COMPARATIVE ANALYSIS OF EXTERNAL AND INTERNAL ROTATION OF LEG IN PIVOT SHIFT TEST AND QUANTIFICATION BY IMAGE ANALYSIS IN PATIENTS WITH CHRONIC ANTERIOR CRUCIATE LIGAMENT INJURIES

Santhamoorthy T¹, Arun K²

HOW TO CITE THIS ARTICLE:

Santhamoorthy T, Arun K. "Comparative Analysis of External and Internal Rotation of Leg in Pivot Shift Test and Quantification by Image Analysis in Patients with Chronic Anterior Cruciate Ligament Injuries". Journal of Evolution of Medical and Dental Sciences 2014; Vol. 3, Issue 32, August 04; Page: 8846-8855, DOI: 10.14260/jemds/2014/3133

ABSTRACT: BACKGROUND: Pivot shift test has been in use as one of the diagnostic test for anterior cruciate ligament injuries over the years. Change in position of the leg was found to produce variation in appreciation of the test. In our observation we found doing the test with leg in external rotation produces better appreciation of the test. **AIM:** Comparison of external and internal rotation of leg in pivot shift test and quantitating it using image analysis in chronic anterior cruciate ligament injuries.

METHODS: Thirty patients with complaints of pain and instability in the knee joint for 2 or more months following injury and having positive Lachman test were chosen randomly. The pivot shift test was performed in all 30 patients first with leg in external rotation and then in internal rotation under anesthesia. Movement of three bony points in relation to each other were captured using 12 mega pixel digital camera and evaluated using image analysis software. **RESULTS AND DISCUSSION:** The femoral Antero posterior (AP) translation from the Gerdy's point suddenly decreased by 6.5+ 1.8 mm (maximum 13mm, minimum 3mm) in all 30 patients on whom pivot shift was performed in external rotation, whereas the femoral AP translation decreased by 2.9+ 1.17 mm (maximum 5mm, minimum 1mm) in 29 patients when the pivot shift test was done in internal rotation. Arthroscopic findings correlated well with pivot shift test being done in external rotation than in internal rotation.

CONCLUSION: The results of this study shows higher diagnostic value of pivot shift test for chronic anterior cruciate ligament (ACL) insufficiency when it is done with leg in external rotation.

KEYWORDS: Pivot Shift, Image Analysis, Anterior Cruciate Ligament, Injuries.

INTRODUCTION: Pivot shifting is a specific phenomenon which occurs in cruciate deficient knee joints. The original pivot shift test was demonstrated by Galway and Mc Intosh in 1972.¹ Since then many modifications and grading systems are in practice.²⁻⁵ Many authors agree that the basic prerequisite for demonstrating this clinical test is presence of intact medial collateral ligament to apply a valgus force and appreciation of reduction or subluxation of tibial plateau from extension to flexion at around 20-30°.^{6,7}

The effect of rotation of tibia while performing the maneuver in grading of this test has been published by few authors with variable results and implications on treatment.⁸ None of them were able to quantify it for routine clinical practice in a consistent manner. In spite of the enormous research in this field, the exact biomechanism behind this clinical test has not been validated and no objective quantification method for routine clinical use is available.

In our clinical observation, we found that performing the maneuver with leg in external rotation in patients with chronic cruciate ligament injuries yielded better appreciation of the shift phenomenon consistently in comparison to internal rotation. Hence, we proposed to conduct a

ORIGINAL ARTICLE

prospective study to compare the effect of rotations of leg on the results of this test in patients with chronic cruciate ligament injuries and to quantify it objectively using image analysis method.⁹

PATIENTS AND METHODS: Thirty patients with complaints of pain and instability in the knee joint for two or more months following injury and having positive Lachman test with soft end point were included in our study after excluding associated Postero Lateral Complex (PLC) and Posterior cruciate ligament (PCL) injury. Twenty six were male and four were female. The mean duration after injury was 4.6 months. One patient who underwent ACL reconstruction 18 months ago which has failed was also included in the study (table-I).

All the patients were examined under anesthesia in supine position with hip in neutral position. Three white circular stickers, each 10mm in diameter were applied on the skin over the bony prominences over lateral aspect of the knee (lateral epicondyle of femur, Gerdy's tubercle and fibular head) as markers for assessing the movement of the lateral condyle of tibia in relation to the lateral condyle of femur in sagittal plane. The distance between the centers of markers over Gerdy's tubercle and fibular head are preliminarily measured.

The pivot shift test performed in all thirty patients first with leg in external rotation of 20° and then in internal rotation of 20° with valgus force at knee from extension to 100° of flexion. The same examiner performed the test in all the thirty patients using no axial force and completing the maneuver over 1-1.2seconds and thus avoiding subjective bias.

The movement of the three stickers were recorded in video using a 12 megapixel digital camera (Nikon, coolpix). The same procedure was carried out on the opposite normal knee for all the patients with 20° external rotation as a control. The background behind the knee was covered by a monotone sheet to reduce noise during the image processing stage. The captured video recordings was reformatted as avi file and made compatible with Image J software. The video was trimmed to have one sequence of pivot shift test. The avi file was opened as stacks of images.

The images were then cropped to capture only the three markers. Then 8-bit conversion was done and now the image was edited to maximize the areas of the markers and to minimize the unwanted area selection. The X-Y plots of the centroids of the detected areas and their outlines were obtained by analyzing the particles. The X-Y plots of the centroids of the three markers were used to calculate the antero-posterior translation of the lateral compartment.

Calculation of lateral compartment translation. In each frame, the X-Y plot of the intersection point termed as "pivot point (P)" between the tibial horizontal line (G-F) and a perpendicular line from the centroid of lateral epicondyle marker (L) to the tibial horizontal line was calculated.

The ratio of the perpendicular offset length of lateral epicondyle point from Gerdy's tubercle point to the length of the tibial horizontal line was calculated from the X-Y plot data. The femoral AP position from the Gerdy's tubercle can then be calculated by multiplying the ratio by the distance of the 2 tibial points from the preliminary measurements (fig-1).

RESULTS: First, the test was performed with leg in external rotation and clinically graded as grade B in 2 patients, grade C in 25 patients and grade D in 3 patients according to IKDC scoring system. Then the test was performed with leg in internal rotation and clinically graded as grade A in 4 patients, grade B in 24 patients and grade C in 2 patients. (Table-II).

ORIGINAL ARTICLE

Image analysis was conducted by an individual who was blinded to the clinical grade for the pivot shift test. The femoral AP translation from the Gerdy's point suddenly decreased on an average by 6.5 ± 1.8 mm (Mean $\pm$ SD) in all 30 patients on whom pivot shift was performed in external rotation. Whereas the femoral AP translation decreased on an average by 2.9 ± 1.17 mm in 29 patients with the pivot shift test done in internal rotation.

In 1 patient with positive Lachman test, there is no sudden drop or peaking in the slope which was performed with the leg in internal rotation. None of the patients opposite normal knee showed such a drop or rise in the translation performed in external rotation. The anterior translation of the distal femur in relation to the tibia typically occurred over a period of 0.2 ± 0.1 sec (graphs-1 to 3). Arthroscopic findings correlate well with pivot shift test being done in external rotation than in internal rotation (table-2).

All patients with complete tear in arthroscopy had a clinical grade of C or D when pivot shift test done in external rotation, whereas, only 3 patients with complete tear showed grade C when tested in internal rotation. Similarly all 5 patients who had partial tear in arthroscopy showed positive pivot shift test (grade B in 2 patients and grade C in 3 patients) done in external rotation.

In contrast only 2 patients with partial tear showed positive pivot shift test (grade B) and 3 of them were negative for the test (grade A) when done in internal rotation. This shows high sensitivity of the test (100%) when performed with leg in external rotation as well as high positive predictive value (83.3%). The unpaired "t" test showing extreme statistical significance ($p < 0.0001$).

DISCUSSION: Though many clinical tests were described for diagnosing anterior cruciate ligament deficient knees, none of them were proved 100% specific or sensitive in accurate diagnosis and for assessing prognosis following surgical or conservative treatment. For ACL deficient knees, Lachman test still remains the gold standard against which other tests were compared.¹⁰ But it has poor prediction on prognosis after ACL reconstructive surgeries.¹¹

Pivot shift test on the other hand has more specificity than lachman test as well as better predictor of prognosis after ACL reconstructive surgery.¹² The pivot shift test has been in general use since its introduction in 1972, but its character and magnitude can vary considerably as it is highly subjective and precluded by patient's complete cooperation. Hence, this test should be performed only under anesthesia.

A couple of controversial points persist in conducting this test, in spite of lot of research over the past three decades. The role of rotation of leg during performance of the test is still not been validated though few studies concluded that external rotation augments the pivot shift phenomenon.^{13, 14}

However, these studies have not graded or explained the exact patho-mechanism for the augmentation. The IKDC scoring system and Jacob's grading system are available to quantify the pivot shift test, but these are clinical observation rather than objective scoring.

The purpose of our present study is to assess the effect of rotation of leg in pivot shift test and to objectively quantify it using the recently introduced image analysis method. The results of our study shows augmentation of the pivot shift test when it is done in external rotation of leg

We would like to propose the following biomechanical concept to support our findings. In normal knee as the lateral tibial plateau and lateral femoral condylar articular surfaces are convex;

ORIGINAL ARTICLE

they should be contoured properly during normal gait and during pivoting movements like jumping or twisting of the knee.⁶

The ACL remains the primary restraint for maintaining the conformity of the condyles during these stresses. When the ACL is deficient, the secondary restraints like lateral meniscus, hamstrings, ilio tibial band and postero-lateral ligament complex will try to maintain the conformity and prevent anterior translation and internal rotation of tibia.¹⁶

But, When one of the secondary restraints also injured, like a tear in lateral meniscus, the lateral tibial plateau tends to subluxate more anteriorly even during normal gait. This would clinically produce marked instability of the knee joint. The pivot shift should be more appreciable in such a patient; but doing the test in internal rotation of tibia would tighten the secondary restraints and restricting its anterior translation thereby decreasing the appreciability of pivot shift test.

In contrary doing the test in external rotation eliminates the effect of most of the secondary restraints to produce better appreciability of the test and higher grade of the test.

The most controversial question which arises in the mind of treating surgeon is whether to reconstruct a partial ACL tear or not. In Patients with instability symptoms and arthroscopically having a partial ACL injury or showing other instability lesions like meniscal or cartilage damage, a positive pivot shift test would implicate that patient requires a reconstruction of ACL even if other tests were negative or low grade.

Hence, even in partial ACL injury testing the pivot shift in external rotation would show higher grade if the ACL is non-functioning, as observed in our study. If the patient fails to show positive test results in both rotations, then conservative treatment would be sufficient. It is understood that elimination of the pivot shift is necessary to achieve successful relief of symptoms and functional outcome.

In order to quantify our findings objectively we used image analysis method as the tool⁹. This new, easily applicable and reproducible method as described by Yuichi Hoshino et al (2012) is cost-effective and seems clinically practicable. Though this method assesses the shift test in single plane (2D), future innovation in this method may provide a way for 3D analysis of the shift test.

Few drawbacks in our study include relatively small sample size, non-homogeneity of the demographic profile of the patients and 2D analysis.

CONCLUSION: This study shows increased AP translation of the femur in relation to tibia when the pivot shift test is being performed in external rotation compared to internal rotation of leg using image analysis and correlating well with arthroscopic findings. Hence, we would like to conclude that, performing this test with leg in external rotation should increase the diagnostic value of this test in chronic ACL insufficiency.

REFERENCES:

1. Galway RD, Beaupr A, Macintosh DL. Pivot shift: a clinical sign of symptomatic anterior cruciate ligament insufficiency. J Bone Joint Surg [Br] 1972:54-57.
2. Losee RE, Johnson TR, Southwick WO. Anterior subluxation of the lateral tibial plateau: a diagnostic test and operative repair. J Bone Joint Surg [Am] 1978:60-A: 1015-1030.
3. Muller W. The knee: form, function and ligament reconstruction. New York etc: Springer-Verlag, 1983.

ORIGINAL ARTICLE

4. Noyes FR, Bassett RW, Grood ES, Butler DL. Arthroscopy in acute traumatic hemarthrosis of the knee: incidence of anterior cruciate tears and other injuries. J Bone Joint Surg [Am] 1980; 62-A: 687-95.
5. Slocum DB, James SL, Larson RL, Singer KM. Clinical test for antero lateral rotary instability of the knee. Clin Orthop 1976; 118: 63-69.
6. Bull AMJ, Andersen HN, Basso O, Target J, Amis AA. Incidence and mechanism of the pivot shift: An in vitro study. Clin Orthop Rel Res. 363, 1999, 219-231.
7. H. Matsumoto. Mechanism of the pivot shift. J Bone Joint Surg [Br] 1990; 72-B: 816-21.
8. R P Jakob, H U Staubli, J T Deland. Grading the pivot shift -objective tests with implications for treatment. J Bone Joint Surg [Am].vol. 69-b, no. 2, march 1987; 294-299
9. Yuichi Hoshino, Paulo Araujo, James J. Irrgang, Freddie H. Fu, Volker Musahl. An image analysis method to quantify the lateral pivot shift test. Knee Surg Sports Traumatol Arthroscopy 2012 20: 703-707
10. Yamamoto Y, Hsu WH, Fisk JA, Van Scyoc AH, Miura K, Woo SL. Effect of the iliotibial band on knee biomechanics during a simulated pivot shift test. J Orthop Res. 2006 May; 24 (5): 967-73.
11. Clayton G Lane, Russell Warren, Andrew D Pearle. The Pivot Shift. J Am Acad Orthop Surg 2008; 16: 679-688.
12. Leitze Z, Losee RE, Jokl P, Johnson TR, Feagin JA. Implications of the pivot shift in the ACL-deficient knee. Clin Orthop Relat Res. 2005 Jul; (436): 229-36.
13. Benjaminse A, Gokeler A, van der Schans CP. Clinical diagnosis of an anterior cruciate ligament rupture: a meta-analysis. J Orthop Sports Phys Ther. 2006 May; 36 (5): 267-88.
14. Bernard R. Bach, Jr Russell F, Warren. The pivot shift phenomenon: results and description of a modified clinical test for anterior cruciate ligament insufficiency. The American Journal of Sports Medicine 1988; 16; 571-576.
15. Manual of arthroscopic surgery. Michael J. Strobel pg: 376.
16. Noyes FR, Butler DL, Grood ES, et al. Clinical paradoxes of anterior cruciate instability and a new test to detect its instability. Orthop Trans 1978 2:36.

Fig-1: calculation of the position of the distal femur using pivot point (P)

Fig-2: cropped image from captured clinical video during pivot shift test

ORIGINAL ARTICLE

Graph 1

Patient -2: complete ACL tear (ERIK-External Rotation Injured Knee, IRIK-Internal Rotation Injured Knee, ERNL-External Rotation Normal Knee)

Graph 2

Patient-1: complete ACL reconstruction failure(ERIK-External Rotation Injured Knee:IRIK-Internal Rotation Injured Knee)

ORIGINAL ARTICLE

Graph 3

Patient-3: partial ACL tear(ERIK-External Rotation Injured Knee:IRIK-Internal Rotation Injured Knee)

PT Sl. no	Age (yrs)	Sex	Occupation	Mode of injury	Side of injury	Duration of injury	Previous reconstruction
1	30	M	Mason	RTA	R	18 months	Yes (18 m ago)
2	25	M	Driver	RTA	R	6 months	Nil
3	48	M	Teacher	Sports	L	3 months	Nil
4	26	M	Engineer	Sports	R	3 months	Nil
5	20	M	Student	Sports	R	2 months	Nil
6	21	M	Student	Sports	R	4 months	Nil
7	25	M	businessman	RTA	L	5 months	Nil
8	39	F	House wife	Self fall	L	6 months	Nil
9	20	M	Student	Sports	R	4 months	Nil
10	30	M	Shop keeper	RTA	R	2 months	Nil
11	22	M	Student	RTA	L	2 months	Nil
12	16	M	Student	SPORTS	L	6 months	Nil
13	22	M	Student	RTA	R	3 months	Nil
14	34	M	driver	RTA	R	5 months	Nil
15	44	F	Bank cashier	RTA	L	4 months	Nil
16	35	F	House wife	Self fall	L	3 months	Nil
17	33	M	Marketing person	RTA	L	4 months	Nil
18	27	M	IT profession	Sports	R	6 months	Nil
19	33	M	painter	Self fall	L	8 months	Nil
20	38	M	Auto mechanic	RTA	L	3months	Nil
21	39	M	Businessman	RTA	R	12 months	Nil

ORIGINAL ARTICLE

22	29	M	Farmer	Sports	R	4months	Nil
23	29	M	Engineer	Sports	R	3 months	Nil
24	42	M	Shop keeper	RTA	L	3 months	Nil
25	18	M	Student	Sports	R	2months	Nil
26	25	M	IT profession	Sports	L	3months	Nil
27	34	M	Doctor	RTA	L	4months	Nil
28	20	M	Student	RTA	L	2months	Nil
29	30	F	House wife	Sports	R	3months	Nil
30	26	M	AC mechanic	RTA	R	5 months	Nil

TABLE-I: DEMOGRAPHIC PROFILE OF THE PATIENTS

PT Sl. no	Lachman test (grade)	Ant drawer test (grade)	Clinical pivot shift test (IKDC grade)		AP translation in image analysis (mm)		Arthroscopic Finding
			External rotation	Internal rotation	External rotation	Internal rotation	
1	C	C	D	C	13	3.5	Complete failure of ACL graft
2	B	B	C	A	4	0	Complete ACL tear
3	B	B	C	B	5.5	3.5	Partial ACL tear
4	C	C	C	B	7	5	Complete ACL tear
5	B	B	C	B	5	1	Complete ACL tear
6	C	C	C	B	7	2	Complete ACL tear
7	C	C	C	B	6	3	Complete ACL tear
8	B	B	C	B	5	2	Complete ACL tear
9	B	A	C	A	6	1	Partial ACL tear
10	C	C	C	B	7.5	2.5	Complete ACL tear
11	B	A	B	A	4.3	2	Partial ACL tear
12	C	B	C	B	6.2	3.6	Complete ACL tear
13	C	B	C	B	7	3	Complete ACL tear

ORIGINAL ARTICLE

14	C	C	C	B	6.5	2.9	Complete ACL tear
15	C	C	C	B	7.2	4	Complete ACL tear
16	C	B	C	B	6.5	3	Complete ACL tear
17	C	C	D	C	9	4	Complete ACL tear
18	C	B	C	B	5.6	2.7	Complete ACL tear
19	C	B	C	B	6	2.8	Complete ACL tear
20	C	C	C	B	7	3.6	Complete ACL tear
21	B	A	B	A	3	1	Partial ACL tear
22	C	C	C	B	6.9	4.1	Complete ACL tear
23	C	C	C	B	7.2	4	Complete ACL tear
24	C	B	C	B	6.6	3.1	Complete ACL tear
25	B	B	C	B	6	2.8	Complete ACL tear
26	C	C	C	B	7.6	3.6	Complete ACL tear
27	C	C	C	B	7	4	Complete ACL tear
28	B	B	C	B	4.2	2.2	Partial ACL tear
29	B	B	C	B	6.9	3.5	Complete ACL tear
30	C	C	D	C	10	5	Complete ACL tear

TABLE-II:COMPARISON OF THE TEST RESULTS WITH ARTHROSCOPY FINDING

ORIGINAL ARTICLE

AUTHORS:

1. Santhamoorthy T.
2. Arun K.

PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Orthopaedics, Sri Venkateswara Medical College Hospital and Research Center, Ariyur, Puducherry.
2. Senior Resident, Department of Orthopaedics, Sri Venkateswara Medical College Hospital and Research Center, Ariyur, Puducherry.

NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Santhamoorthy T,
5, Ragavendra Illam,
Indhira Gandhi St,
Nainarmandapam,
Puducherry-605004.
Email: santhamoorthy@yahoo.com

Date of Submission: 15/07/2014.

Date of Peer Review: 16/07/2014.

Date of Acceptance: 28/07/2014.

Date of Publishing: 04/08/2014.