ISSN: 3029-0872

Research Article

Journal of Medical and Clinical Nursing Studies

Correlation between Clinical Tests of Anterior Cruciate Ligament (ACL) Deficiency and Degree of Anteroposterior (AP) Laxity and Rotational

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Received: January 27, 2026; **Accepted:** February 04, 2026; **Published:** February 12, 2026

ABSTRACT

Background: Accurate assessment of both anteroposterior (AP) and rotational instability is essential in the evaluation and management of anterior cruciate ligament (ACL) injuries. While clinical tests provide qualitative information, quantitative assessment of knee laxity remains limited. MRI of the knee combined with the Porto KT knee testing device (PTKD) allows objective measurement of translational and rotational instability.

Objectives: To quantitatively assess AP and rotational instability in ACL-deficient knees using MRI knee with PTKD, to evaluate the correlation between AP and rotational instability, and to study the correlation between anterior drawer test (ADT) grading and MRI-derived AP laxity measurements.

Materials and Methods: Forty patients aged 20–60 years with clinical suspicion of ACL injury underwent MRI knee with PTKD. Ten patients with isolated ACL sprain were excluded, and 30 patients (20 males, 10 females) with partial or complete ACL tears were included. MRI was performed on 1.5T and 3T systems using standard knee protocols with additional oblique sagittal imaging along the ACL. Quantitative AP and rotational laxity measurements were obtained using PTKD under controlled posterior–anterior stress with the knee positioned at 20° flexion. AP laxity was measured at the lateral tibial plateau (LP), while rotational instability was calculated from the difference in anterior tibial translation between the medial and lateral plateaus under internal rotation. Pearson correlation analysis was performed.

Results: Mean PA stress displacement at the neutral lateral plateau (9.54 ± 5.57 mm) was higher than that at the medial plateau (6.62 ± 3.72 mm). The mean AP laxity was 4.66 ± 2.83 mm. A significant moderate-to-strong positive correlation was observed between PA stress neutral lateral plateau displacement and rotational instability ($r = 0.5896$, $p < 0.001$). AP laxity also showed a significant positive correlation with rotational instability, though of lesser strength ($r = 0.392$, $p = 0.035$).

Conclusion: MRI knee with PTKD enables reliable quantitative assessment of both AP and rotational instability in ACL-deficient knees. Lateral tibial plateau displacement under PA stress is a sensitive indicator of rotational instability. MRI with PTKD serves as a valuable adjunct to clinical examination and may aid in surgical decision-making for ACL reconstruction.

Introduction

The ACL arises from the anteromedial aspect of the intercondylar area on the tibial plateau and passes upwards and backwards to attach to the posteromedial aspect of the lateral femoral condyle. The ACL tibial footprint substantially overlaps the anterior root lateral meniscus footprint [1].

The ACL measures 31-38 mm in length and 10-12 mm in width, with the anteromedial bundle (6-7 mm) slightly thicker than the posterolateral bundle (5-6 mm) 2. However, it is considered to be the weaker of the two cruciate ligaments. Like the posterior cruciate ligament, the ACL is intracapsular but extrasynovial having its own synovial membrane [2].

The ACL consists of two components named for their tibial attachment sites [2]:

- anteromedial bundle (AMB)
- attaches from the roof of the intercondylar notch to the anteromedial part of tibial attachment area of ACL.
- posterolateral bundle (PLB)
- more vertically orientated, and slightly shorter
- attaches from the wall of the intercondylar notch to posterior part of tibia attachment site of ACL

The ACL functions to prevent posterior translation of the femur on the tibia (or anterior displacement of the tibia) during flexion-extension of the knee. The anteromedial bundle is responsible

Citation: Madhuri Ghate. Correlation between Clinical Tests of Anterior Cruciate Ligament (ACL) Deficiency and Degree of Anteroposterior (AP) Laxity and Rotational. J Med Clin Nurs Stud. 2026. 4(1): 1-4. DOI: doi.org/10.61440/JMCNS.2026.v4.111

for the posterior translation of the femur at 30 degrees flexion, and the posterolateral bundle resists hyperextension and prevents posterior translation of the femur in extension [3,4]. It resists internal rotation of the tibia on the femur, crucial for twisting movements.

More detailed anatomical preparations have shown that the ACL is actually divided into two separate bundles, with separate attachments, and subsequently separate functions [5]. The antero-medial (AM) bundle is fixed to the medial part of the tibial attachment and in the antero superior part of the femoral attachment, and is located more anterior in the extended knee. The PL bundle is fixed to the lateral part of the tibial attachment and in the postero inferior part of the femoral attachment, and is located more posterior in the extended knee. Due to this anatomical design, the AM bundle is longer than the PL bundle, but the strain in the PL bundle is potentially higher. However, the respective position of the two bundles changes with the knee flexion angle: at full flexion, the femoral attachment of the PL bundle is located just anterior to the AM bundle. Due to these modifications, both bundles experience different kinematic behaviour: the AM bundle remains relatively isometric during the whole range of motion, with a tendency to tighten with flexion, while the PM bundle is tightened in full extension, slackened beyond 20◦of flexion and tightened again in full flexion [6].

ACL is one of the most commonly injured ligament in knee joint. Pathological laxity which arises because of ACL tear is also complex consisting of two components: translatory and rotatory instability. Clinical examination is the first line and important investigation to assess ACL laxity. Manual examinations (Anterior drawer test, posterior drawer test, Pivot shift test, Lachmen test etc) are influenced by surgeon's training, experience and technique reliability, providing inexact appreciations. This leads to diagnostic confusion [7]. Thus, the ideal tool to evaluate the knee should be a mean to assess both the ''anatomy'' and the ''function'' in the same examination.
MRI is the modality which gives anatomical details of the ligaments and tendons. In order to give functional information and improve the diagnostic capacity a new method was developed using the Porto-knee testing device (PKTD) with measurements performed between bony landmarks.

Purpose of this study was:
- To quantitatively assess anteroposterior instability in Knee joint using MRI Knee with PTKD
- To quantitatively assess Rotational instability in Knee joint using MRI Knee with PTKD
- To study quantitatively correlation between AP and rotational instability in ACL deficient knee using MRI knee with PTKD
- To study correlation between anterior drawer test grading and AP laxity measurement using MRI knee with PTKD

Materials and Methods
A total of 40 patients aged between 20 and 60 years old with clinical suspicion of anterior cruciate ligament (ACL) tear were evaluated by an orthopedician at the outpatient department (OPD). The anterior drawer test was conducted for clinical grading, and all patients had knee MRI using PortoKT Device (PTKD) on 3T GE Healthcare MRI scanner. 10 patients who showed ACL sprain on MRI were excluded from the study. The final sample of study candidates consisted of 30 patients (20 male and 10 female).

Clinical grading of anterior drawer test from the Orthopedic Department was graded as mild (2-5 mm), moderate (5-10 mm) and severe (>10 mm).

The MRI examination was performed on a 3T system using the below mentioned protocol, which included axial, coronal and sagittal proton density fat-saturated (PDFS) images; sagittal and coronal T1-weighted images (T1WI); and thin (2mm) oblique sagittal T2-weighted images (T2WI) being oriented along the ACL.

Measurements of anteroposterior (AP) and rotational laxity were made using the PortoKT Device (PTKD), which is an MRI-compatible arthrometric device.
In the assessment, a stress was applied posterior–anterior (PA) through the mechanism of a piston to the point of pain by the patient. (Figure 1)

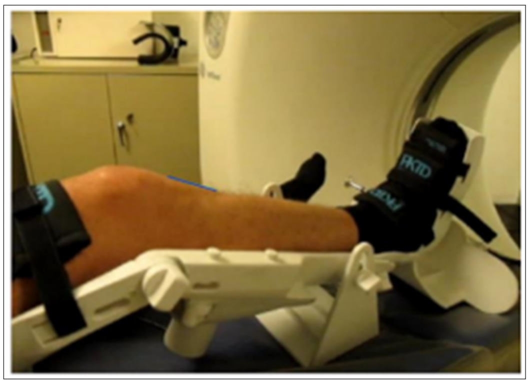


Figure 1: Pa Stress Applied by Ptkd Piston.

The leg was kept at approximately 20° flexion. The foot was maintained throughout the test commencing in a neutral position, then into 40° of internal rotation, while recording the movements noted in the tibia in response to PA stress in PD FS sequence.

Measurements of anterior tibial translation were taken by drawing a line perpendicular (tangent) to the tibial slope at posterior most point of lateral plateau of tibia and another parallel line tangent to posterior most point of lateral femoral condyle. Distance between two line is measured in mm as also suggested by Tashiro et al. This procedure is repeated with knee in flexion with foot first is neutral position with PA stress and then in internal rotation with PA stress. AP laxity is calculated by measuring difference between Anterior tibial translation in medial and lateral plateau with foot in Neutral position with PA stress.

Rotational instability is calculated by difference in Anterior tibial translation in medial and lateral plateau with foot in internal rotation position with PA stress. (Figure 2)

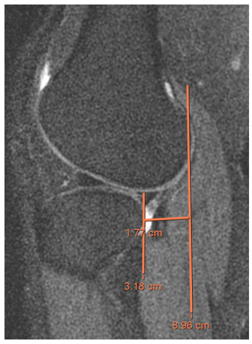
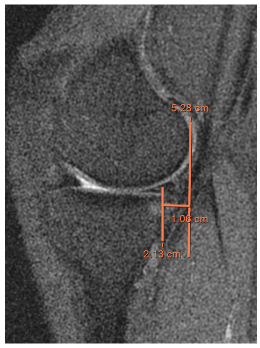
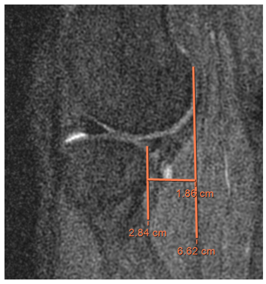
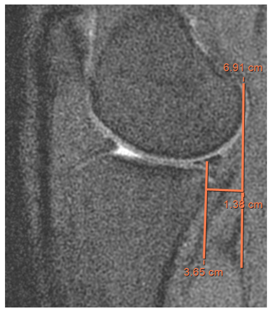
PA Stress Neutral Lateral plateau	Significant Anterior tibial translation seen --17.7 mm	
PA Stress Neutral medial plateau	Significant Anterior tibial translation seen --10.8 mm	
PA Stress Int Rotation Lateral plateau	Significant Anterior tibial translation seen --18.6 mm	
PA Stress Int Rotation Medial plateau	Significant Anterior tibial translation seen --13.8 mm	

Figure 2: Laxity Measurements with Porto Kt Are Measured as Follows

Results

The analysis of 40 patients provides a detailed look at the relationship between knee stability measurements and clinical grading. Descriptively, the PA **stress Neutral Lateral Plateau (LP)** showed a mean displacement of **9.54 mm** (+5.57), which was notably higher than the **PA stress Neutral Medial Plateau (MP)** mean of **6.62 mm** (+3.72). The average **AP Laxity** across the group was **4.66 mm** (+2.83). (Table 1) When categorized by the Clinical Grading of the Anterior Drawer Test (ADT), the cohort was distributed among 9 patients in Grade 1, 17 patients in Grade 2, and 14 patients in Grade 3. (Table 2)

Table 1: Result of Clinical Examination (Anterior Drawer Test -Adt) of Acl Deficient Knee

	Grade 1	Grade 2	Grade 3	Total
Number of Patients	9	17	14	40

Table 2: Results of MRI Knee with PTKD in ACL deficient knee

Variable	Minimum	Maximum	Mean	Standard Deviation
PA stress Neutral MP	0	15	6.62	3.72
PA stress Neutral LP	0	20.9	9.54	5.57
AP Laxity	-2.1	11.3	4.66	2.83

The correlational data revealed significant associations between these objective measurements and rotational instability. A Pearson correlation analysis showed a **moderate to strong positive relationship** (p= 0.5896, p < 0.001 between **PA stress**

Neutral Lateral Plateau and Rotational instability (LP-MP), suggesting that higher lateral displacement is a strong indicator of increased rotational instability. While **AP Laxity** also showed a statistically significant positive correlation with rotational instability (p= 0.392, p = 0.035), the relationship was weaker, indicating that lateral plateau stress may be a more sensitive metric for assessing rotational shifts than standard AP laxity alone.

Discussion

The combination of detailed anatomical assessment of the ACL on MRI with quantitative estimation of ACL laxity using PTKD provides an added diagnostic advantage to radiologists in both detection and objective grading of ACL injury. This additional quantitative information also benefits surgeons by complementing and supporting clinical examination findings. An important observation in this study was the significant association between anterior drawer test (ADT) grading and AP laxity, particularly when measurements were obtained from the lateral tibial plateau alone. This finding supports the reliability of MRI with PTKD as a quantitative tool for assessing ACL laxity.

In situations where clinical evaluation with ADT cannot be reliably performed due to pain or muscle guarding, MRI with PTKD offers a dependable alternative for estimating ACL laxity and guiding surgical decision-making. Rotational laxity can also be measured reliably and quantitatively using PTKD. The observed correlation between AP laxity and the degree of rotational instability highlights the clinical importance of assessing rotational instability, which should be considered during surgical planning. PTKD may aid in identifying patients who require higher graft constraint to achieve adequate rotational stability during ACL reconstruction.

PTKD also shows potential in the assessment of residual laxity following ACL reconstruction. Residual rotational laxity may be an important contributor to graft failure, and further studies are planned to evaluate residual translational and rotational laxity in the postoperative knee. Partial ACL tears, which are occasionally challenging to diagnose on conventional MRI alone, can be better characterized with the addition of PTKD. The application of controlled anterior and posterior stress helps straighten the ligament, allowing improved anatomical visualization while simultaneously providing quantitative information regarding translational and rotational instability associated with partial tears.

Clinical examination using the anterior drawer test in this study was performed by a single examiner, and therefore the possibility of examiner-related bias cannot be entirely excluded. However, this approach represents the standard operating protocol at our institution, and all examinations were conducted by the responsible treating surgeon, ensuring consistency across assessments.

Conclusion

Patients with greater anteroposterior (AP) instability demonstrated correspondingly higher rotational instability in ACL-deficient knees, underscoring the role of PTKD in quantitatively assessing the contribution of the ACL to rotational stability. MRI of the knee performed with PTKD can therefore serve as a valuable adjuvant quantitative modality alongside established clinical examinations such as the anterior drawer test and the pivot shift test for screening and confirming both AP and rotational laxity of the knee joint. Furthermore, MRI knee with PTKD may assist in surgical decision-making by providing objective measurements that support the indication for ACL reconstruction.

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