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Posterior tibial slope measurement in patients with and without anterior cruciate ligament tear on MRI

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Abstract
Background: Anterior Cruciate Ligament (ACL) is most vulnerable to injury post trauma amongst all the ligaments of knee joint. Anatomy of the proximal tibia has come under focus as one of the possible risk factors for ACL injury.
Aims
1. To determine whether greater Posterior Tibial Slope (PTS) measured on Magnetic Resonance Imaging (MRI) is a risk factor for ACL tear.
2. To observe the PTS – ACL relationship in both genders separately.
3. To observe PTS-ACL relationship after contact and non-contact injury.
4. To compare PTS measurements on lateral radiographs with MRI.

Study Design: Observational cross-sectional study.
Materials and Methods: MRI knee of 160 patients with knee trauma was done. The PTS was measured on sagittal MRI and lateral radiograph. The data was analyzed for association of increased PTS and ACL tear. Final results on MRI were compared with lateral radiographs.
Statistical analysis used: Independent t- test.
Results: The mean PTS on MRI of those with ACL injury was 14.3° compared with 9.9° for those with no injury (P = .001). The mean PTS on X-Ray of those with ACL injury was 14.4º compared with 8.6º for those with no injury (P = .001). Majority of patients with ACL tear has PTS more than 12º.
Conclusion: Greater PTS angle is a risk factor for ACL injury. ACL injury is influenced by the PTS than the nature of injury or gender. Both MRI and X-Ray proved useful to evaluate the PTS and identify the at-risk individuals for ACL tear.

Keywords: Anterior cruciate ligament (ACL), posterior tibial slope (PTS), magnetic resonance imaging (MRI), contact injury, non-contact injury, observational cross-sectional study, lateral radiograph

Introduction
Anterior Cruciate ligament (ACL) provides 90% stability to the knee joint and also helps in soft and easy movement of the knee. The ACL is most vulnerable and common to get injured during sports and road traffic accidents [1]. ACL injury can have lasting effects on the stability and mobility of the joint and inturn the quality of life.
Identifying the at- risk subjects can be of great help in the Sports fraternity and in jobs pertaining to Army, manual labour etc. Recently one of the risk factors that was highlighted was the anatomy of the knee joint which included Posterior Tibial Slope (PTS) as potential factor for ACL tear [2]. In athletes with increased PTS, the risk of an anterior tibial translation may be reduced by planning the physiotherapy and muscle strengthening programme [3, 4].
With the given background, we keep the aims and objectives of the study as follows:
1. To determine whether greater Posterior Tibial Slope (PTS) measured on Magnetic Resonance Imaging (MRI) is a risk factor for ACL tear.
2. To study the influence of gender and nature of injury on ACL tear.
3. To compare PTS measurements on lateral radiographs with MRI.

Methods
160 patients with history of knee trauma were studied with MRI knee and lateral knee radiographs.

Selection of patients

Inclusion criteria

1. All the patients with knee trauma.
2. Patients in age group of 16-50 years.

Exclusion criteria

1. Patients having a history of metallic implants.
2. Claustrophobic patients.
3. Patients with previous knee surgery.
4. Old or new tibial plateau fractures.
5. Pathologies like osteoarthritis which altered the morphology of tibial plateau.

Equipment used: A standard 1.5 T MRI machine. Standard 300 mA X-Ray System was used for lateral knee Radiograph.

Measurement of Posterior Tibial Slope: A standard software named **"IC Measure – 2.0.0.245"** was used which is a software for manual on-screen image measurement and image acquisition. The posterior tibial slope was measured on the mid-sagittal T2W/T1W/PD images where ACL anatomy is well seen and is parallel to Blumensaat's line. To measure the PTS angle:

1. First line was drawn tangential to posterior tibial cortex.
2. Second line was drawn perpendicular to the first line.
3. Third line was drawn tangential to the surface of the tibial plateau.
4. The angle between the third and the second lines was considered as posterior tibial slope [5].

The diagrammatic representation is as shown in the figure1a and 1b below.

The tibial slope of all 160 patients were calculated using this method. The data was charted under various headings like details of the patient, Age, Nature of injury (contact/ noncontact) and status of the ACL on the scan (intact / tear). Using the data, comparison between various parameters of the study was done as per the aims and objectives decided and results were made using the independent t test.

Results

Table 1: Mean PTS angle on MRI.

ACL status	Number (Total: 160)	Mean PTS angle (MRI)	Std deviation	Mean difference	p-value
Intact	72	9.97	3.58	4.40	0.001*
Tear	88	14.37	4.39		

*Statistically Significant Value

Table 2: PTS measurements and ACL status on MRI.

PTS (degree)	Intact ACL (No. of patients)	ACL tear (No. of patients)
2 – 3.9	1	0
4 – 5.9	9	1
6 – 7.9	11	8
8 – 9.9	11	6
10 – 11.9	29	8
12 – 13.9	7	16
14– 15.9	0	19
16 – 17.9	2	14
18 – 19.9	1	8
More than 20	1	8
Total (160)	72	88

Table 3: Nature of injury and ACL status

ACL Status	Total	Non-Contact Injury			Contact Injury		
		Number	PTS	SD	Number	PTS	SD
Intact	72	50	9.8288	3.5651	22	10.3141	3.6750
Tear	88	38	14.9063	3.0503	50	13.9762	5.1921
Total	160	88	Mean difference: 5.077. p – 0.001*		72	Mean difference: 3.662. p – 0.004*	

*Statistically Significant Value

Table 4: Gender and ACL status

ACL Status	Total	Male			Female		
		Number	PTS	SD	Number	PTS	SD
Intact	72	45	10.4378	3.4546	27	9.2093	3.7179
Tear	88	61	15.3170	4.3155	27	12.2559	3.8783
Total	160	106	Mean difference: 4.879. p – 0.001*		54	Mean difference: 3.046 p – 0.005*	

*Statistically Significant Value

Table 5: Mean PTS on MRI, X-Ray and ACL status.

ACL Status	PTS Angle measurement				Mean Difference	p-value (Independent T-Test)
	MRI		X-ray			
	Mean	Std D	Mean	Std D		
Tear	14.3778	4.39947	14.4290	4.56970	0.0511	0.940
Intact	9.9771	3.58009	8.6754	2.89847	1.301	0.018*

*Statistically Significant Value

Discussion

ACL is main stabilizer of knee joint. ACL is the most common to get injured after knee trauma. ACL injury affects the stability of knee joint which restricts the activity and productivity of patient ultimately affecting the quality of life. ACL injury is very common with Road traffic accidents and in sports in India. Per year, almost 50,000 hospital admissions occur related to ACL injury. There is a necessity to determine risk factors and causes of injury and to develop preventive measures in order to reduce the incidence of injuries.

Recently, anatomic variations are considered as a risk factor

for a primary ACL injury, especially the PTS [6, 7]. Many studies found a correlation between the PTS and ACL. Two variables: gender and nature of injury were considered in this study and the results were derived by data collected on two modalities -MRI and X-Ray.

Total 160 patients were studied: 106 males (66.3%) and 54 females (33.8%). Of the total subjects 72 (45%) had intact ACL and 88 (55%) had ACL tear (table 1)

In current study, the mean PTS angle in male patients with intact ACL is 10.43º and with ACL tear is 15.31º. The mean PTS angle in female patients with intact ACL is 9.20º and with ACL tear is 12.25º. Differences were statistically significant in both genders. Therefore, steep posterior tibial slope is considered a risk factor for ACL tear in both genders. Overall, the mean PTS in patients with ACL tear is 14.37 ± 4.39º. The mean PTS in patients with intact ACL is 9.97 ± 3.58^0. Thus, patients with PTS less than 9.97º are less prone to ACL injury and patients with PTS > 14.37º are more prone to ACL injury. Only 4 out of 72 patients (5.55%) had an abnormal PTS angle of >14º but the ACL was intact (Table 2). 3 of these patients had non-contact twist injury and 1 patient had mild contact injury. 15 out of 88 patients (17%) had a normal PTS angle of <9.9^0 (Table 2).14 of these patients had major Road traffic accidents. 1 patient was a female soccer player having sports injury.

In present study ACL tear was found to be more common in patients with contact injury (56.8%) than in non-contact injury (43.2%) (table 3). In patients with contact injury, mean PTS with ACL tear was 13.97^0 and with intact ACL was 10.31º. In patients with non-contact injury, mean PTS with ACL tear was 14.90^0 and with intact ACL was 9.82^0. These mean values are similar as those assessed in all patients without considering nature of injury (table 1). ACL status (injury) is influenced by the PTS angle than the nature of injury.

In this study, PTS of every patient was measured on MRI as well as on X-Ray. Patients with ACL tear had a mean PTS of 14.37^0 on MRI and 14.42^0 on X-Ray. Subjects with intact ACL had a mean PTS of 9.97^0 on MRI and 8.67^0 on X-Ray. Thus, both the modalities give almost the similar results – Greater the PTS slope, more is the risk of ACL injury. Proper positioning is mandatory while taking radiographs. Subtle rotation may cause inaccurate measurements. This pitfall is taken care of in MRI.

Moreover, Knee joint anatomy including the PTS and its measurement, the ligaments and joint surfaces is better seen on MRI. Also, there is no radiation exposure [8].

There were more numbers of males in the study as compared to the females and also more number of younger patients. This can be attributed to increased activity and mobility amongst the young male population. The result of the study is similar to previous studies but the cut-off values in all studies are different. This may be due to variable epidemiological and racial factors [9]. Method of measuring angles by MRI or radiographs should be unique and standard. A large sample size and use of two different modalities increased the accuracy of the study. Factors like nature of injury and gender were considered separately and the results were significant in all groups.

Limitations of the study: The other extrinsic risk factors for ACL tear which included playing/ walking surface, shoe type and other anatomic variables like intercondylar notch width, increased body mass index, landing kinematics etc. were not considered in this study which might have resulted in the above conflicting results [3, 10]. PTS cannot be assumed as an isolated risk factor for ACL tear.

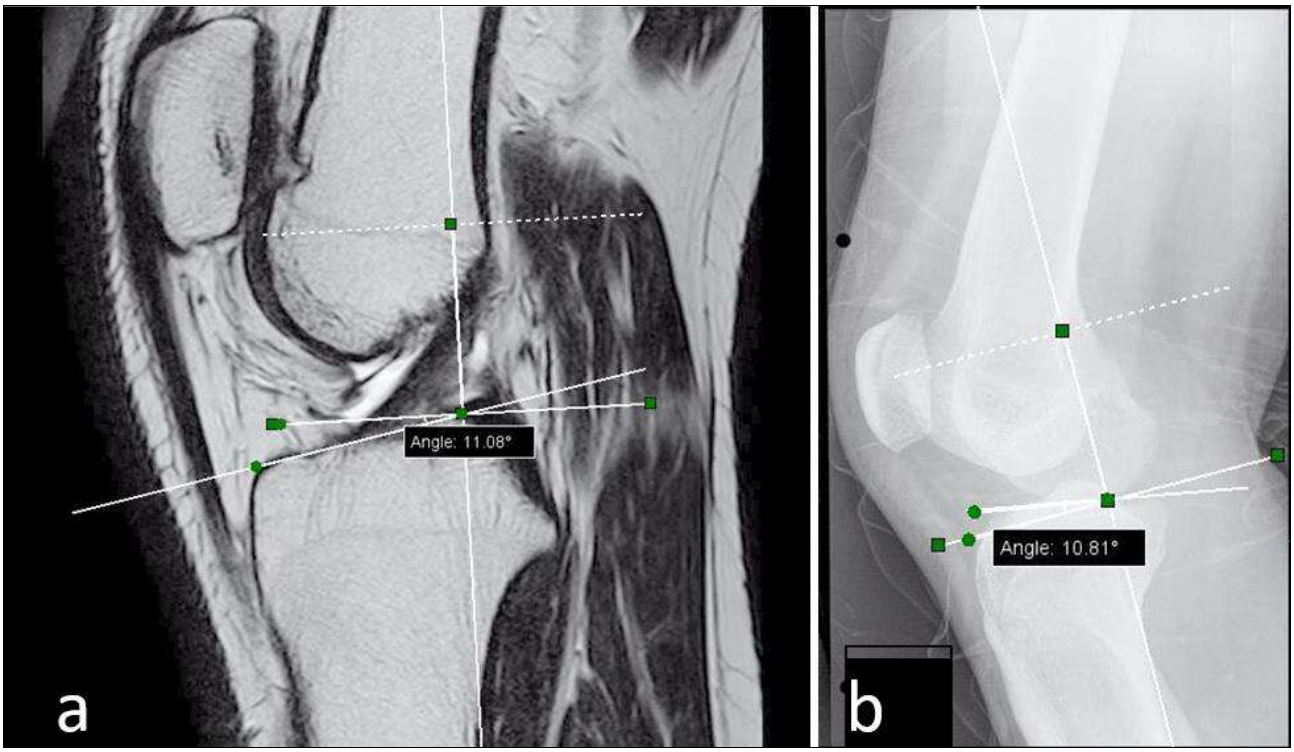

Fig 1a: Intact ACL in contact injury- Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 11.08o.

Fig 1b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 10.81o

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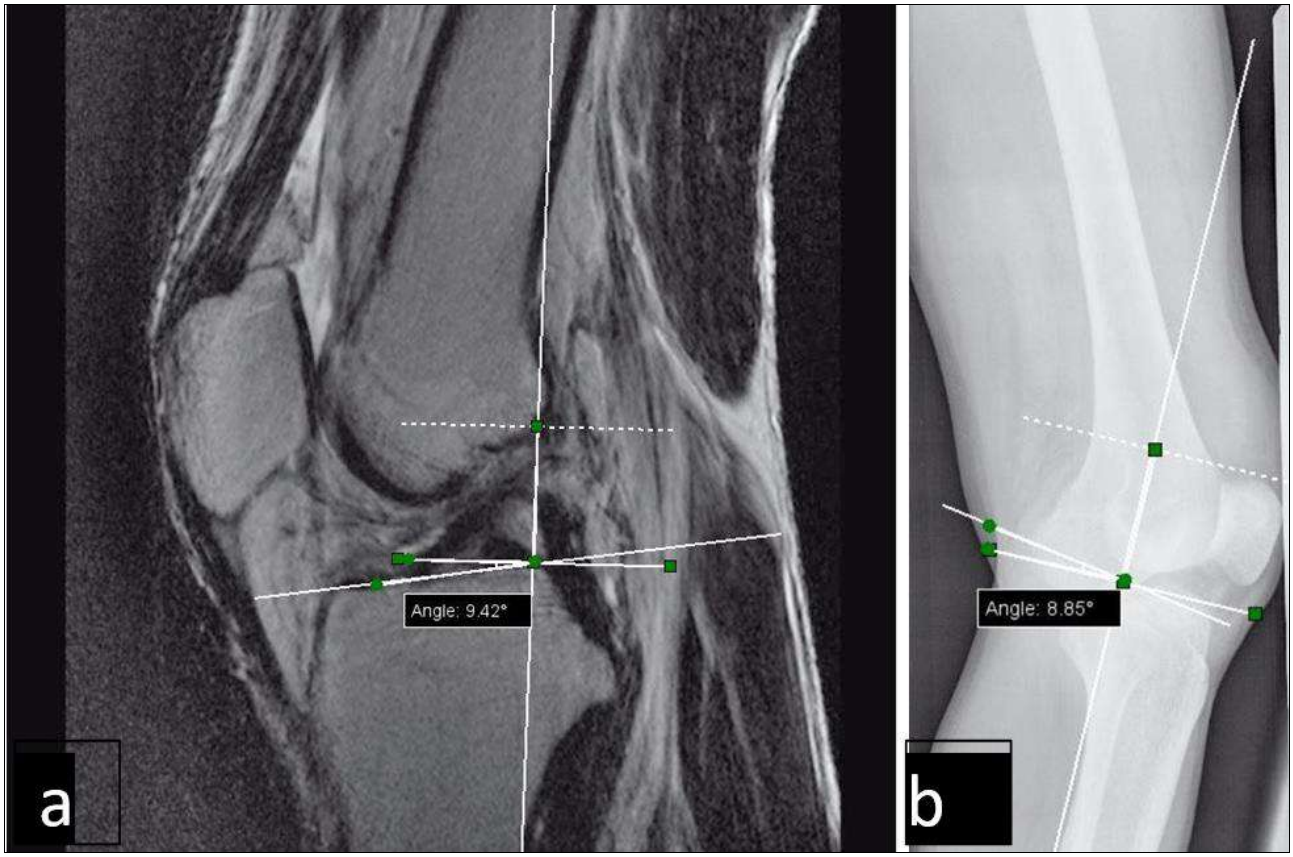

Fig 2a: Intact ACL in non-contact injury: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 9.42o.

Fig 2b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 8.85o.

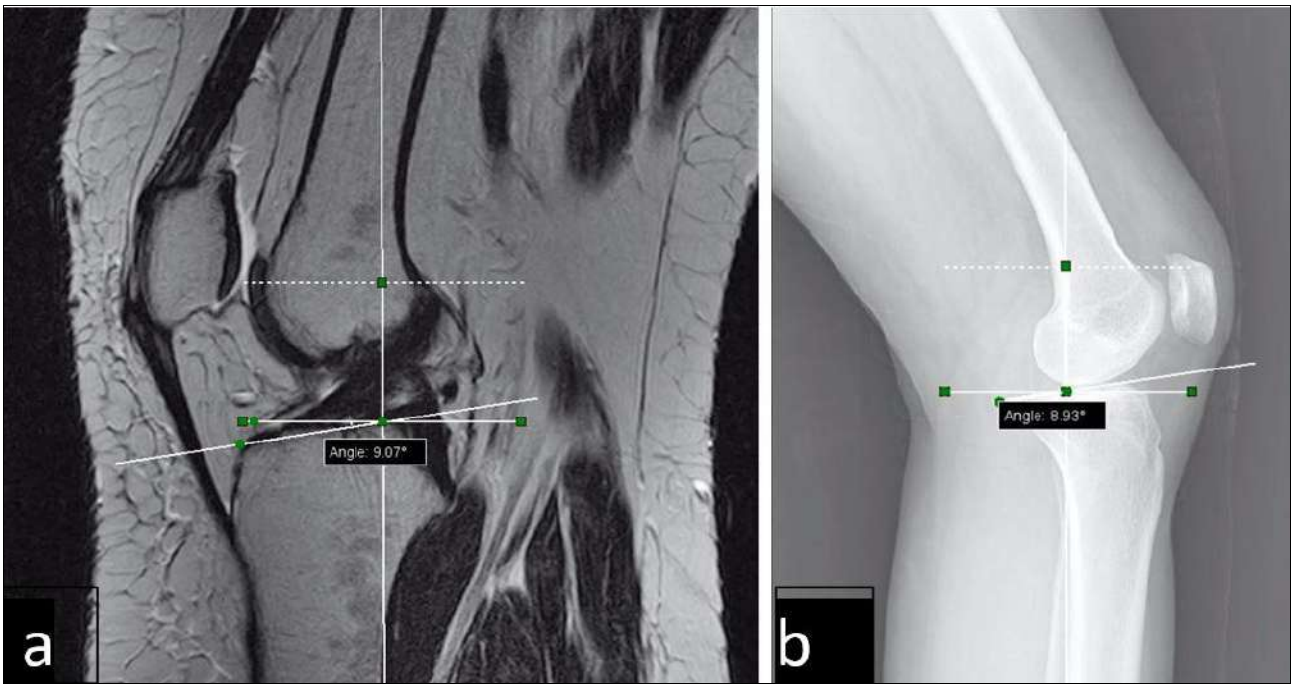

Fig 3a: Intact ACL in non-contact injury – Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 9.07o.

Fig 3b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 8.93o.

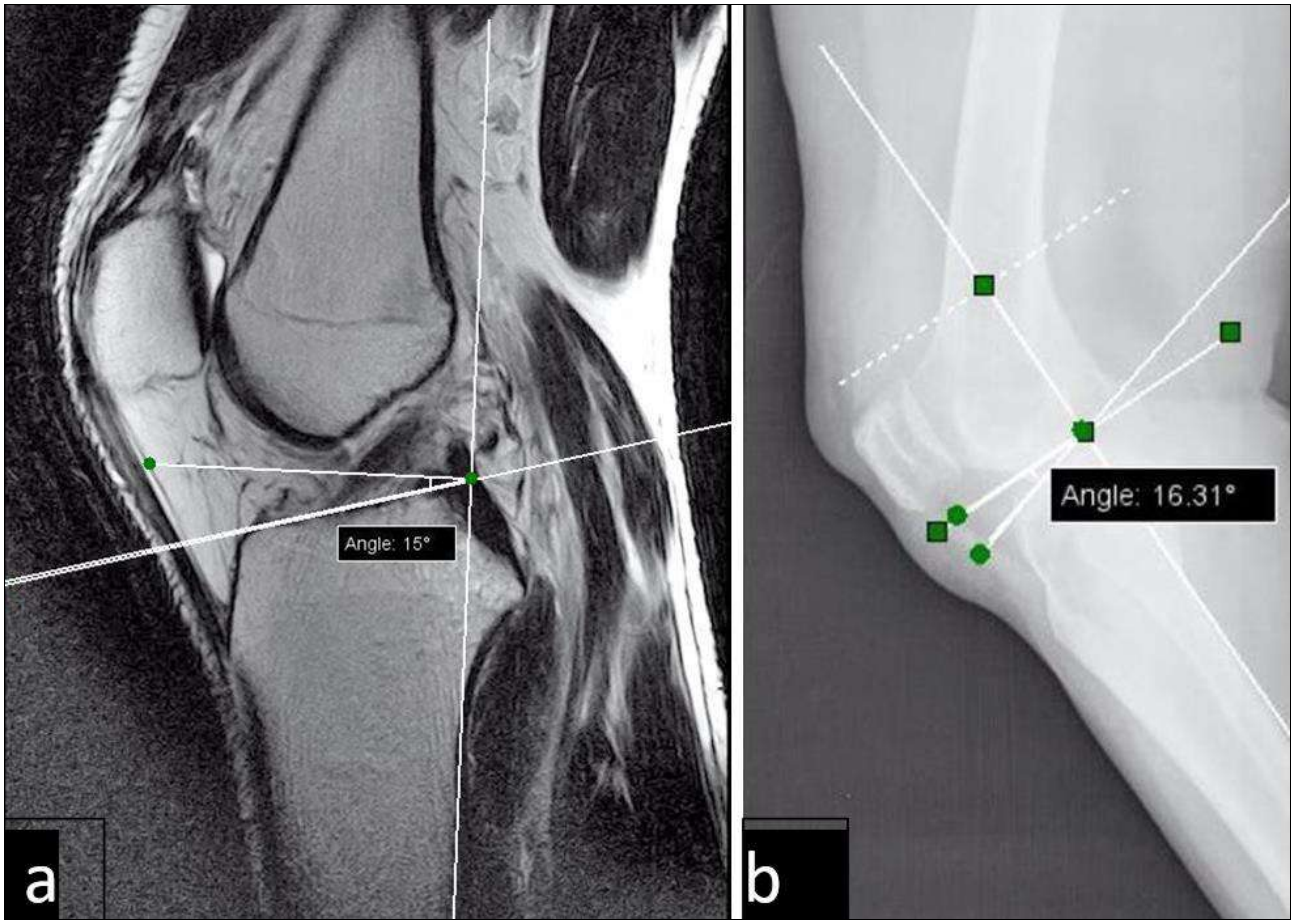

Fig 4a: Partial ACL tear in contact injury- Tibial slope angle measured on midsagittal section on MRI. The angle in this measure 15o.

Fig 4b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 16.31o.

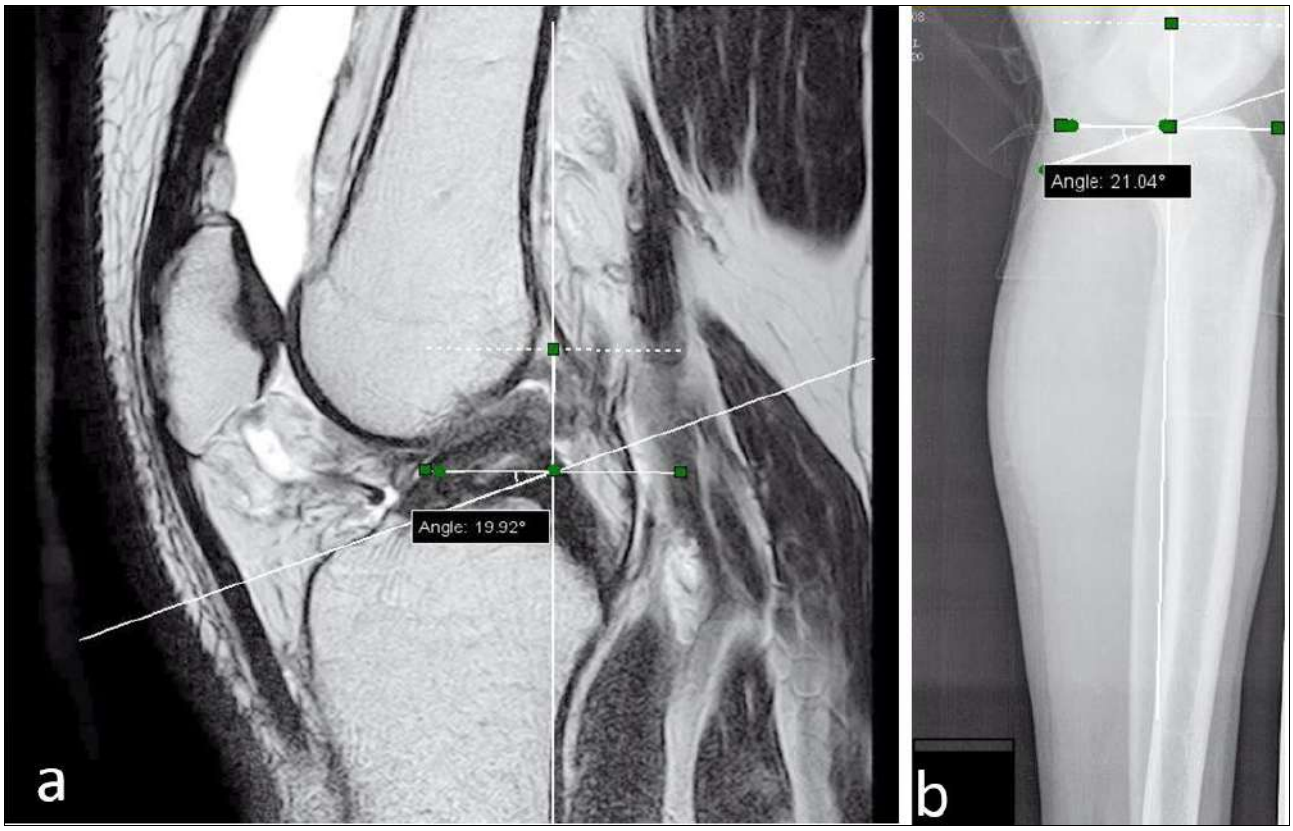

Fig 5a: Partial ACL tear in non-contact injury: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 19.92o.

Fig 5b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 21.04o.

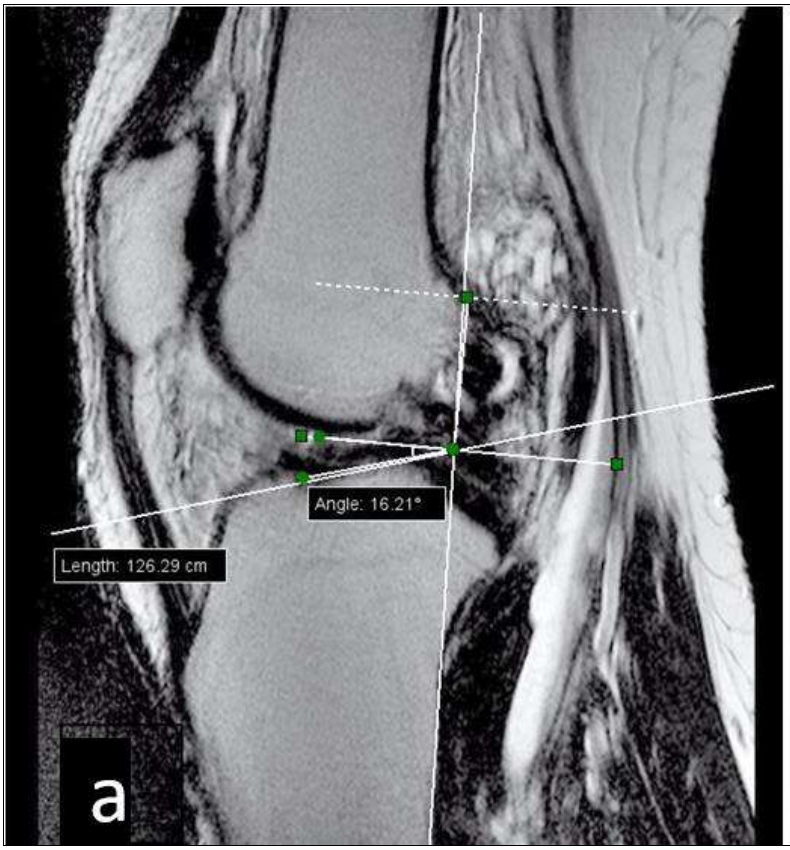

Fig 6a: Complete ACL tear in contact injury: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 16.21o.

Fig 6b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 16.27o.

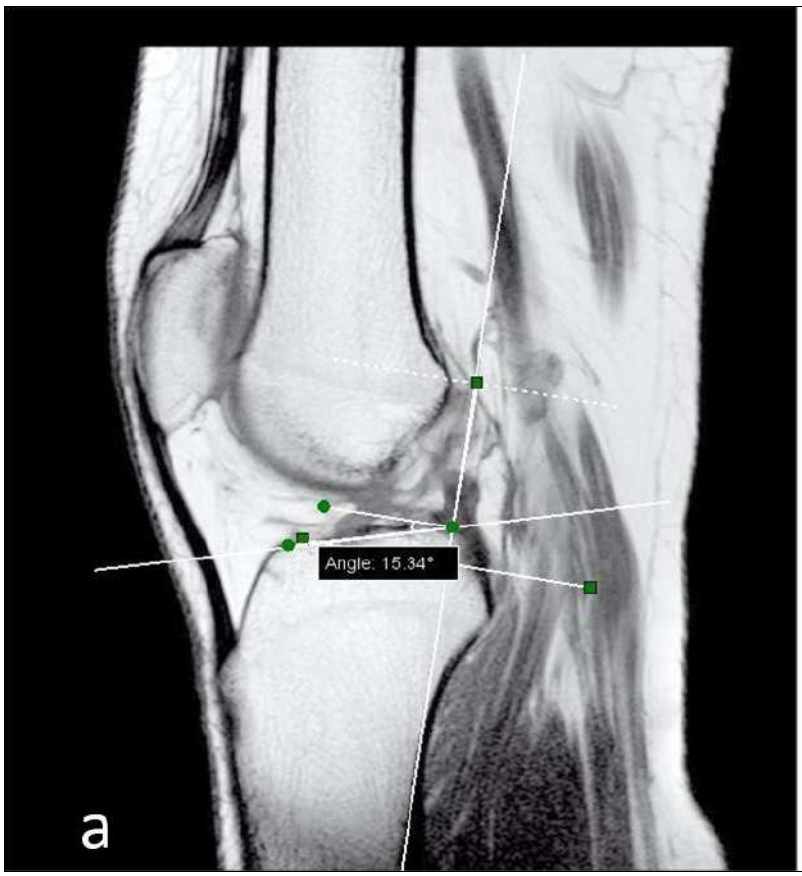

Fig 7a: Complete ACL tear in non-contact injury: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 15.34o.

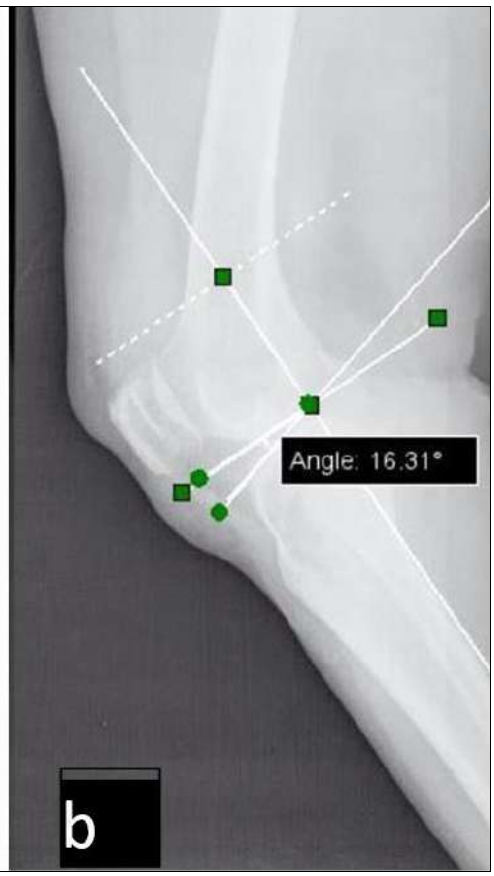

Fig 7b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 16.31o.

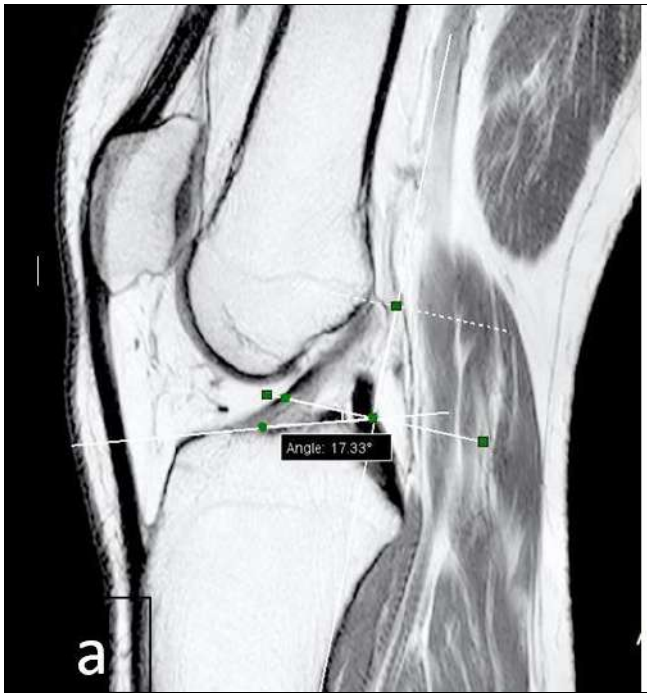

Fig 8a: Intact ACL with abnormal PTS: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 17.33o.

Fig 8b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 15.17o.

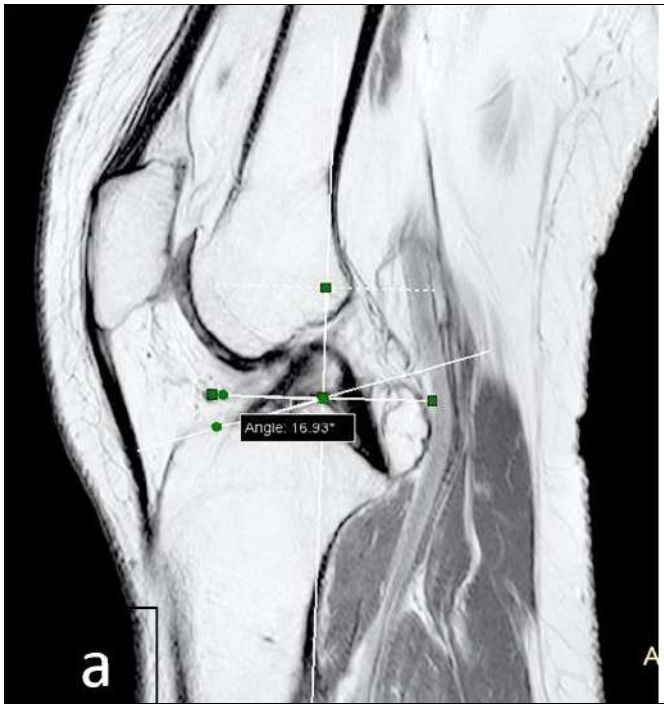

Fig 9a: Intact ACL with abnormal PTS: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 16.93o.

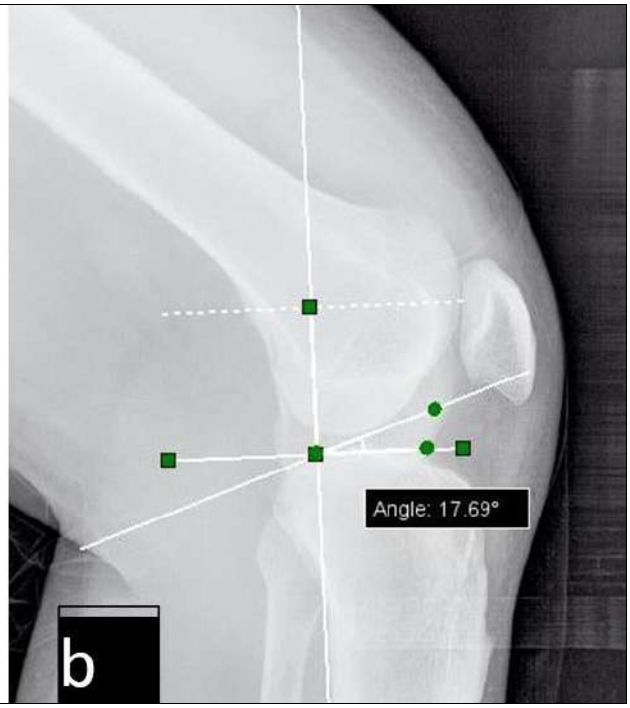

Fig 9b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 17.69o.

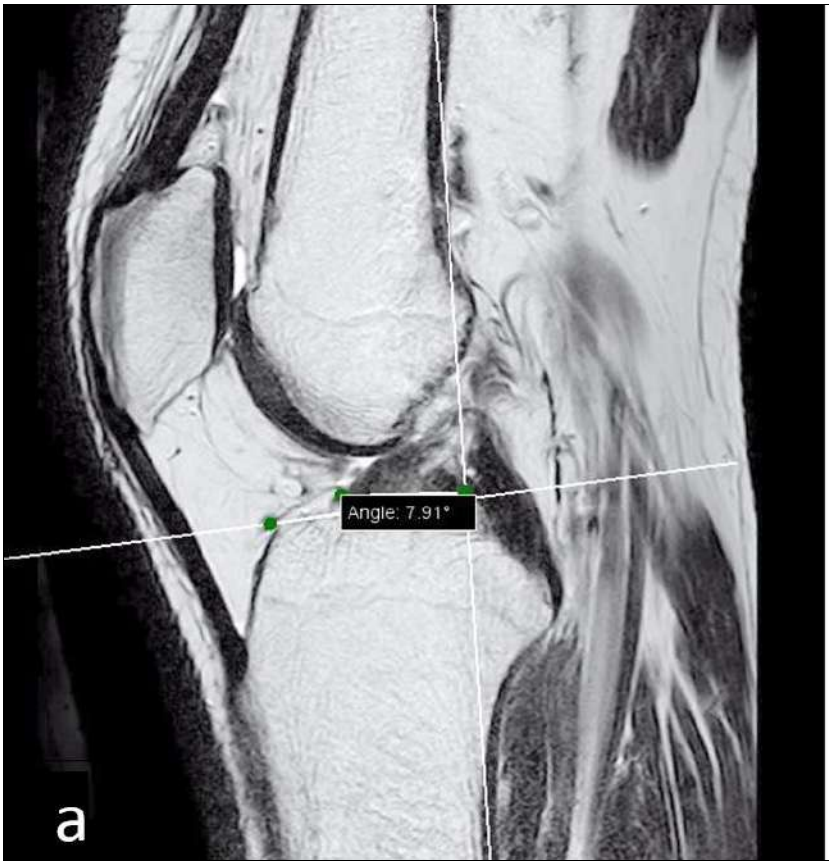

Fig 10a: ACL tear with normal PTS: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 7.91o.

Fig 10b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 7.21o.

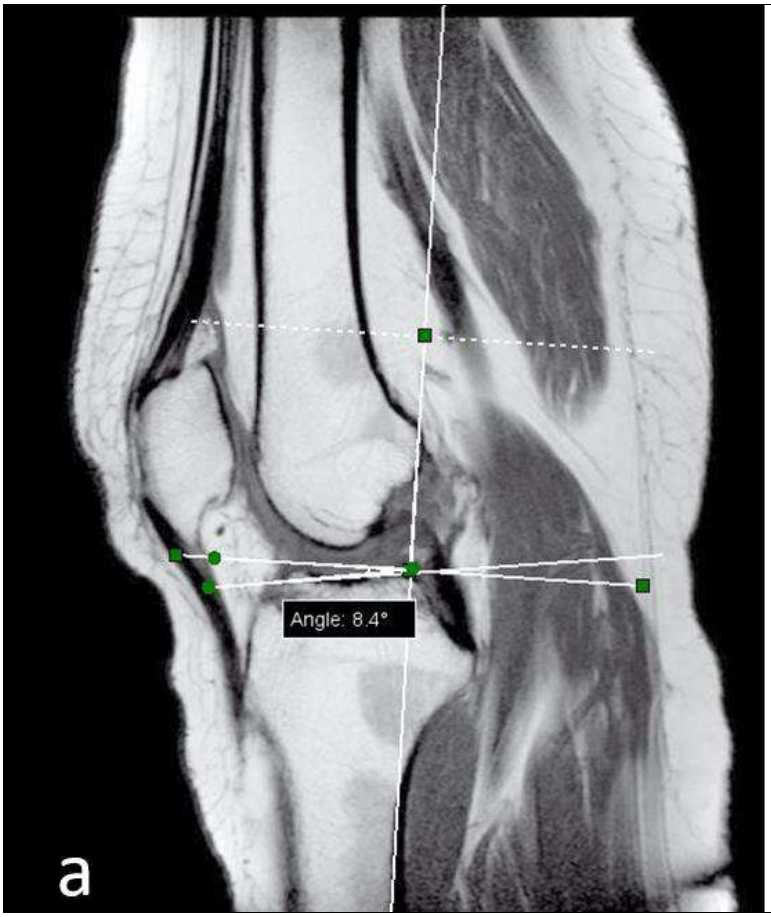

Fig 11a: ACL tear with normal PTS: Tibial slope angle measured on midsagittal section on MRI. The angle in this patient measure 8.4o.

Fig 11b: Tibial slope angle measured on midsagittal section on lateral radiograph. The angle in this patient measure 7.36o.

Conclusion

Greater posterior tibial slope angle is a risk factor for ACL injury**.** Patients with PTS less than 9.97º are less prone to ACL injury and patients with PTS > 14.37º are more prone to ACL injury. ACL injury is not influenced by gender or nature of injury (contact / non-contact). Both MRI and X-Ray can be used to evaluate the PTS and identify the at-risk individuals for ACL tear.

Conflict of Interest

Not available

Financial Support

Not available

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