

The Effect of Tibial Slope and Size of the Intercondylar Notch on Rupture of the Anterior Cruciate Ligament

Ahmed Abd-Elhamid Shamma, Tharwat Abd-Elghany Elsayed and Amr Ahmed Khattab

Orthopedic Surgery Department, Faculty of Medicine, Al-Azhar University, Egypt
dr_3mour@yahoo.com

Abstract: Objective: The aim of this study is to evaluate the influence of the tibial slope and the size of the inter condylar notch on rupture of the anterior cruciate ligament and to predict the athletes who more susceptible to ACL injuries. **Background:** The anterior cruciate ligament (ACL), which is located in the intercondylar notch of the femur, is one of the major stabilizing intra capsular ligaments in the knee joint. ACL is proximally attached to the postero-medial surface of the lateral femoral condyle and distally to the anterior part of the inter condylar eminence of the tibia. Injuries to the knee joint are common in athletes and the ACL is the most frequently ruptured ligament of the knee. The purpose of this prospective study is to establish a normal range for the notch width index and to correlate inter condylar notch size and anterior cruciate ligament injuries. The normal intercondylar notch ratio is 0.231 ± 0.044 . The inter condylar notch width index for men is larger than that for women. ACL injuries have statistically significant inter condylar notch stenosis. The posterior tibial slope (PTS) plays a very important role in the kinematics and biomechanics of the knee joint. Increased medial PTS has been reported to be associated with anterior cruciate ligament (ACL) injuries in teenagers and adult. **Patient & Methods:** We will follow about 50 cases complaining of knee pain and follow up them. We will divide them to two groups GROUP A; with ACL injuries GROUP B (controlled group); with intact ACL and we will measure the posterior tibial slope and notch index in both groups to compare the results in both groups. We will measure posterior tibial slope from lateral view of plain X ray and the notch index from coronal view of MRI. **Patient Age:** Adult > 15 years old Patient admitted to Al azhar university hospitals (El – Hussien and Sayed Galal Hospitals). **Results:** The group with ACL rupture had a statistically significantly increased PTS and a smaller NWI than controlled group. When a high PTS and / or a narrow NWI were defined as risk factors for ACL rupture, 80% of patient had at least one risk factor present, only 24% had both factors present. In both groups the PTS was negatively correlated to the NWI. PTS and NWI appear to be correlated to rupture of the ACL. From these results, either a steep PTS or a narrow NWI predisposes an individual to ACL injury. From these results, both PTS and NWI appear to be correlated with ACL rupture, When a high tibial slope (> 10.5) and/or a tighter notch ($NWI < 0.22$) were introduced as risk factors for ACL injury, 88% of the patients in the ruptured ACL group had one (52%) or two (36%) risk factors present, only 12% of (group 1) with ruptured ACL have normal values of posterior tibial slope and notch width index. **Conclusion:** It has been suggested that an increase posterior tibial slope (PTS) and a narrow notch width index (NWI) increase the risk of anterior cruciate ligament (ACL) injury.

[Ahmed Abd-Elhamid Shamma, Tharwat Abd-Elghany Elsayed and Amr Ahmed Khattab. **The Effect of Tibial Slope and Size of the Intercondylar Notch on Rupture of the Anterior Cruciate Ligament.** *Nat Sci* 2016;14(12):254-260]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). <http://www.sciencepub.net/nature>. 40. doi:[10.7537/marsnsj141216.40](https://doi.org/10.7537/marsnsj141216.40).

Keywords: Effect; Tibial Slope; Intercondylar; Notch; Rupture; Anterior Cruciate Ligament

1. Introduction

The anterior cruciate ligament (ACL) which is located in the intercondylar notch of the femur is one of the major stabilizing intra capsular ligaments in the knee joint. ACL is proximally attached to the postero-medial surface of the lateral femoral condyle and distally to the anterior part of the inter condylar eminence of the tibia. Injuries to the knee joint are common in athletes and the ACL is the most frequently ruptured ligament of the knee (**Johnson, 1983**).

The purpose of this prospective study is to establish a normal range for the notch width index and to correlate inter condylar notch size and anterior cruciate ligament injuries. The normal inter condylar

notch ratio is 0.231 ± 0.044 . The inter condylar notch width index for men is larger than that for women. ACL injuries have statistically significant inter condylar notch stenosis (notch width index 0.189). Unfortunately, ACL injuries can be devastating. Numerous reconstructive procedures have been devised to treat an ACL tear (**Burnett and Fowler, 1985**).

Finding ways to predict the risk of ACL injury and preventing it is of great importance. It has been suggested that narrow intercondylar notch increase the risk of ACL injury (**Palmer 2007**).

To study the role of notch stenosis in ACL tears, use of notch width index (NWI)-the ratio of the width of the intercondylar notch to the width of the distal

femur at the level of the popliteal groove-eliminates magnification variability and differences in patient body size and stature (Souryal et al., 1988).

Some studies have mentioned that there is a relationship between femoral intercondylar notch stenosis and ACL tears, while others have not. If this relationship exists, it could be an important variable to identify athletes at risk of development of ACL tears. Performing this cross-sectional study to investigate if a narrow intercondylar notch width is a risk factor for development of ACL tears (Davis et al., 1999).

The posterior tibial slope (PTS) plays a very important role in the kinematics and biomechanics of the knee joint. Shelburne showed that increased PTS increased the tibial shear force and anterior tibial translation at the knee which is particularly important in individuals undergoing proximal tibial osteotomy (Good et al., 2003).

Increased medial PTS has been reported to be associated with anterior cruciate ligament (ACL) injuries in teenagers and adult. According to Giffin increasing the Posterior tibial slope helps stabilising knees which are posterior cruciate ligament (PCL) deficient (Lombardo et al., 2005).

2. Patients and Methods:

This study is a prospective study of 25 cases of post traumatic ACL tears, who had sustained an isolated, complete rupture of the ACL, as confirmed by clinical examination, MRI and arthroscopy (group 1), and control group of 25 patients (group 2) matched for age and gender with group (1) all cases were done in Al Al-Azhar University Hospitals (AL-Hussein & Saied Galal Hospitals) between September 2015 and September 2016. All patients were managed in Egypt and were selected from the outpatient clinic of Al-Azhar university hospitals according to definite general criteria. All patients were less than 49 years old without degenerative or arthritic changes in plain radiography. All cases in (group1) were subjected to clinical examination including; history, mechanism of injury & investigations including; plain X-ray and MRI. All those in (group2) had undergo MRI of the knee and had no previous ligamentous knee injury, knee surgery or radiological evidence of osteoarthritis of the knee.

Inclusion and Exclusion Criteria:

Inclusion criteria of (group 1):

- The presence of ACL injury
- Skeletal maturity
- Complete rupture of ACL, as confirmed by clinical examination, MRI and arthroscopy

Inclusion criteria of (group 2):

- Skeletally mature patient
- Had no previous ligamentous injuries as confirmed by clinical examination, MRI

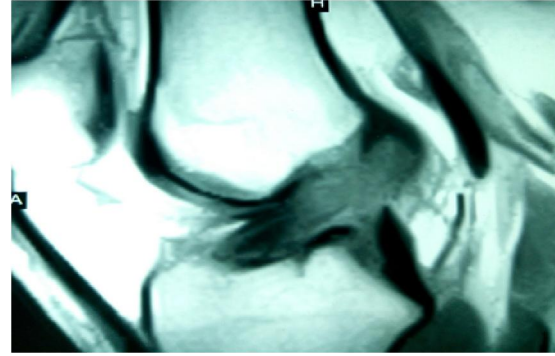


Figure (1): Sagittal MRI showing ACL tear



Figure (2): Lateral x ray of the knee

Exclusion criteria of two groups:

- Degenerative or arthritic changes in plain radiography.
- Age: between 15 and 49 years.

Radiological assessment:

All patients had lateral x ray (in 20 to 30 of flexion) and MRI of the knee. The assessment was completed with a true lateral of the knee in which the femoral condyles were superimposed. This confirmation was necessary since for measurement of the tibial slope, the distance between the posterior edges of the condyles on the lateral view should be <5mm.

Magnetic resonance imaging;

The NWI, is the width of the inter condylar notch at the level of the popliteal groove divided by

the bi condylar width at the same level. The scans were performed supine with the knee extended and rebuilt in T₁ and T₂, with coronal sections orthogonal to the inter condylar notch.

Patients**Age prevalence:**

The youngest patient was 15 years old, while the oldest one was 49 years old in (group 1). The mean age was 35 years in (group 1) while the youngest patient was 25 in (group 2) while the oldest patient was 52. The mean age in group 2 was 38 in (group 2).

Gender prevalence:

There were 20 men in (group 1) and 5 women in (group 1) and 16 men in (group 2) and 9women in (group 2).

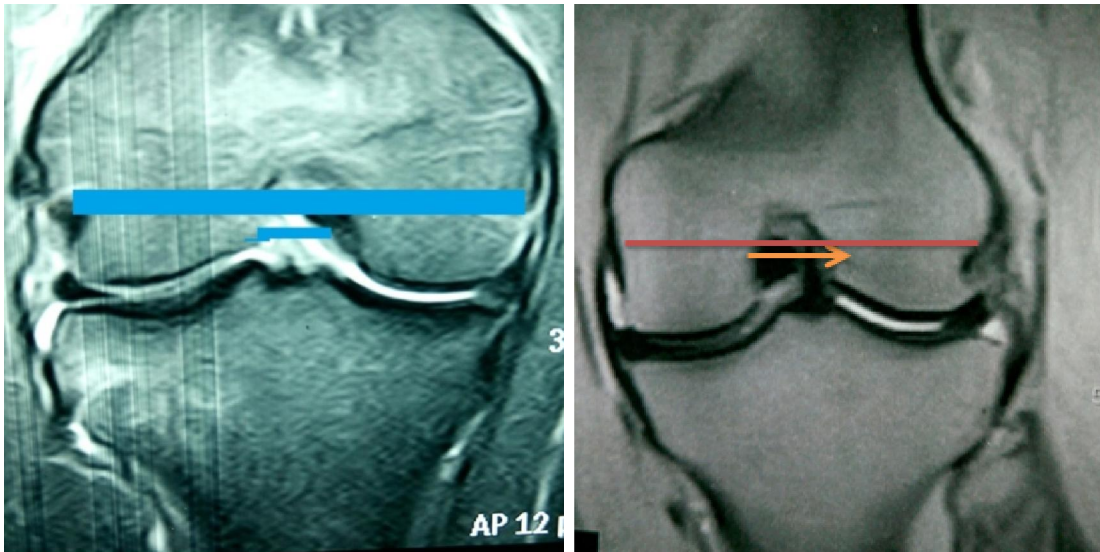


Figure (3): Coronal view of MRI at level of popliteal groove

Knee affected:

The right knee was affected in 17 cases of (group 1) while the left knee was affected in 8 cases in the same group.

In (group 2) we examine, plain x ray, MRI for right knee in 13 cases while left knee in 12 cases.

Giving way:

It was present in 23 cases of (group1) with ACL injury while not found in (group 2).

Sports activity:

20 cases had trauma during playing sports, while 5 had trauma to the knee during their daily activity in (group 1).

3. Results:

It has been suggested that an increase posterior tibial slope (PTS) and a narrow notch width index (NWI) increase the risk of anterior cruciate ligament (ACL) injury. The aim of this study was to establish

why there are reports on their significance. A total of (25) patients with ruptured ACL and (25) patients with intact ACL were included in the study.

The group with ACL rupture had a statistically significantly increased PTS and a smaller NWI than controlled group. When a high PTS and / or a narrow NWI were defined as risk factors for ACL rupture, 80% of patient had at least one risk factor present, only 24% had both factors present. In both groups the PTS was negatively correlated to the NWI. PTS and NWI appear to be correlated to rupture of the ACL. From these results, either a steep PTS or a narrow NWI predisposes an individual to ACL injury.

From these results, both PTS and NWI appear to be correlated with ACL rupture, When a high tibial slope (> 10.5) and /or a tighter notch (NWI< 0.22) were introduced as risk factors for ACL injury, 88% of the patients in the ruptured ACL group had one (52%) or two (36%) risk factors present, only 12% of

(group 1) with ruptured ACL have normal values of posterior tibial slope and notch width index.

In (group B) in which patients with ACL injury had only one risk factors either increased posterior tibial slope above $10,5^\circ$ or narrow notch width index in 13 cases, we found that 8 patients had narrow notch width index less than 0,21 while only 5 cases had increased posterior tibial slope more than $10,5^\circ$.

We found in (group 1) with ACL tear there are 17 cases with notch stenosis while normal in 8 cases,

and there are 14 cases with high posterior tibial slope with 11 cases with normal values.

Table (1): Risk factors in (group1) with ACL tear

Risk factor	Positive	negative
Narrow (NWI)	17	8
High (PTS)	14	11

Table (2): Comparison between control group and patients group regarding age, sex and side of injury.

		Control No.= 25	Patient No.= 25	Chi-square test	
				X ²	P-value
Age	Mean \pm SD	31.56 \pm 7.01	28.56 \pm 8.56	1.356	0.181
	Range	20 – 47	17 – 49		
Sex	Female	9 (36.0%)	6 (24.0%)	0.857	0.355
	Male	16 (64.0%)	19 (76.0%)		
Side	LT	12(48.0%)	7 (28.0%)	2.122	0.145
	RT	13 (52.0%)	18 (72.0%)		

The previous table shows that there was no statistically significant difference found between control group and patients group regarding age, sex and side with p-value = 0.181, 0.355, 0.145; respectively.

Table (3): Comparison between control group and patients group regarding PTS and NWI.

		Control No.= 25	Patient No.= 25	Independent t-test	
				t	P-value
PTS ^o	Mean \pm SD	7.80 \pm 1.38	9.68 \pm 1.73	-4.249	<0.001
	Range	6 – 11	6 – 13		
NWI	Mean \pm SD	0.26 \pm 0.017	0.22 \pm 0.021	6.539	<0.001
	Range	0.23 – 0.29	0.20 – 0.27		

The previous table shows that there was highly statistically significant increase in the level of PTS in patients group than control group with p-value < 0.001 and also the table shows that there was highly statistically significant decrease in the level of NWI in patients group than control group with p-value < 0.001.

Table (4): Mode of trauma and duration before operation in the patients group.

		Patient group No.= 25
Mode of trauma	Falling down stairs	1 (4.0%)
	Falling on the ground	4 (16.0%)
	Playing sport	20 (80.0%)
Duration before surgery (months)	Mean \pm SD	7.48 \pm 4.85
	Range	1 – 19

Table (5): Correlation of PTS with the other studied parameters.

	PTS ^o	
	r	P-value
NWI	-0.143	0.494
Age	0.100	0.634
Duration before operation (Months)	0.049	0.816

The previous table shows that there was no statistically significant correlation found between PTS and NWI, age and duration before operation.

Table (6): Relation of PTS with sex, mode of trauma and side of injury.

		PTS°		Independent t-test	
		Mean ± SD	Range	t	P-value
Sex	Female	10.33 ± 2.42	7 – 13	1.067	0.297
	Male	9.47 ± 1.47	6 – 12		
Mode of trauma	Falling down stairs	8 ± 0	8 – 8	0.403	0.673
	Falling on the ground	9.44 ± 0.96	6 – 13		
	Playing sport	9.35 ± 1.57	11 – 12		
Side	LT	9.57 ± 1.13	8 – 11	-0.192	0.849
	RT	9.72 ± 1.93	6 – 13		

The previous table shows that there was no statistically significant relation found between PTS level and sex, mode of trauma and side of injury.

Table (7): Correlation of NWI with the other studied parameters.

	NWI	
	r	P-value
Age	-0.159	0.221
Duration before operation (Months)	-0.334	0.103

No statistically significant correlation found between NWI and the other studied parameters.

Table (8): Relation of NWI with sex, mode of trauma and side of injury.

		NWI		Independent t-test	
		Mean ± SD	Range	t	P-value
Sex	Female	0.21 ± 0.01	0.2 – 0.23	-1.494	0.149
	Male	0.23 ± 0.02	0.2 – 0.27		
Mode of trauma	Falling down stairs	0.23 ± 0	0.23 – 0.23	0.201	0.819
	Falling on the ground	0.22 ± 0.02	0.2 – 0.24		
	Playing sport	0.23 ± 0.02	0.2 – 0.27		
Side	LT	0.23 ± 0.02	0.21 – 0.27	1.084	0.290
	RT	0.22 ± 0.02	0.2 – 0.27		

The previous table shows that there was no statistically significant relation found between NWI level and sex, mode of trauma and side of injury.

4. Discussion

The tibial plateau is not horizontal. It has posteriorly inclined slope. The posterior tibial slope is directed posteriorly and inferiorly relative to the long axis of the middle of the shaft of the tibia (**Strandring 2008**).

Posterior tibial slope is defined as the angle between the perpendicular to the middle part of the diaphysis of the tibia and the line representing the posterior inclination of the tibial plateau (**Genin, Weill and Julliard 2009**).

Articular surface of tibia in the knee joint consists of lateral and medial condyles which are in contact with the condyles of femur. With tibial axis,

this surface makes an angle (PTS) of 7–10 degrees. A greater PTS with axial loading generates a greater anterior translation of tibia (**Dejour and Bonnin 1994**).

Many studies found a correlation between the PTS and ACL insufficiency (**Webb et al., 2013**).

However, authors used different diagnostic methods; some used lateral radiography, others computerized tomography, while the majority, used MRI slices (**Terauchi et al., 2011**).

In our study we determine PTS using lateral x ray. All patients had lateral x ray in 20 to 30 of flexion and MRI of the knee. The assessment was completed with a true lateral of the knee under fluoroscopic

control to ensure that the femoral condyles were superimposed. This confirmation was necessary since for measurement of the tibial slope, the distance between the posterior edges of the condyles on the lateral view should be <5mm (**Julliard, et al., 1993**).

The functional tibial slope as described by *Julliard et al.* was used to determine the PTS, which is the angle between the tangent to the medial tibial plateau and the lateral mechanical axis of the leg. We felt this method was the most suitable, as other techniques do not use the full length of the tibia, not related to its mechanical axis (**Julliard et al., 1993**).

It had been found a statistically significantly steeper PTS in the patients with a ruptured ACL than in the uninjured group. However, others report differently. *Meister et al.* found no correlation between the PTS and risk of ACL rupture (**Meister, et al. 1998**).

Todd et al. found that an increased PTS was a possible risk factor in women, they found no association in men (**Todd et al., 2010**).

Also, although an increased PTS leads to an anterior shift in the resting position of the tibia, two studies have shown that this does not increase strain in the ACL (**Shelburne et al., 2011**).

Intercondylar notch:

The role of a narrow inter condylar notch in ACL injury is less controversial. We found that the NWI was significantly narrower in those with a ruptured ACL. Various mechanisms whereby a narrow notch increases the risk of ACL injury have been suggested. Most authors feel that it presents a risk of impingement, particularly when the knee is extended (**Fung et al., 2007**).

Others consider that the width of the notch reflects the size and hence the strength of the ACL. (**Stijak et al., 2008**).

Simon et al. suggested that those with a narrower notch have a more vertical coronal orientation of the ACL, which potentially influences the loads it experiences (**Simon et al., 2010**).

Others, however, found no association between the width of the inter condylar notch and risk of ACL injury, and concluded that the width of the notch alone cannot explain ACL tears (**Lombardo et al., 2005**).

Our data indicate that both factors play a significant role in increasing the risk of ACL injury. When a high PTS (> 10.5) and /or a tight notch (NWI< 0.21), were defined as risk factors, 80% of the patients with a ruptured ACL had at least one these factors (PTS in 28 patients, NWI in 24) but only 24% of patients had both.

Conclusion:

It has been suggested that an increase posterior tibial slope (PTS) and a narrow notch width index

(NWI) increase the risk of anterior cruciate ligament (ACL) injury. The aim of this study was to establish why there are reports on their significance. The posterior tibial slope (PTS) plays a very important role in the kinematics and biomechanics of the knee joint. All patients had lateral x ray (in 20 to 30 of flexion) and MRI of the knee.

The notch width index to measure and compare inter condylar notch width. The purpose of this prospective study is to establish a normal range for the notch width index and to correlate inter condylar notch size and anterior cruciate ligament injuries. The normal inter condylar notch ratio is 0.231 +/- 0.044. It has been suggested that an increase posterior tibial slope (PTS) and a narrow notch width index (NWI) increase the risk of anterior cruciate ligament (ACL) injury.

References:

1. Burnett QM and Fowler PJ. Reconstruction of the anterior cruciate ligament: historical overview. *Orthop Clin North Am*, 1985; 16(1):143-57.
2. Davis TJ, Shelbourne KD and Klootwyk TE. Correlation of the intercondylar notch width of the femur to the width of the anterior and posterior cruciate ligaments. *Knee Surg Sports Traumatol Arthrosc*, 1999; 7(4):209-14.
3. Dejour H and Bonnin M. Tibial translation after anterior cruciate ligament rupture: two radiological tests compared. *J Bone Joint Surg Br*, 1994; 76:745-9.
4. Fung DT, Hendrix RW, Koh JL and Zhang LO. ACL impingement prediction based on MRI scans of individual knees. *Clin Orthop*, 2007; 460: 210-218.
5. Genin P, Weill G and Julliard R. The tibial slope. Proposal for a measurement method. *J Radiol*, 2009; 74:27-33.
6. Good L, Odensten M and Gillquist J. Intercondylar notch measurements with special reference to anterior cruciate ligament surgery. *Clin Orthop Relat Res*, 2003; (263):185- 9.
7. Johnson RJ. The anterior cruciate ligament problem. *Clin Orthop Relat Res*, 1983; (172):14-8.
8. Julliard R, Genin P, Weil G and Palmkrantz P. The median functional slope of the tibia. *Rev Chir Orthop Reparatrice Appar Mot*, 1993; 79:625-34.
9. Lombardo S, Sethi PM and Starkey C. Intercondylar notch stenosis is not a risk factor for anterior cruciate ligament tears in professional male basketball players: an 11- year prospective study. *Am J Sports Med*, 2005; 33: 29 – 34.

10. Meister k, Talley M Cand Horosdyski MB. Caudal slope of the tibia and its relationship to noncontact injuries to the ACL, *Am J Knee Surg*, 1998; 11: 217- 219.
11. Palmer I. On the injuries to the ligaments of the knee joint: a clinical study. 1938. *Clin Orthop Relat Res*, 2007; 454:17-22.
12. Shelburne KB, Kim HJ, Stereu WI and Pandy MG. Effect of posterior tibial slope on knee biomechanics during functional activity. *J Orthop Res*, 2011; 29: 223 – 231.
13. Simon RA, Everhart JS, Nagaraia HN and Chaudhari AM. A case – control study of anterior cruciate ligament volume, tibial plateau slopes and intercondylar notch dimensions in ACL- injured knees. *J Biomech*, 2010; 43: 1702-1707.
14. Souryal TO, Moore HA and Evans JP. Bilaterality in anterior cruciate ligament injuries: associated intercondylar notch stenosis. *Am J Sports Med*, 1988; 16(5):449-54.
15. Standring S. *Grey’s Anatomy: The Anatomical Basis of Clinical Practice*. 40th ed. London (UK): Churchill Livingstone Elsevier, 2008; p-1397.
16. Stijak L Herzog BF and Schai P. Is there an influence of the tibial slope of the lateral condyle on the ACL lesion? a case- control study. *Knee Surg Sports Traumatol Arthrosc*, 2008; 16: 112-117.
17. Terauchi M, Hatayama K, Yanagisawa S, Saito K and Takagishi K. Sagittal alignment of the knee and its relationship to noncontact anterior cruciate ligament injuries. *Am J Sports Med*, 2011; 39:1090-4.
18. Todd MS, Lalliss S, Garcia E, De Berardino TM and Cameron KL. The relationship between posterior tibial slope and anterior cruciate ligament injuries. *Am J Sports Med*, 2010; 38:63- 67.
19. Webb JM, Salmon LJ, Leclerc E, Pinczewski LA and Roe JP. Posteriortibial slope and further anterior cruciate ligamentinjuries in the anterior cruciate ligament–reconstructed patient. *Am J Sports Med*, 2013; 41(12):2800-4.

12/25/2016