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UTILIZING ANTERIOR TIBIAL TRANSLATION SIGN ON MAGNETIC RESONANCE IMAGING FOR DIFFERENTIAL DIAGNOSIS OF PARTIAL AND COMPLETE ANTERIOR CRUCIATE LIGAMENT TEARS

Radio-Diagnosis

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ABSTRACT

Introduction: The anterior cruciate ligament (ACL) is a critical structure within the knee joint, playing a pivotal role in maintaining stability during various dynamic movements, including cutting, pivoting, and jumping. This study aims to evaluate the predictive value of pre-operative static ATT in knees with ACL injury. **Material and Methods:** This study constituted a retrospective descriptive research endeavour encompassing patients who underwent both MRI and knee arthroscopy at Jaipur National University, Institute for Medical Science and Research Centre from October 2023 to March 2024. Clinical data gleaned from in-patient records from the Department of Orthopaedics included demographic particulars such as age, sex, height, weight, and occupation. Patients were dichotomized into two subgroups predicated on arthroscopic findings: partial ACL tear or complete ACL tear. Subsequently, patient diagnostic images were reviewed, and anterior tibial translation distances were meticulously measured. The means of anterior tibial translation distances in each subgroup were then computed, and the unpaired t-test for the mean difference of each subgroup was executed. Furthermore, a comparative analysis was conducted between the cut-off value derived in this investigation and those reported in antecedent studies. MRI protocols entailed knee protocol scans with the 1.5-Tesla Siemens Sempra, encompassing sagittal, coronal, and axial planes with distinct pulse sequences. Anterior tibial translation distance was meticulously defined as the distance between the most posterior cortex of the tibia and femur, acquired at the midsagittal plane of the lateral femoral condyle. The measurement was conducted relative to a plane parallel to the long axis of the image. **Results:** The results suggest that the test demonstrates outstanding sensitivity, specificity, positive predictive value, and negative predictive value, all reaching 100% (with confidence intervals ranging from 84.56% to 100% for sensitivity and positive predictive value, and from 75.29% to 100% for specificity and negative predictive value). **Conclusion:** Employing a 7mm threshold on the anterior tibial translation sign for the diagnosis of complete ACL tears represents a valuable clinical tool with significant implications for patient management.

KEYWORDS

Complete tear, Partial tear, anterior cruciate ligament, MRI

INTRODUCTION

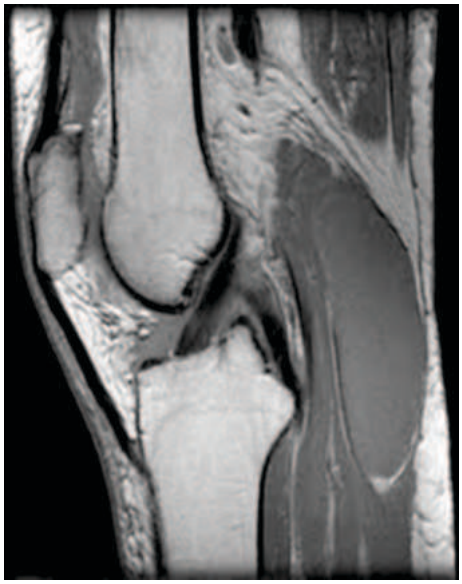
The anterior cruciate ligament (ACL) is a critical structure within the knee joint, playing a pivotal role in maintaining stability during various dynamic movements, including cutting, pivoting, and jumping[1]. Serving as one of the primary ligaments of the knee, the ACL functions to prevent anterior translation and internal rotation of the tibia over the femur. Incidence of ACL injury ranks among the most prevalent knee injuries, frequently encountered during sports activities or traumatic events. These injuries manifest across a spectrum of severity, spanning from partial tears affecting only a segment of the ligament to complete tears resulting in its total disruption. Given the implications for treatment planning and patient outcomes, accurate diagnosis of ACL injury extent is paramount.[2] Magnetic Resonance Imaging (MRI) emerges as a cornerstone non-invasive imaging modality, offering intricate visualization of soft tissue structures within the knee, inclusive of the ACL. This paper scrutinizes the anterior tibial translation sign's role on MRI in delineating between partial and complete ACL tears. The ACL, one of the cardinal knee ligaments, originates from the posteromedial aspect of the lateral femoral condyle and inserts into the anterolateral aspect of the anterior tibial spine. Functionally, it acts to curb excessive anterior translation of the tibia relative to the femur and to counteract rotational forces applied to the knee. Injury to the ACL compromises knee stability, predisposing individuals to recurrent instability episodes and further joint damage.

Mechanistically, ACL tears typically stem from non-contact deceleration or landing manoeuvres, such as sudden directional changes, hyperextension, or valgus force application to the knee.[3] Sports-related activities, including cutting and pivoting motions, also contribute significantly to ACL injury incidence. Understanding the injury mechanisms underpins the identification of high-risk activities and the implementation of preventive strategies. Diagnosis of ACL tears hinges on a multifaceted approach encompassing patient history, physical examination, and imaging studies. Patients often recount a popping sensation concomitant with immediate swelling and knee joint instability following injury.[4] While physical examination manoeuvres such as the Lachman test and anterior drawer test are instrumental in assessing ACL integrity, their utility may be limited in cases of partial ACL tears. Radiological imaging, notably MRI, plays a pivotal role in confirming diagnosis and gauging the extent of ACL injury.[5]

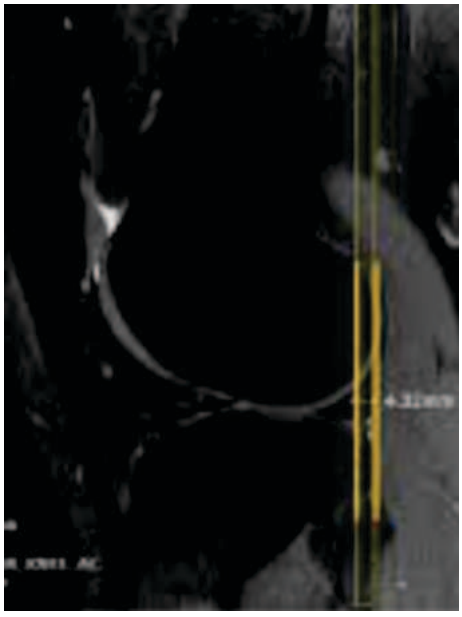
MRI facilitates detailed visualization of knee soft tissue structures, enabling accurate assessment of ACL integrity and the identification of associated injuries, including meniscal tears, bone bruising, and ligamentous avulsions.[6] MRI findings, encompassing fluid signal intensity within the ligament substance and ligament fibre discontinuity, contribute to diagnosis confirmation and injury extent determination. Early and precise ACL tear diagnosis assumes significance, given the potential for knee instability and subsequent osteoarthritis, potentially necessitating high osteotomy or total knee replacement in the future. MRI emerges as a reliable diagnostic tool, aiding in ACL tear diagnosis and categorization into partial or complete tears. Diagnosis confirmation on MRI hinges on sagittal images illustrating disrupted ACLs and direct signs like non-visualization, wavy contour, discontinuity, high signal intensity on T2-weighted images, and thickening of the ACL. Additionally, associated ligament injuries may accompany ACL tears.[7]

The anterior tibial translation (ATT) sign characterizes an abnormal tibial-femoral relationship post-ACL injury, particularly on MRI, during knee flexion.[8] Partial ACL tears may exhibit abnormal anterior translation on MRI, signifying ACL laxity, while complete tears typically manifest as marked anterior tibial translation, indicative of significant ligament fibre disruption. Studies employing MRI have elucidated the static tibiofemoral relationship across various ACL injury states, correlating static ATT results with ACL injury types.[9] Notably, patients with failed ACL reconstruction demonstrate greater anterior tibial subluxation compared to those with acutely disrupted

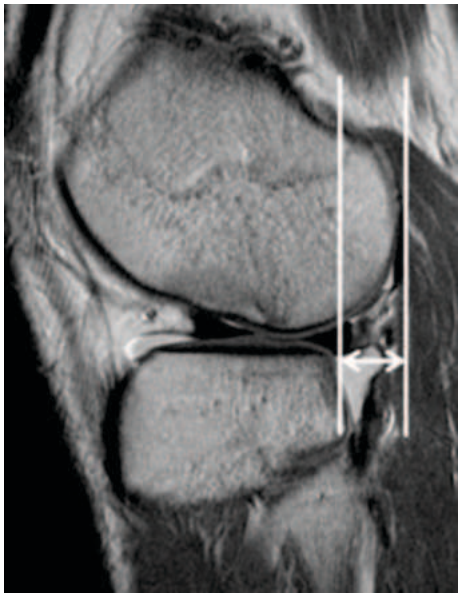
ACLs. Furthermore, primary ACL tear cases exhibit increased ATT concomitant with meniscal tears, collateral ligament tears, and chondral injuries, alongside associated knee joint effusions, mucoid degeneration, and bone contusions. Despite MRI's accuracy, false-positive and false-negative results may arise. To enhance diagnostic accuracy, indirect signs of ACL tear, such as the anterior tibial translation sign, should complement routine direct signs.[8,10] Although indirect signs confer high specificity, their sensitivity remains relatively low. In this study, we concentrate on the anterior tibial translation sign due to its straightforward measurement and correlation with ACL function. A positive sign denotes an anterior tibial translation distance exceeding 7 mm in complete tear cases, with 5-7 mm representing lower and upper limits in partial tear instances. Furthermore, a meta-analysis incorporating data from nine studies unveiled a significant menstrual cycle-related effect on anterior knee laxity among women, with laxity peaking during ovulatory or post-ovulatory phases due to hormonal variations.[8] Women also exhibited higher mean anterior knee translation values than age-matched males. Moreover, anterior knee laxity decreased with increasing BMI in select study subgroups. This study aims to evaluate the predictive value of pre-operative static ATT in knees with ACL injury. We hypothesize that greater static ATT values will correlate with complete ACL tears compared to lower ATT values, as corroborated by imaging and operative confirmation.



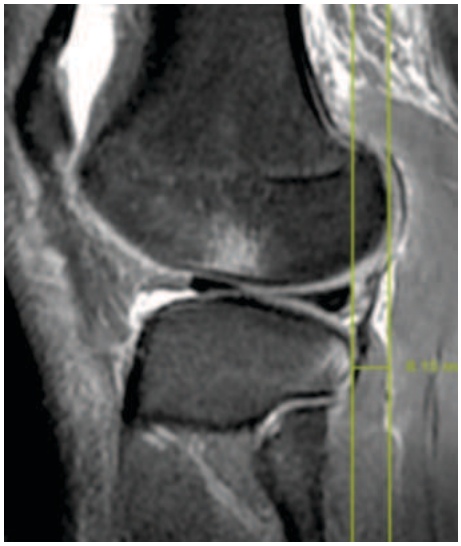
Normal Anterior Cruciate Ligament on T2W Image



Measurement of Anterior Tibial Translation Sign in Normal Anterior Cruciate Ligament on MRI in Sagittal T2W Image



Measurement of Anterior Tibial Translation in Partial Anterior Cruciate Ligament Tear on MRI in Sagittal T2W Image



Measurement of Anterior Tibial Translation in Complete Anterior Cruciate Ligament Tear on MRI in Sagittal T2W Image

MATERIALS AND METHODS

This study constituted a retrospective descriptive research endeavour encompassing patients who underwent both MRI and knee arthroscopy at Jaipur National University, Institute for Medical Science and Research Centre from October 2023 to March 2024. Clinical data gleaned from in-patient records from the Department of Orthopaedics included demographic particulars such as age, sex, height, weight, and occupation. Patients were dichotomized into two subgroups predicated on arthroscopic findings: partial ACL tear or complete ACL tear. Subsequently, patient diagnostic images were reviewed, and anterior tibial translation distances meticulously measured. The means of anterior tibial translation distances in each subgroup were then computed, and the unpaired t-test for mean difference of each subgroup was executed. Furthermore, a comparative analysis was conducted between the cut-off value derived in this investigation and those reported in antecedent studies. MRI protocols entailed knee protocol scans with the 1.5-Tesla Siemens Sempra, encompassing sagittal, coronal, and axial planes with distinct pulse sequences. Anterior tibial translation distance was meticulously defined as the distance between the most posterior cortex of the tibia and femur, acquired at the midsagittal plane of the lateral femoral condyle. The measurement was conducted relative to a plane parallel to the long axis of the image. Assessing the anterior tibial translation sign on MRI mandates a comprehensive approach, involving meticulous observation and measurement to interpret the degree of

anterior translation accurately. A structured guide delineates the methodology for measuring anterior tibial translation sign on MRI, encompassing image selection, identification of reference points, assessment of anterior translation, comparison between knees, quantification of translation, interpretation of findings, and clinical correlation. It is imperative to underscore that proficiency in musculoskeletal imaging interpretation and knee anatomy familiarity are indispensable requisites for accurate measurement of the anterior tibial translation sign on MRI.

Statistical Analysis

Descriptive statistics were reported as mean (SD) for continuous variables, frequencies (percentage) for categorical variables. Chi square was used to find the association between categorical variables. Diagnostic accuracy was measured and ROC curve was illustrated. Data were statistically evaluated with IBM SPSS Statistics for Windows, Version 26.0., IBM Corp., Chicago, IL.

RESULTS

Table 1: Distribution of Demography Details Among the Study Participants (N=35)

S. No	Variable	Complete tear (n=22)	Partial Tear (n=13)	X2 (df), p
1	Age	31.3611.33	25.4611.76	0.16
2	Gender			
	Female	5 (22.7)	2 (5.4)	0.27 (1)
	Male	17 (77.3)	11 (84.6)	0.60
3	Meniscus Injury			
	Anterior horn of lateral meniscus	0 (0)	1 (7.7)	8.19 (6) 0.23
	Anterior horn of medial meniscus	1 (4.5)	0 (0)	
	Medial and Lateral meniscus	1 (4.5)	0 (0)	
	Posterior horn of lateral meniscus	5 (22.7)	2 (15.4)	
	Posterior horn of medial meniscus	7 (31.8)	6 (46.2)	
	Radial tear	0 (0)	2 (15.4)	
4	Collateral Injury	4 (18.2)	2 (15.4)	0.79 (3)
	Lateral Collateral	1 (4.5)	0 (0)	0.85
	Medial and Lateral Collateral	1 (4.5)	1 (7.7)	
	Medial Collateral	16 (72.7)	10 (76.9)	
	Absent			

Regarding age, the mean age of patients with complete tears (31.36 ± 11.33 years) appears slightly higher than those with partial tears (25.46 ± 11.76 years), although this difference was not statistically significant ($X2 = 0.16$, $df = 1$, $p = 0.69$). Gender distribution shows a predominance of males in both groups, with 77.3% in the complete tear group and 84.6% in the partial tear group, indicating no significant association between gender and tear type ($X2 = 0.27$, $df = 1$, $p = 0.60$). In terms of meniscus injury location, the majority of complete tears occurred at the posterior horn of both the lateral (22.7%) and medial (31.8%) meniscus, while partial tears were more evenly distributed among various locations. A chi-square test revealed a significant association between tear type and meniscus injury location ($X2 = 8.19$, $df = 6$, $p = 0.23$), suggesting that tear type may influence the location of meniscal injury.Regarding collateral ligament injuries, the majority of cases in both groups had no collateral injury. However, there was a higher proportion of collateral injuries among patients with complete tears (lateral collateral: 18.2%, medial and lateral collateral: 4.5%, medial collateral: 4.5%) compared to those with partial tears (lateral collateral: 15.4%, medial collateral: 7.7%), although this difference was not statistically significant ($X2 = 0.79$, $df = 3$, $p = 0.85$). Overall, these findings suggest that while age and gender may not significantly influence the type of meniscal tear, the location of the tear appears to be associated with tear type, with complete tears more commonly occurring at specific meniscal locations. Additionally, collateral ligament injuries do not seem to differ significantly between complete and partial meniscal tears (Table 1).

Table 2: Diagnostic Accuracy Of Anterior Tibial Translation Sign And Type Of Tear Among The Study Participants (N=35)

S. No	ATT	Complete tear (n=22)	Partial Tear (n=13)
1	>7mm	22	0
2	<7mm	0	13

The results suggest that the test demonstrates outstanding sensitivity, specificity, positive predictive value, and negative predictive value, all reaching 100% (with confidence intervals ranging from 84.56% to 100% for sensitivity and positive predictive value, and from 75.29% to 100% for specificity and negative predictive value). These findings affirm the test's status as a highly dependable tool for diagnosing the condition with confidence and precision (Table 2).

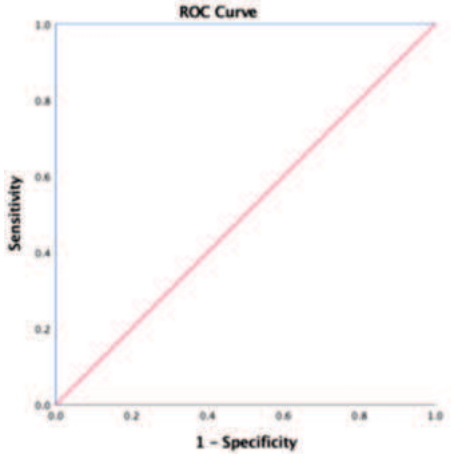
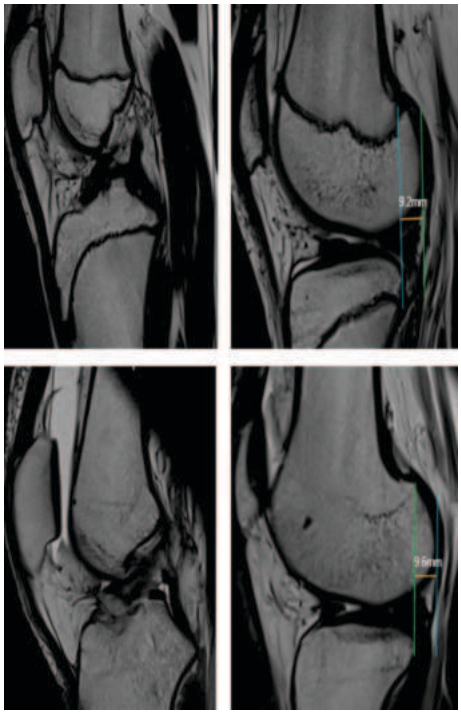


Figure 1: ROC Curve Between Anterior Tibial Translation Sign And Type Of Tear (n=35)

Table 3: Area Under The Curve (N=35)

Area Under the Curve				
Test Result Variable(s)				
Area	Std. Errora	Asymptotic Sig.b	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
1.000	.000	.000	1.000	1.000
Under the nonparametric assumptiona				
Null hypothesis: true area = 0.5b				

The area under the curve (AUC) analysis indicates a perfect classification performance of the test result variable(s), with an AUC value of 1.000 and a standard error of 0.000. The asymptotic significance level is 0.000, indicating a highly significant result. Additionally, the 95% confidence interval for the AUC ranges from 1.000 to 1.000, further confirming the excellent discriminatory ability of the test (Table 3, Figure 1).



Complete Anterior Cruciate Ligament Tear seen in T2W Sagittal

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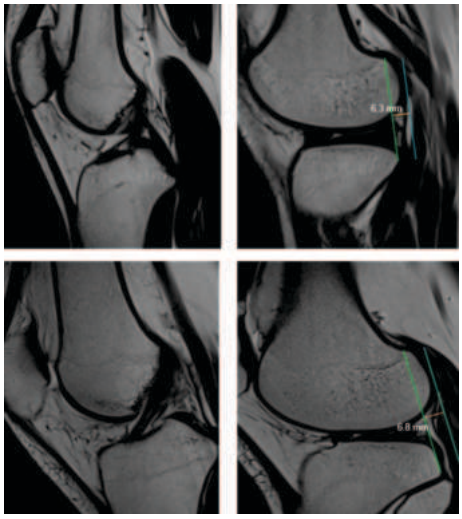
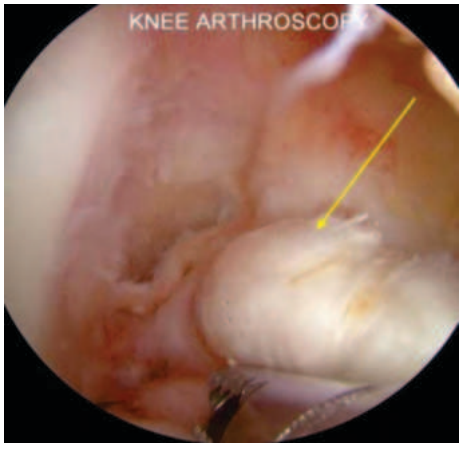
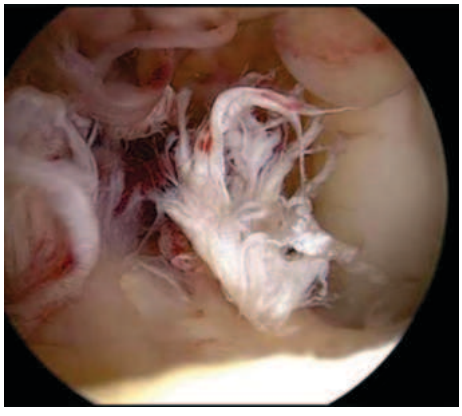


Partial Anterior Cruciate Ligament Tear seen in T2W Sagittal



Partial ACL Tear on Knee Arthroscopy



Complete ACL Tear on Knee Arthroscopy

DISCUSSION

The use of a 7mm cut-off on the anterior tibial translation sign for diagnosing complete ACL tears is a subject of extensive discussion and deliberation within the orthopaedic and radiology spheres. This threshold signifies the point beyond which anterior translation of the tibia in relation to the femur is deemed abnormal, indicative of a complete ACL rupture. Below, we delve into the rationale behind opting for this specific cut-off value, its clinical ramifications, and the associated limitations. The selection of a 7mm cut-off for anterior tibial translation is underpinned by a confluence of empirical data, biomechanical investigations, and clinical insights. Studies have underscored that ACL tears engender heightened anterior translation of the tibia during dynamic knee manoeuvres like the Lachman or anterior drawer tests. By quantifying the extent of anterior translation on imaging modalities like MRI, clinicians can objectively gauge the severity of ACL injury and navigate treatment strategies accordingly. The 7mm threshold emanates from research correlating this value with elevated sensitivity and specificity in diagnosing complete ACL tears.

Employing a 7mm cut-off for anterior tibial translation carries significant clinical implications for ACL injury management. Surpassing this threshold indicates a complete ACL rupture, signalling the necessity for surgical intervention to restore knee stability and forestall further joint deterioration. Individuals with complete ACL tears may manifest instability symptoms, such as knee buckling or giving way during daily activities or sports engagements. Consequently, surgical ACL reconstruction is often advocated to reinstate knee function and mitigate long-term complications like meniscal tears or osteoarthritis.[11] Notwithstanding its widespread adoption, the 7mm cut-off for anterior tibial translation harbours several limitations and considerations necessitating deliberation. Firstly, its accuracy may fluctuate contingent on factors such as patient anatomy, imaging methodology, and the presence of concurrent injuries. Moreover, quantifying anterior tibial translation on MRI demands expertise and may be susceptible to interobserver variability.

In our study, we also found that complete tears were are more prevalent at specific locations, particularly the posterior horn of both the lateral and medial meniscus. Conversely, partial tears exhibited a more evenly distributed distribution across various meniscal locations. The significant association between tear type and meniscus injury location suggests that tear type may indeed influence the specific location of meniscal injury. This observation underscores the importance of considering tear characteristics in the assessment and management of meniscal injuries. Furthermore, the analysis of collateral ligament injuries provided additional insights into the injury profile of patients with meniscal tears. While the majority of cases in both tear groups did not present with collateral injuries, there was a slightly higher proportion of collateral injuries among patients with complete tears compared to those with partial tears. Although this difference did not achieve statistical significance, it hints at potential associations between tear type and collateral ligament injuries. However, further investigation with larger sample sizes may be warranted to elucidate this relationship conclusively.

Chan WP et al. demonstrated that anterior tibial subluxation exceeding 5 mm can serve as an additional indicator in diagnosing a complete tear of the ACL.[11] Similarly, in a separate investigation conducted by Vahey TN et al., it was found that a subluxation of 5 mm or greater exhibited a sensitivity of 58% and a specificity of 93%.[12] Furthermore, Vahey TN et al. reported that an anterior tibial translation of 7 mm or more was associated with 100% specificity for complete ACL tears.[12] Oldrini G et al. indicated that MRI yielded a sensitivity of 91.1% and a specificity of 82.9% in detecting abnormal ACLs.[13] Additionally, Numkarunarunrote N et al. identified that in distinguishing an intact ACL from partial or complete ACL tears, optimal accuracy was achieved at a cut-off distance of 3.5 mm, accompanied by corresponding levels of sensitivity and specificity of 83.1% and 74.1%, respectively.[14]

Future research endeavours should pivot towards refining diagnostic parameters to enhance the precision and reliability of ACL tear diagnosis. Leveraging advanced imaging modalities like 3D MRI reconstruction or dynamic imaging techniques holds promise in deepening our comprehension of knee biomechanics and facilitating more meticulous assessments of ACL integrity.

CONCLUSION

Employing Anterior Tibial Translation Sign as a tool to diagnose and differentiate between partial and complete Anterior Cruciate Ligament Tears when there is a diagnostic dilemma radiologically can be a valuable tool with significant implications for patient management. A cut-off of 5-7mm is indicative of partial ACL tear while a measurement of 7mm or more can diagnose complete ACL tears. However, its application necessitates a cautious approach, considering various factors such as patient-specific anatomy, imaging modalities utilized, and clinical presentation. Looking ahead, endeavours aimed at enhancing diagnostic precision should prioritize advancements in imaging technology, refinement of measurement methodologies, and the execution of prospective studies to validate threshold values and their corresponding clinical outcomes. Moreover, interdisciplinary teamwork involving orthopaedic surgeons, radiologists, biomechanical engineers, and researchers will be pivotal in addressing the multifaceted aspects of ACL injuries and optimizing patient

treatment strategies. By continually enhancing our understanding of ACL biomechanics and diagnostic approaches, we can elevate patient outcomes, mitigate the risk of long-term complications, resume daily activities and elevate the overall standard of care for individuals grappling with ACL tears.

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