrometry (Yoon et al. 2009). Sonnery-Cottet et al. performed 36 AM bundle reconstructions, achieving a significant difference in side-to-side difference between preoperative (4.8 mm, min. 3, max. 6) and postoperative (0.8 mm, min. 0, max. 2) instrumented laxity (Sonnery-Cottet et al. 2010).

## Summary

Partial ACL tears, involving either the AM or the PL bundle, present a challenging diagnosis for the surgeon. Laximetry, mainly through the evaluation of rotatory knee laxity via the pivot-shift test, is the most specific clinical examination for diagnosis of partial ACL tears. New noninvasive technologies, made for daily use in the office, are being developed and may open new perspectives in knee ligament evaluation. These technologies include electromagnetic tracking devices, inertial sensors, and image analysis with the iPad. New treatment algorithms are being developed with specific and individualized treatment for partial, complete, and combined ACL injuries. Surgical reconstruction of partial ACL tears can involve preservation of the ACL stump, single-bundle reconstruction of isolated AM or PL bundle tears (under preservation of the intact bundle), or single-bundle augmentation during revision ACL reconstruction. Ultimately, improved diagnosis and treatment of partial ACL tears will lead to a more individualized surgery and improved clinical outcomes for patients.

## Cross-References

- ▶ Anterior Cruciate Ligament Injuries and Surgery: Current Evidence and Modern Development
- ▶ Innovation in Sports Medicine
- ▶ Personalized Treatment Algorithms for Anterior Cruciate Ligament Injuries
- ▶ Platelet-Rich Plasma: From Laboratory to the Clinic
- ▶ Primary Anterior Cruciate Ligament Repair in Athletes with Mesenchymal Stem Cells and Platelet-Rich Plasma
- ▶ Return to Play Decision-Making Following Anterior Cruciate Ligament Reconstruction: Multi-factor Considerations
- ▶ Return to the Field for Football (Soccer) After Anterior Cruciate Ligament Reconstruction: Guidelines
- ▶ Revision Anterior Cruciate Ligament Reconstruction
- ▶ Role of Growth Factors in Anterior Cruciate Ligament Surgery
- ▶ Single Versus Double Anterior Cruciate Ligament Reconstruction in Athletes
- ▶ Structured Rehabilitation Model with Clinical Outcomes After Anterior Cruciate Ligament Reconstruction

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