Asian Journal of Orthopaedic Research

3(4): 6-12, 2020; Article no.AJORR.56959

Reliability of Different Methods for Measuring Stress Radiographs in Posterior Cruciate Ligament Insufficiency

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SC and PS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PS and CL managed the analyses of the study. Author SC managed the literature searches, ethical consideration and data management. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Parth Trivedi, C.M. Patel College of Physiotherapy, India.
Reviewers:
(1) Guzelali Ozdemir, Ankara City Hospital, Turkey.
(2) Marc Prod'homme, Neuro Orthopedic Center, Switzerland.
Complete Peer review History: http://www.sdiarticle4.com/review-history/56959

Original Research Article

Received 09 March 2020
Accepted 14 May 2020
Published 29 May 2020

ABSTRACT

Aims: This study aims to assess the intraobserver and interobserver reliability of various measurement methods of stress radiographs in PCL insufficiency.
Study Design: Descriptive study.
Place and Duration of Study: Department of Orthopaedics, at Rajavithi Hospital, Bangkok between December 2015 and June 2016.
Methodology: Three measurement methods including Mid-Mid Method, Blumensaat's Line-Posterior Tibia Method and Blumensaat's Line-Anterior Tibia Method were employed. Each technique performed twice by two orthopaedic surgeons. Patients were assessed at day 0 and at 4 weeks. Intrarater and interrater reliability of measurements in PCL Radiographs were observed.
Results: The findings indicate that the Blumensaat's line-posterior tibia method showed the highest intraobserver reliability. For intrarater agreement, each method produced high correlation ($r > 0.9$) at both week 0 and 4. Regarding interrater agreement between two surgeons, high correlation ($r > 0.8$) was found in Mid-Mid Method and Blumensaat's Line-Posterior Tibia Method, while the Blumensaat's Line-Anterior Tibia method gave medium level of correlation

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(r=0.528-0.675). Both surgeons indicated similar results for each pair of measurement. The Mid-Mid Method and Blumensaat's Line-Posterior Tibia Method showed positive correlation of measurement. Mid-Mid Method and Blumensaat's Line-Anterior Tibia Method, and Blumensaat's Line-Posterior Tibia Method and Blumensaat's Line-Anterior Tibia Method showed negative correlation of measurement.

Conclusion: The Blumensaat's line-anterior tibia method produced the highest intraobserver and interobserver reliability in measuring stress radiographs in posterior cruciate ligament insufficiency.

Keywords: Stress radiograph; posterior cruciate ligament; Blumensaat's line-posterior tibia; Blumensaat's line-anterior tibia.

1. INTRODUCTION

The incidence of posterior cruciate ligament (PCL) injuries is 3% of outpatient knee injuries and 38% of acute traumatic knee hemarthrosis [1]. PCL-deficient knee examinations need to be performed by experienced doctors since they usually involve a posteriorly translated position (posterior sag) which can be mistakenly diagnosed as ACL insufficiency [2].

Stress radiography devices are reliable, causing only few mistakes, and widely used abroad. In August 2014, Rajavithi Hospital and the Faculty of Applied Science of King Mongkut's University of Technology North Bangkok used the Rajavithi Stress Device for the first time in Thailand [3]. The Rajavithi Stress Device can confirm the diagnosis of sagittal knee instability and are more reliable than physical examinations [4].

In the diagnosis of PCL injuries, stress radiography devices can measure the translation of the tibia relative to the femur and compare the injured side with the uninjured side. Translation differences of 0-7 mm, 8-11 mm and ≥12 mm can be interpreted as isolated PCL partial tears, isolated PCL complete tears and combined PCL and PLC tears, respectively [5].

The important factors in the measurement of translation are assigned points on the femur and the tibia. However, the positions of the knee landmarks are affected by changes in the degree of flexion and the rotation of the knee. The peripheral landmarks can be changed by the degree of rotation while the central landmarks can be changed by the degree of flexion [6-7]. Therefore, Wirz et al. recommended a central-peripheral method to determine the translation of the tibia [7].

According to the above-mentioned concept, we chose the central and peripheral landmarks (the Blumensaat's line as a femoral landmark and the anterior cortical line of the proximal tibia as a tibial landmark) because they can be easily identified.

The purpose of this study is to evaluate the intraobserver and interobserver reliability of various measurement methods of stress radiographs in PCL insufficiency.

2. MATERIALS AND METHODS

Stress radiographs in 20 patients with PCL insufficiency were examined at Rajavithi Hospital between December 2015 and June 2016. Informed consent forms were obtained from patients and those who refused to participate were excluded. The research protocol was reviewed and approved by the ethics committee of Rajavithi Hospital. The examination was performed in the lateral decubitus position with the knee flexed at 90 degrees. Using the Rajavithi Stress Device, a 90-newton posterior force was applied to the proximal leg 10 cm below the joint line (Fig. 1).Clinical examination was performed such as anterior cruciate ligament, Lachman test and range of motion.

2.1 Measurement Methods

In the examination**,** three measurement methods were applied, each performed twice by two observers who are orthopaedic surgeons. Patients were assessed at day 0 and at 4 weeks.To reduce recall bias, the radiographs were renumbered in the second-time measurements. The reference line refers to the line between the medial and lateral tibial plateau. The 3 measurement methods are as follows:

1. **Mid-Mid Method:** This measurement method was proposed by Jacobsen [8] and Staubli [9]. From the reference line, a perpendicular line was drawn tangentially to the midpoint between the most posterior contour of the medial and lateral femoral

condyle and tibial plateau. The distance between these 2 points was measured (Fig. 2).

2. **Blumensaat's Line-Posterior Tibia Method:** This measurement method was proposed by Jackman T, et al. [5]. A point on the posterior aspect of the tibia was identified 15 cm distal to the reference line (Fig. 3A). From that point, a line was extended parallel to the posterior cortex and proximal to the knee joint (Fig. 3B). A perpendicular line was drawn from this line to the posterior point of the Blumensaat's line and the distance was measured (Fig. 3C).
3. **Blumensaat's Line-Anterior Tibia Method:** From the reference line, perpendicular lines were drawn tangentially to the most posterior point of the Blumensaat's line and the distance between that point and the connecting point between the anterior cortex of the proximal tibia and the tibial plateau was measured (Fig. 4).

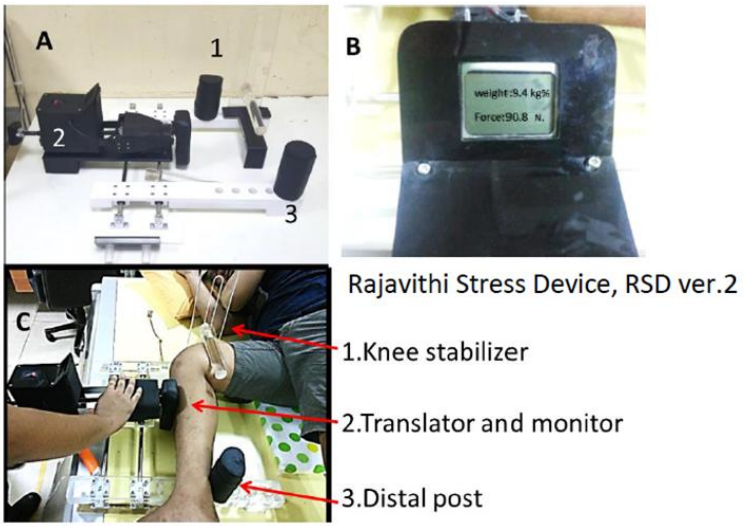

Fig. 1. The rajavithi Stress device, RSD version 2

A; the RSD with body, knee stabilizer (proximal post), distal post, translator and monitor (B). C; the RSD and the translator are applied with a 90-newton force posterior translation on the anterior surface of the tibia and 10 cm below the joint line

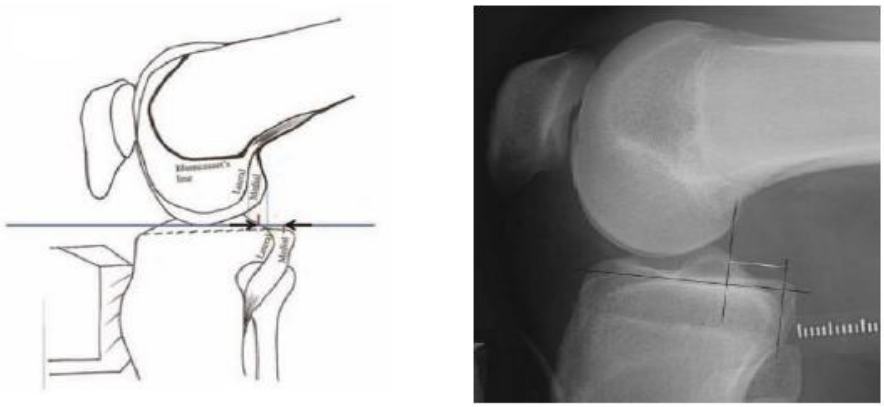

Fig. 2.The mid-mid method

From the reference line, a perpendicular line was drawn tangentially to the midpoint between the most posterior contour of the medial and lateral femoral condyle and tibial plateau. The distance between these 2 points was measured

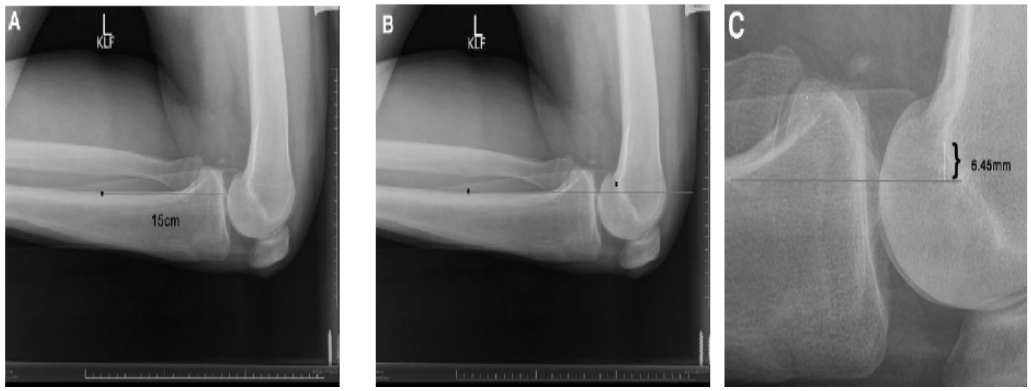

Fig. 3. The Blumensaat line-posterior tibia method

A, a point was identified along the posterior cortex 15 cm from the joint line. B, a line was then drawn from that point parallel to the posterior cortex, through the femoral condyles (line), and the most posterior point of the Blumensaat line was marked (asterisk). C, a perpendicular line was drawn from that point to intersect the first line and in this case measured 6.45 mm

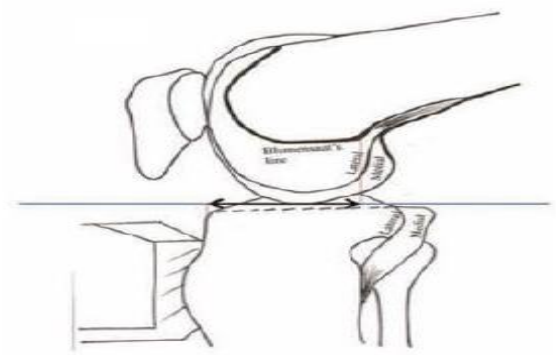

Fig. 4. The Blumensaat line-anterior tibia method

From the reference line, perpendicular lines were drawn tangentially to the most posterior point of the Blumensaat's line and the distance between that point and the connecting point between the anterior cortex of the proximal tibia and the tibial plateau was measured.

2.2 Statistical Analysis

Statistical analysis was conducted to test the reliability by running a paired t-test to analyze the intraobserver (in each observer between the first-time and second-time measurements) and interobserver (between two observers in the first-time and second-time measurements) reliability. *Pearson's correlation test* was performed to assess the reliability of each method. A p-value less than 0.05 was set as a statistical significance.

3. RESULTS

The subjects were 30 males and 10 females with mean age of 31.25 years. Most knees were left side (55%). The posterior drawer test (PDT) grading 3 was most observed. Main causes of injury were motorvehicle accident (60%) followed by sport injuries (30%) and occupational and home injuries. Demographic data of subjects are shown in Table 1.

The Blumensaat's Line-Posterior Tibia Method showed the highest intraobserver reliability. The intraobserver reliability results of the first observer were as follows: Mid-Mid Method: 0.917, Blumensaat's Line-Posterior Tibia Method: 0.941 and Blumensaat's Line-Anterior Tibia Method: 0.909; the intraobserver reliability results of the second observer were Mid-Mid Method: 0.975, Blumensaat's Line-Posterior Tibia Method: 0.995 and Blumensaat's Line-Anterior Tibia Method: 0.978 (Table 2). All of the 3 measurement methods showed excellent intraobserver reliability. The interobserver reliability results of the first-time measurements

were as follows: Mid-Mid Method: 0.858, Blumensaat's Line-Posterior Tibia Method: 0.916 and Blumensaat's Line-Anterior Tibia Method: 0.528; the interobserver reliability results of the second-time measurements are Mid-Mid Method: 0.917, Blumensaat's Line-Posterior Tibia Method: 0.806 and Blumensaat's Line-Anterior Tibia Method: 0.675 (Table 3). The Mid-Mid and Blumensaat's Line-Posterior Tibia Methods produced the high interobserver reliability. The reliability between methods found that Mid-Mid and Blumensaat's Line-Posterior Tibia Method produced excellent reliability. The reliability results of the first and second observers are 0.576 and 0.697 which positive correlation, respectively (Table 4).

4. DISCUSSION

The important finding of this study was that the Blumensaat's line-anterior tibia method produced the highest intraobserver and interobserver reliability. However, this study was conducted among a group of patients with PCL insufficiency only.

Stress radiography devices are reliable and reproducible, resulting in few errors. Hewett et al compared stress radiographs with both the KT-2000 arthrometer and the posterior drawer test [10]. They concluded that the radiographic technique was superior to both the arthrometer and the physical examination in determining posterior laxity. Although stress radiography was superior to both the arthrometer and the physical examination as only skeletal elements are measured, which eliminates the errors induced by soft tissues, the accuracy of stress radiographs was influenced by multiple variables. The absence of patients' relaxation may lead to quadriceps muscle activity and thus reduced posterior displacement [11]. The most problematic variable was rotational error, which can be introduced from rotation of the limb, rotation of the x-ray beam or both produced by the translation of the knee.

The new method in this study was the Blumensaat's line-anterior tibia method. We adopted this method because both points can be easily identified and were less affected by knee flexion angles and rotation. In the Blumensaat's line-posterior tibia method, we found that a line parallel to the posterior tibial cortex was difficult to draw due to the champagne glass-shaped posterior tibial plateau. In the Mid-Mid method, the tibial reference point was difficult to determine because of the variable contours, especially of the medial tibial plateau, which was larger and squared more posteriorly than the lateral tibial plateau. However, the Mid-Mid method also gave high Intraraterand interrater reliability.

Young Seuk Lee et al. reported that the Blumensaat's line-anterior tibia method produced the best results of the reliability measurement and the test-retest reproducibility [12]. However, in his study, he used the horizontal line as the reference line which was affected by knee flexion angles. Therefore, we used the line between the medial and lateral tibial plateau as the reference line.

Table 1. Demographic data(n = 40)

Demographic Factors		Number	Percentage
Gender			
	Male	30	75.0
	Female	10	25.0
Age	Mean (min-max, yrs.)	31.25 (17-56)	
Side			
	Left	22	55.0
	Right	18	45.0
PDT Grading			
	1	0	0.0
	2	10	25.0
	3	30	75.0
Causes of injury			
	Motor vehicle accident	24	60.0
	Sport injuries	12	30.0
	Occupational injuries	2	5.0
	Home injuries	2	5.0

PDT; posterior drawer test

Table 2. Intrarater reliability of measurements in posterior drawer stress radiographs at week 0 and week 4 (Intrarater agreement)

Surgeons	Methods	Week 0	Week 4	Correlation	*P*	*P*
1	Mid-Mid Method	17.41±6.15	17.01±6.29	0.917	<0.001*[r]	0.493[t]
	Blumensaat's Line-Posterior Tibia Method	4.20±7.30	4.06±8.63	0.941	<0.001*[r]	0.829[t]
	Blumensaat's Line-Anterior Tibia Method	29.19±5.23	30.08±6.00	0.909	<0.001*[r]	0.129[t]
2	Mid-Mid Method	16.30±5.22	16.36±5.14	0.975	<0.001*[r]	0.809[t]
	Blumensaat's Line-Posterior Tibia Method	5.65±6.51	5.64±6.03	0.995	<0.001*[r]	0.959[t]
	Blumensaat's Line-Anterior Tibia Method	30.96±6.37	30.72±5.79	0.978	<0.001*[r]	0.442[t]

*r = P from Correlatiom, t = P from Paired t-test, * = significance at P less than 0.05*

Table 3. Interrater Reliability of Measurements in Posterior Drawer Stress Radiographs between two surgeons at week 0 and week 4 (Intrarater agreement)

Times	Methods	Surgeon 1	Surgeon 2	Correlation	*P*	*P*
Week 0	Mid-Mid Method	17.41±6.15	16.30±5.22	0.858	<0.001*[r]	0.134[t]
	Blumensaat's Line-Posterior Tibia Method	4.20±7.30	5.65±6.51	0.916	<0.001*[r]	0.040*[t]
	Blumensaat's Line-Anterior Tibia Method	29.19±5.23	30.96±6.37	0.528	0.017*[r]	0.182[t]
Week 4	Mid-Mid Method	17.01±6.29	16.36±5.14	0.917	<0.001*[r]	0.278[t]
	Blumensaat's Line-Posterior Tibia Method	4.06±8.63	5.64±6.03	0.806	<0.001*[r]	0.189[t]
	Blumensaat's Line-Anterior Tibia Method	30.08±6.00	30.72±5.79	0.675	<0.001*[r]	0.556[t]

*r = P from correlatiom, t = P from paired t-test, * = significance at P less than 0.05*

Table 4. Agreement of measurement among three different methods between two surgeons

Surgeon	Mid-Mid Method	Blumensaat's Line-posterior tibia method	Blumensaat's Line-anterior tibia method	Correlation	*P*	*P*
1	17.21±6.14	4.13±7.89	-	0.576	<0.001*[r]	<0.001*[t]
	17.21±6.14	-	29.64±5.58	-0.588	<0.001*[r]	<0.001*[t]
	-	4.13±7.89	29.64±5.58	-0.692	<0.001*[r]	<0.001*[t]
2	16.33±5.11	5.64±6.19	-	0.697	<0.001*[r]	<0.001*[t]
	16.33±5.11	-	30.84±6.01	-0.432	0.005[r]	<0.001*[t]
	-	5.64±6.19	30.84±6.01	-0.536	<0.001*[r]	<0.001*[t]

*r = P from Correlatiom, t = P from Paired t-test, * = significance at P less than 0.05*

In our study, we didn't test the reliability of these methods in determining posteriorlaxity. The limitation was few samples of patient. Further research should increase number of subjects.

5. CONCLUSION

The Blumensaat's line-anterior tibia method produced the highest intraobserver and interobserver reliability in measuring stress radiographs in posterior cruciate ligament insufficiency. The measurement method form this study was acceptable. These methods would be applied to diagnose isolated PCL deficiency instead of MRI.

CONSENT

Informed and written consent forms were obtained from patients.

ETHICAL APPROVAL

This study was reviewed and approved by the Ethics committee, Rajavithi hospital (No 245/2561).

ACKNOWLEDGEMENTS

The authors wish to thank all the individuals who contributed data for the purposes of this study. We are grateful for the staffs of Medical Research Division, Rajavithi Hospital for assisting manuscript preparation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/56959