Anterior Tibial Subluxation Based on Tibial Bone Axis Using Knee Extended Load-Bearing Radiograph could Predict the Rotational Instability of the Knee

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INTRODUCTION:

Anterior cruciate ligament reconstruction (ACLR) improves anterior-posterior and rotational instability of the knee joint, resulting in closer to physiological knee motion. However, the knee after ACLR still has abnormal movement and proceeds to the development of postoperative traumatic osteoarthritis (PTOA). Objective indicators are important for accurate assessment of knee motion. Dynamic manual tests to assess instability, i.e. the Lachman test (Lach) and the Pivot shift test (PS), involve the problem of examiner's bias. Anterior Tibial Subluxation (ATS) is the evaluation tool for assessing the femur-tibia positioning using the images. The ATS on MRI in the non load-bearing knee extension position has been reported as a useful evaluation tool for the knee after ACLR. We hypothesized that ATS in load-bearing would reflect knee instability acutely. The purpose of this study was to investigate the relationship between knee instabilities and several ATS measures using a knee extended load-bearing radiograph.

METHODS:

This is a part of a prospective multicenter ACLR cohort study, approved by our institutional review board and all patients signed a consent form. Patients who had taken knee extended load-bearing radiographs both preoperatively and 3-month postoperatively were included in this study. Cases with complex ligament injuries were excluded. Each ATS was measured preoperatively and 3-month postoperatively, and preoperative posterior tibial slope (PTS) was obtained from the radiographs. Age, body mass index (BMI), time from injury to surgery, Lach, and PS were obtained from the database. Lach and PS were evaluated by IKDC grade under preoperative anesthesia, with B or below defined as “Low grade” and C or above as “High grade”.

We examined the following two ATS measurement methods, (1) Drawing a line perpendicular to the medial tibial articular surface and tangent to the posterior margin of the medial and lateral sides of the tibia, respectively. Similarly, a line was drawn tangent to the medial and lateral posterior femoral condyles, and the distance between the medial and lateral lines was measured as articular surface-ATS (AS-ATS) (Figure 1a). (2) The tibial bone axis was translated so that it was tangent to the medial and lateral posterior tibial and posterior femoral condyles, respectively. The distance between the medial and lateral lines was measured as bone axis-ATS (BA-ATS) (Fig. 1b). The tibial bone axis was defined as a line passing through the midpoint of the anteroposterior cortex at 5 cm and 15 cm from the articular surface.

Each ATS was evaluated as lateral (l-ATS), medial (m-ATS), difference between lateral and medial (d-ATS), and midpoint between medial and lateral (mid-ATS). ATS measurements for twenty-four knees were measured twice by two orthopaedic surgeons (over 5 years of experience) to calculate intraclass correlation coefficients (ICC) (1.1) and ICC (2.1) to assess the reproducibility. The pre and postoperative ATS were compared by paired t-test. Multiple regression analyses were performed to investigate the factors associated with preoperative ATS in each method. Each ATS was determined as the dependent variable and Lach, PS, PTS, BMI, age, and time from injury were determined as explanatory variables.

The significance level for statistical analysis was set at p-value < 0.05. All statistical analyses were performed using JMP Pro Version 15.0.0.

RESULTS:

Fifty-nine patients, 27 males and 32 females, with a mean age of 26.7 years were included in this study. The mean BMI was 23.4, the median time from injury was 4 months. The High grade and Low grade of Lach and PS were 26 and 33 cases, and 20 and 39 cases respectively.

ICCs were good or excellent for all ATS measuring methods, with ICC=0.85 or greater. In particular, the intra-rater reliability was excellent with ICC > 0.9.

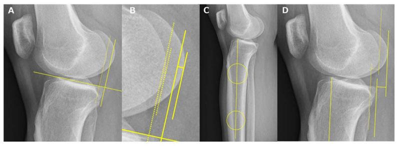
The mean PTS was 11.2°. The summary of ATS is shown in Table 1. Every preoperative ATS was greater than ATS 3-month postoperatively ($p<0.05$) .

Multiple regression analysis showed that each ATS parameter was not correlated with the Lach. While the AS-ATS was not correlated with the PS, the l-ATS and d-ATS of BA-ATS were correlated with the PS ($p<0.05$) (Table 2).

DISCUSSION AND CONCLUSION:

The reproducibilities of ATS in both methods were favorable. Every ATS 3-month postoperatively was significantly improved from that of preoperatively. Furthermore, the BA-l-ATS and BA-d-ATS in a knee extended load-bearing lateral radiograph could predict the rotational instability of the knee. This BA-ATS method would be a useful evaluation tool for ACLR.

Figure 1. Method of measuring ATS on the lateral view radiograph



(A) Drawing a line perpendicular to the medial tibial articular surface and tangent to the posterior margin of the medial and lateral sides of the tibia, respectively. (B) Similarly, a line was drawn tangent to the medial and lateral posterior femoral condyles, and the distance between the medial and lateral lines was measured as Articular Surface-ATS (AS-ATS).
(C) A line through the midpoint of the anteroposterior cortex at 5 cm and 15 cm from the tibial articular surface was defined as the tibial bone axis. (D) The tibial bone axis was translated so that it was tangent to the medial and lateral posterior tibial and posterior femoral condyles, respectively. The distance between the medial and lateral lines was measured as Bone Axis-ATS (BA-ATS).
The ATS was determined as a positive value if the tibia was positioned anterior to the femur.

Table1. ATS measurement

AS-ATS	ICC (1, 1)	95%CI	ICC (2, 1)	95%CI	Pre-ATS, mm	Post-ATS, mm	p-value
lateral	0.96	0.91-0.98	0.94	0.88-0.98	1.2 ± 4.1	-2.6 ± 3.7	<0.0001
medial	0.91	0.81-0.96	0.87	0.72-0.94	1.2 ± 3.5	-0.7 ± 3.0	<0.0001
midpoint	0.94	0.88-0.98	0.91	0.80-0.96	1.3 ± 3.2	-1.6 ± 2.7	<0.0001
difference	0.95	0.89-0.98	0.9	0.78-0.95	-0.1 ± 4.3	-1.9 ± 4.0	0.004
BA-ATS							
lateral	0.96	0.91-0.98	0.93	0.86-0.97	8.2 ± 4.8	5.2 ± 4.0	<0.0001
medial	0.94	0.86-0.97	0.95	0.90-0.98	8.6 ± 3.8	6.9 ± 4.0	<0.0001
midpoint	0.96	0.91-0.98	0.97	0.94-0.99	8.6 ± 3.8	6.1 ± 3.6	<0.0001
difference	0.91	0.81-0.96	0.86	0.70-0.93	-0.3 ± 4.6	-1.7 ± 3.8	0.03

ICC of the ATS measurement method and the value of ATS pre-ACLR and 3-month post-ACLR.
Abbreviation: ICC, Intraclass Correlation Coefficient; CI, Confidene Interval; ATS, Anterior Tibial Subluxation; ACLR, Anterior Cruciate Ligament Reconstruction; AS, Articular Surface; BA, Bone Axis

Table2. Multi regression analysis of predicting ATS with standardized β results

		Lachman test	Pivot shift test	Age	BMI	Time from injury to operation	PTS
AS-ATS	lateral	-0.05	0.20	0.09	0.07	-0.24	-0.21
	medial	0.12	-0.01	0.26	**-0.34**	-0.11	0.12
	midpoint	-0.02	0.18	0.18	-0.08	-0.24	-0.05
	difference	-0.15	0.19	-0.14	**0.35**	-0.13	**-0.30**
BA-ATS	lateral	-0.11	**0.31**	**0.11**	0.18	-0.29	**0.27**
	medial	0.11	-0.04	0.22	**-0.29**	<0.01	**0.59**
	midpoint	-0.04	0.18	0.17	-0.03	-0.21	**0.51**
	difference	-0.21	**0.33**	**-0.08**	**0.42**	-0.28	-0.24

Abbreviation: ATS, Anterior Tibial Subluxation; AS, Articular Surface; BA, Bone Axis; BMI, Body Mass Index; PTS, Posterior Tibial Slope
Red bold value indicates p<0.05