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Restoration of the Meniscus: Form and Function

The American Orthopaedic Society for Sports Medicine

Posterior Tibial Slope Influences Static Anterior Tibial Translation in Anterior Cruciate Ligament Reconstruction

A Minimum 2-Year Follow-up Study

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Background: Posterior tibial slope (PTS) has recently been identified as a risk factor for anterior cruciate ligament (ACL) injuries because of an associated increase in anterior tibial translation (ATT) and ACL loading. However, few studies concerning the correlation between PTS and postoperative ATT have been published.

Purpose: To analyze the relationship between PTS and postoperative ATT in ACL reconstruction (ACLR).

Study Design: Case control study; Level of evidence, 3.

Methods: Included in this retrospective study were 40 consecutive patients who underwent ACLR (28 male, 12 female; median age, 22 years; range, 14-44 years) from October 2010 to June 2011. The patients were divided into 3 groups based on medial and lateral PTS values as measured on MRI. Demographic data and results of the manual maximum side-to-side difference with a KT-1000 arthrometer at 30° of knee flexion before ACLR and at final follow-up were collected; results were divided into ATT $\leq$2 mm, 2 mm $<$ ATT $<$ 5 mm, and ATT $\geq$5 mm. First, the distribution of ATT in the 3 groups was compared, and then correlation analysis and logistic regression were conducted to determine the correlation between PTS and ATT. Finally, the thresholds of medial and lateral PTS were calculated.

Results: Results of the ATT measurements were collected at a mean of 27.5 months (range, 24.0-37.0 months) after ACLR. The group with a PTS $\geq$5° had significantly more cases of ATT $\geq$5 mm than the group with a PTS $<$3° (medial PTS: P = .005; lateral PTS: P = .016). There were statistically significant correlations with ATT for both medial (r = 0.43, P = .005) and lateral (r = 0.36, P = .02) PTS. Medial or lateral PTS resulted in the increased probability of ATT $\geq$5 mm, with an odds ratio of 1.76 (P = .011) and 1.68 (P = .008), respectively. The threshold of an increased risk of ATT $\geq$5 mm was a medial PTS $>$5.6° (P = .003) or a lateral PTS $>$3.8° (P = .002).

Conclusion: There was a significant correlation between PTS and postoperative anterior knee static stability in this study. Patients with a steeper medial or lateral PTS showed a higher risk of ATT $\geq$5 mm at thresholds of 5.6° and 3.8°, respectively.

Keywords: anterior cruciate ligament reconstruction; anterior tibial translation; medial posterior tibial slope; lateral posterior slope; correlation; risk factor

An increasing number of studies concerning the correlation between posterior tibial slope (PTS) and anterior cruciate ligament (ACL) injury have recently been published.[1,3,9,19] To explain this correlation, it has been suggested that tibial slope influences the biomechanics of the tibiofemoral joint with respect to an increase in anterior tibial translation (ATT), tibial shear force, and ACL loading.[2,14,16,17] It is reasonable to suppose that the same mechanism that influences the natural ACL might also influence the reconstructed ACL autograft. The risk factor for ACL injuries might also be a risk factor for postoperative ATT.

To our knowledge, very few studies regarding the relationship between PTS and ACL clinical outcomes have been published. Zaffagnini et al[22] discovered a positive correlation between PTS and postoperative manual maximum displacement results with a KT-1000 arthrometer of the indexed knee in patients undergoing combined ACL reconstruction (ACLR) and high tibial osteotomy. Webb et al[21]

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reported that an increased PTS is associated with the increased odds of a further ACL injury after ACLR. However, Hohmann et al[8] reported that ACL-reconstructed knees with a higher PTS had better function.

The purpose of this study was to determine the relationship between 2 static variables, PTS and postoperative static ATT, in ACL-reconstructed knees. The hypotheses were that (1) a medial and/or lateral tibial slope had a significant positive correlation with postoperative ATT and (2) patients with a steeper medial and/or lateral PTS have a higher incidence of ATT ≥5 mm.

MATERIALS AND METHODS

Study Design

We retrospectively reviewed all patients who underwent ACLR at our institution from October 2010 to June 2011. A total of 121 patients who underwent ACLR performed by a single surgeon were identified. The patients were eligible for inclusion in this study if they (1) had a complete ACL tear, (2) had a unilateral ACL injury, (3) had both ACLR and magnetic resonance imaging (MRI) performed at our institution, (4) were younger than 45 years, (5) underwent single-bundle ACLR with a hamstring tendon autograft, and (6) had a noncontact ACL injury. The exclusion criteria were (1) a concomitant posterior cruciate ligament (PCL) lesion, lateral collateral ligament, or medial collateral ligament grade 3 lesion; (2) revision ACLR; (3) total meniscectomy; (4) skeletal malalignment of the lower limb (varus aligned: hip-knee-ankle angle >182°, valgus aligned: hip-knee-ankle angle <178°); (5) previous knee surgery before ACLR; and (6) general joint laxity. Of the 81 excluded patients, there were 40 Achilles tendon allograft or hybrid graft reconstructions, 32 double-bundle ACLRs, 3 revision ACLRs, 1 concomitant superficial medial collateral ligament reconstruction, 3 concomitant PCL lesions, 1 total meniscectomy, and 1 previous arthroscopic surgery (medial partial meniscectomy). Of the 40 study participants, 27 cases were combined with a medial meniscus injury, of which 4 cases of medial meniscus posterior horn lesions were identified. All of the 4 lesions were repaired with an all-inside technique, and they were well maintained according to MRI at final follow-up. The other 23 medial meniscus tears were treated by partial meniscectomy. This study was approved by the local ethics committee, and all enrolled patients signed an informed consent form.

Demographic data and results of the manual maximum side-to-side difference with a KT-1000 arthrometer (MEDmetric, San Diego, California, USA) at 30° of knee flexion were acquired. The data were collected before ACLR and at final follow-up by a senior surgeon. The ATT was defined as the manual maximum side-to-side difference as measured by a KT-1000 arthrometer, and the medial and lateral PTS were measured on initial MRI scans before primary reconstruction.

To discover the distribution of postoperative ATT, the PTS measurements were divided into tertiles. The first tertiles of medial and lateral PTS were 3.6° and 2.6°, and the second tertiles were 5.3° and 5.6°, respectively. Consequently, we divided the medial and lateral PTS values as PTS <3°, 3° ≥ PTS < 5°, and PTS ≥5°. First, the distributions of ATT in the 3 groups were compared. Then, analyses were conducted to determine the correlation between PTS and ATT. Logistic regression was performed to determine if PTS was a risk factor for ATT ≥5 mm and to determine the threshold for a significantly increased risk of ATT ≥5 mm.

An ATT ≥5 mm is one of the criteria of ACLR failure according to Kamien et al,[12] and an ATT ≤2 mm is defined as normal according to International Knee Documentation Committee (IKDC) guidelines.[7] We therefore separated ATT measurements at final follow-up into 3 groups: ATT ≤2 mm, 2 mm < ATT < 5 mm, and ATT ≥5 mm.

Surgical Technique and Rehabilitation Protocol

All single-bundle ACLRs were performed by a single senior surgeon using 4-strand hamstring tendon autografts. The diameter of the autograft was between 7.5 and 9 mm. The tibial tunnel was drilled at the center of the footprint, and the femoral tunnel was drilled at the anteromedial bundle position through the anteromedial portal. The RigidFix and IntraFix systems (DePuy Mitek, Raynham, Massachusetts, USA) were used for femoral and tibial side fixations, respectively, and the graft was tensioned at 20 lb with the knee slightly flexed.

All patients underwent the same rehabilitation protocol. A hinged knee brace locked in full extension was used for the first 4 weeks. One week after surgery, passive range of motion from 0° to 90° was started with the brace unlocked. Partial weightbearing was not allowed until 4 weeks after surgery with the hinged brace locked in full extension. Full weightbearing was begun at 6 weeks. Jogging was not permitted until 3 months postoperatively. Patients were allowed to return to sports at 9 to 12 months after surgery.

PTS Measurement

Measurements of medial and lateral PTS using conventional MRI scans with a T1 sequence were performed according to the method of Hudek et al.[11] The MRI scans were obtained with a 1.5-T MRI scanner (Symphony, Siemens Medical Solutions, Erlangen, Germany).

To measure PTS, a 3-step procedure proposed by Hudek et al[10,11] was applied. The first step was to define the central sagittal slice, which consisted of the intercondylar eminence, the anterior and posterior tibial cortices appearing as a concave shape, and the tibial attachment of the PCL (Figure 1A). The second step was to draw a circle tangent to the proximal, anterior, and posterior tibial borders and then a second circle centered on the perimeter of the first circle. The line connecting the centers of the circles was defined as the tibial longitudinal axis. The last step was to measure the angle between the line perpendicular to the tibial longitudinal axis and the tangent to the medial and lateral tibial plateaus. The tangent to the medial and lateral tibial plateaus was defined as the line connecting the uppermost of sites on the superior-anterior and posterior cortices on the middle slice between the most

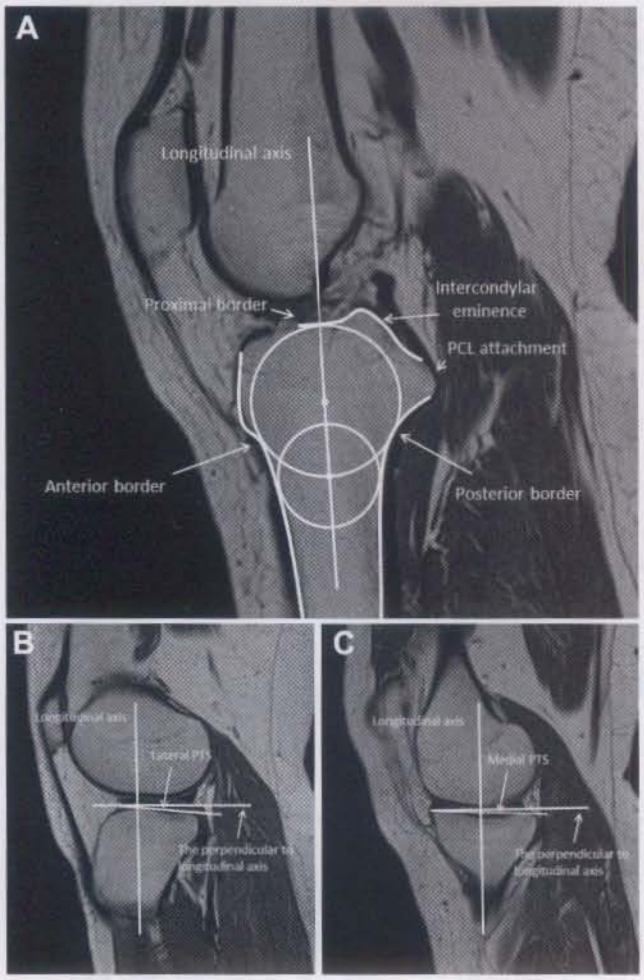

Figure 1. To measure posterior tibial slope (PTS) by conventional MRI scans, the 3-step procedure proposed by Hudek et al[10,11] was applied. (A) First, the central sagittal slice, consisting of the intercondylar eminence, the anterior and posterior tibial cortices appearing as a concave shape, and the tibial attachment of the posterior cruciate ligament, was identified. Then, the proximal tibial anatomic axis was defined by drawing a circle tangent to the proximal, anterior, and posterior tibial borders and then a second circle centered on the perimeter of the first circle. The line connecting the centers of the circles was defined as the tibial longitudinal axis. Third, the tibial slope angle was measured. (B, C) The angle between the line perpendicular to the tibial longitudinal axis and the tangent to the lateral and medial tibial plateaus was the lateral and medial tibial PTS, respectively. The tangent to the lateral and medial tibial plateaus was defined as the line connecting the uppermost of sites on the superior-anterior and posterior cortices on the middle slice between the most lateral/medial slice and the central sagittal slice.

lateral/medial slice and the central sagittal slice (Figure 1B and 1C).

All of the measurements were performed by 2 authors (Y.L. and G.S.). To determine the interobserver and intraobserver reproducibility, the intraclass correlation coefficient (ICC) was calculated by randomly selecting 18 patients (9 medial PTS and 9 lateral PTS); ICC values >0.9 were considered excellent, and values between 0.8 and 0.9 were considered good.[11] Two blinded observers measured both the medial and lateral PTS, and 1 independent observer measured all selected patients twice 1 month apart. The interobserver and intraobserver ICCs for the medial PTS measurement were 0.85 and 0.89, and the interobserver and intraobserver ICCs for the lateral PTS measurement were 0.95 and 0.96, respectively.

Statistical Analysis

All analyses were performed on SPSS software for Windows (v 19.0, SPSS Inc, Chicago, Illinois, USA) and GraphPad Prism (v 6.0, GraphPad Software, San Diego, California, USA). An a priori power analysis was conducted. For $\alpha = .05$, a power of 0.8, and with a difference of ATT >2 mm as significant, the calculated minimum sample size was 33 patients. For $\alpha = .05$, a power of 0.8, and to discover a statistically significant ($P < .05$) correlation of $r > 0.45$ between PTS and ATT, the calculated minimum sample size was 36 patients. As a result, 40 was set as an adequate sample size.

The normality tests demonstrated that patient age, time from injury to ACLR, follow-up time, and ATT at final follow-up were not normally distributed, while both medial and lateral PTS were. The Pearson χ^2 test was used to compare sex, injury side, and distribution of the associated injury. The interobserver and intraobserver reproducibility were determined by the ICC. The Kruskal-Wallis and Mann-Whitney U tests were used to compare age, time from injury to ACLR, and follow-up time. A Spearman rank correlation test was performed to identify the relationship between PTS and ATT. A linear regression was conducted to calculate the correlation coefficient and relationship between PTS and ATT. A binary logistic regression was also conducted to determine the odds of ATT $\geq$5 mm in medial and lateral PTS.

A receiver operating characteristic (ROC) curve was drawn to identify the efficacy and thresholds of PTS as a predictor of postoperative knee anterior stability. An area under the curve (AUC) of <0.7 was poor, 0.7 < AUC < 0.9 was good, and AUC >0.9 was considered an excellent predictor. Each point on the ROC curve was defined by the value of specificity and 1 − sensitivity calculated from each value of PTS. The threshold was a PTS value in which the maximum Youden index[4] (Youden index = specificity + sensitivity − 1) was acquired. The level of significance was set as $P < .05$.

RESULTS

For all 40 participants (28 male, 12 female), the mean ± standard deviation age was 23.5 ± 6.5 years. All data were collected a mean 27.5 ± 3.0 months after ACLR. The mean medial PTS was 4.6° ± 2.8°, and the mean lateral PTS was 4.2° ± 3.4°. All demographic data and postoperative ATTs

TABLE 1
Preoperative Demographic Data of the PTS Groups[a]

	PTS <3°		3° ≤ PTS <5°		PTS ≥5°		*P* Value[b]	
	Medial (n = 11)	Lateral (n = 14)	Medial (n = 10)	Lateral (n = 9)	Medial (n = 19)	Lateral (n = 17)	Medial	Lateral
Age, median (range), y	23 (17-44)	23.5 (17-34)	23.5 (18-34)	23 (15-44)	20 (14-37)	21 (14-37)	.26	.94
Sex, male/female, n	10/1	12/2	6/4	5/4	12/7	11/6	.20	.25
Time from injury to ACLR, median (range), mo	2 (0.1-60)	2.5 (0.1-24)	1.25 (0.1-24)	1 (0.1-60)	1 (0.1-96)	1 (0.1-96)	.79	.55
Follow-up time, median (range), mo	25 (25-37)	13 (12-24)	26 (24-31)	14 (12-17)	28 (25-37)	15 (11-20)	.36	.62
Injury side, left/right, n	4/7	9/5	7/3	4/5	11/8	9/8	.29	.64
Associated injury, n							.23	.13
Medial meniscus injury	2	3	6	4	11	12		
Lateral meniscus injury	1	2	1	1	1	0		
Medial + lateral meniscus injury	5	5	1	2	2	1		

[a]ACLR, anterior cruciate ligament reconstruction; PTS, posterior tibial slope.
[b]The *P* values are comparing all 3 groups.

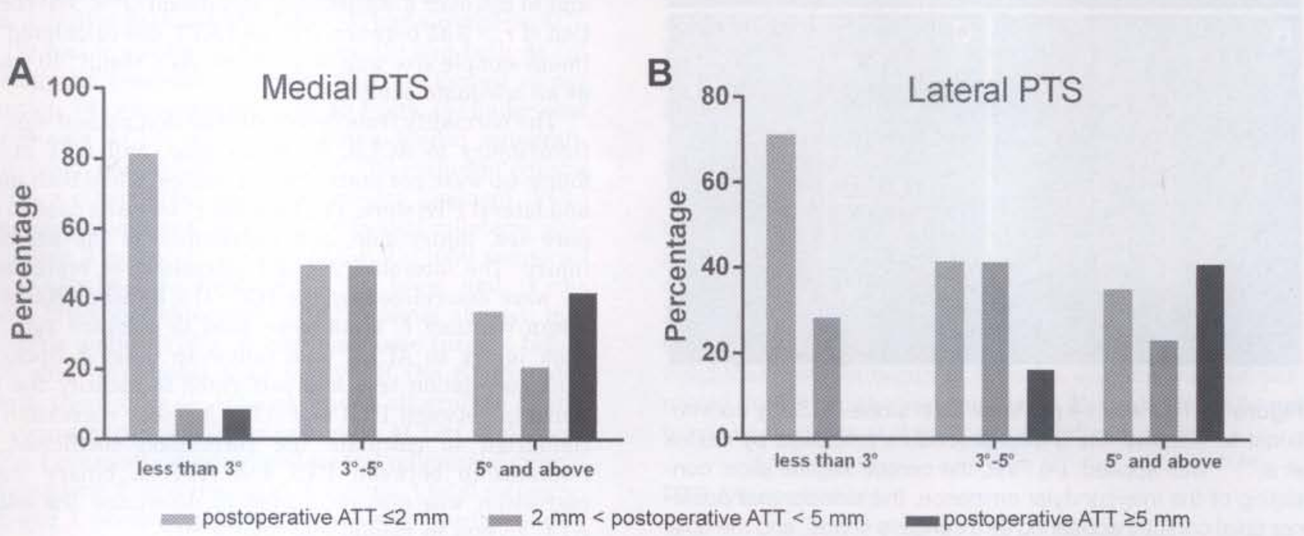

Figure 2. The distribution of postoperative anterior tibial translation values among (A) the 3 medial and (B) 3 lateral posterior tibial slope groups.

are listed in Table 1. There were no significant differences among the medial and lateral PTS groups.

The distribution of postoperative ATT values is illustrated in Figure 2. The group with a lateral PTS ≥5° had significantly more cases of postoperative ATT ≥5 mm than the group with a lateral PTS <3° (P = .016) (Table 2). A significant difference also existed between the groups of medial PTS ≥5° and medial PTS <3° (P = .005).

A significant but moderate linear correlation was found between the medial (r = 0.41, β = .33 ± .11, P = .01) and lateral PTS (r = 0.40, β = .23 ± .10, P = .01) and postoperative ATT (Figure 3).

When all of the patients were separated into 2 groups corresponding to postoperative ATT ≥5 mm and ATT <5 mm, the binary logistic regression revealed an association between PTS and ATT ≥5 mm (medial PTS: P = .011; lateral PTS: P = .008). The odds ratios (ORs) were 1.76 (95% confidence interval [CI], 1.14-2.72) for the medial PTS and 1.68 (95% CI, 1.14-2.46) for the lateral PTS.

To explore the threshold, an ROC curve was drawn (Figure 4). The AUC of the medial PTS was 0.83 ± 0.08 (P = .003). The threshold of the medial PTS was 5.6° (sensitivity: 77.8%; specificity: 77.4%). Patients with a medial PTS >5.6° had 3.5 times (OR, 3.5; 95% CI, 1.4-8.4; P = .006) the risk of postoperative ATT ≥5 mm compared with patients with a medial PTS ≤5.6°.

Lateral PTS was also an effective predictor of postoperative ATT ≥5 mm (AUC = 0.85 ± 0.07; P = .002). The cutoff value was 3.8° (sensitivity: 100%; specificity: 58.1%). The OR value was not reached because of the absence of cases of postoperative ATT ≥5 mm with a lateral PTS <3.8°.

TABLE 2
Postoperative ATT of the PTS Groups[a]

	PTS <3°		3° ≤ PTS <5°		PTS ≥5°		
	Medial (n = 11)	Lateral (n = 14)	Medial (n = 10)	Lateral (n = 9)	Medial (n = 19)	Lateral (n = 17)	Total, n (%)
Postoperative ATT, n							
ATT ≤2 mm	9	10	5	5	7	6	21 (52.5)
2 mm < ATT < 5 mm	1	4	5	2	4	4	10 (25.0)
ATT ≥5 mm	1	0	0	2	8	7	9 (22.5)

[a]There was a statistically significant difference in the distribution of postoperative anterior tibial translation (ATT) among the 3 medial posterior tibial slope (PTS) groups and among the 3 lateral PTS groups (P = .18 and P = .046, respectively).

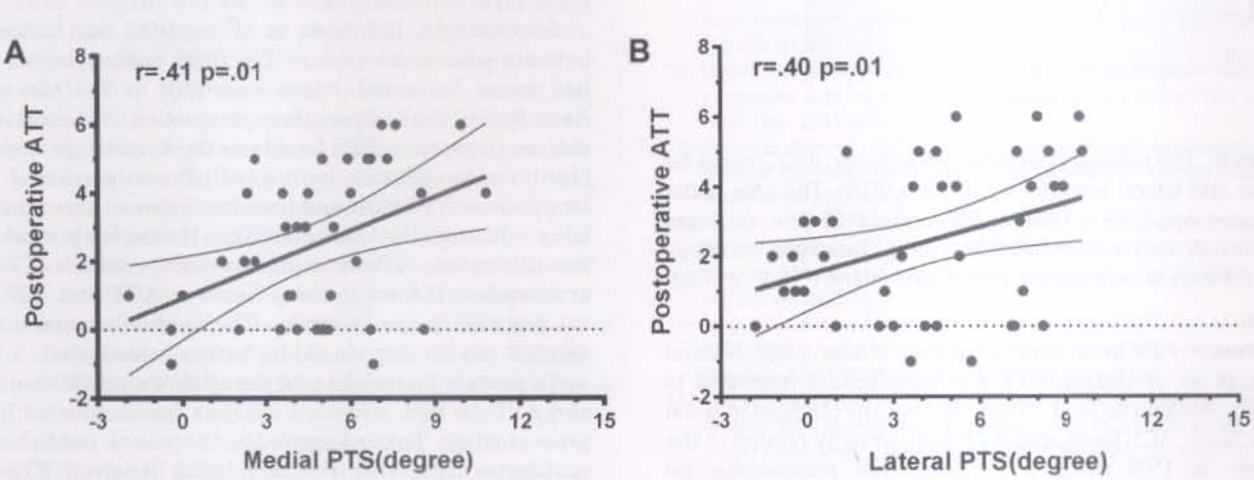

Figure 3. The relationship between postoperative anterior tibial translation (ATT) and (A) lateral posterior tibial slope (PTS) (r = 0.43, P < .005) and (B) mecial PTS (r = 0.36, P = .02). Spearman correlation analysis and linear regression showed a moderate but significant correlation between both lateral and medial PTS and postoperative ATT.

DISCUSSION

The principal purpose of this study was to identify the relationship between PTS and postoperative ATT. The present results supported the hypothesis. The most important finding of this study was the moderate but significant correlation between ATT and both the medial and lateral PTS. In addition, patients with a medial PTS >5.6° or lateral PTS >3.8° have a higher risk of ATT ≥5 mm.

The MRI measurement protocol applied in the present study was invented by Hudek et al[11] and recommended by Lipps et al,[13] who reported good to excellent interobserver and intraobserver reproducibility. In the present study, we achieved a medial and lateral PTS of 4.6° ± 2.8° and 4.2° ± 3.4° (P = .094), respectively, which were comparable with those in a previous study by Hudek et al,[10] who reported a mean medial and lateral PTS of 4.6° ± 2.4° and 5.0° ± 3.6°, respectively, without a significant difference (P = .248) among patients.

When comparing postoperative ATT among groups with a PTS <3°, 3° ≤ PTS < 5°, and PTS ≥5°, the results demonstrated that the group with a PTS ≥5° had significantly more cases of ATT ≥5 mm than the group with a PTS <3° (P = .016). Until now, there had been no consensus for grading or classifying PTS.[8] Hohmann et al[8] arbitrarily divided PTS into 3 intervals—0° to 4°, 5° to 9°, and >10°—and found an anterior tibial slope with a value that was higher and more extended than that in the present study. This difference may be because lateral radiographs were applied in the Hohmann et al[8] study. Hudek et al[11] claimed that the PTS measured on a lateral radiograph was higher than that obtained from MRI. Based on the lateral radiographs, the PTS ranged from 6.1° to 10.1°,[1,8,13,20,22] whereas the MRI measurements of the lateral PTS ranged from 4.9° to 5.3°,[10,11,15] which were smaller than the measurements obtained from the lateral radiographs.

Recently, other researchers have demonstrated a relationship between PTS and ACL injury. Hashemi et al[6] demonstrated that lateral PTS is a risk factor for complete ACL tears using MRI scans. Similarly, Sonnery-Cottet et al[18] also identified a steep PTS as a significant risk factor for ACL ruptures using lateral radiographs.

As PTS has been proved to be a risk factor for ACL injuries, the mechanism of PTS influencing the kinetics and kinematics of the knee joint has been investigated.[5,15-17,20] Giffin et al[5] performed osteotomies in 10 cadaveric knees

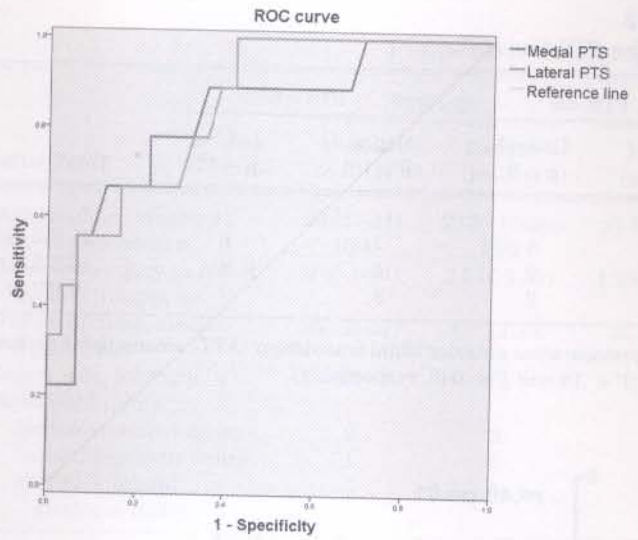

Figure 4. The receiver operating characteristic (ROC) curve for medial and lateral posterior tibial slope (PTS). The area under the curve was 0.83 ± 0.08 for the medial PTS (P = .003) and 0.85 ± 0.07 for the lateral PTS (P = .002). There was no significant difference between the medial and lateral PTS (P = .726).

to increase PTS to an average of 4.4°. Under a 200-N axial force, at 30° of flexion, ATT was significantly increased to 4.7 mm. Shelburne et al[17] reported that the changes in tibial shear force, ACL force, and ATT were linearly related to the change in PTS using a 3-dimensional musculoskeletal model. The authors reported that a 5° increase in PTS resulted in a 2-mm increase in ATT when standing. A statistical analysis conducted by Dejour and Bonnin[2] revealed that a 10° increase in the tibial slope resulted in a 3-mm increase on the radiological Lachman test. In the present study, according to the linear correlation analysis, calculated from the slope (β) of medial and lateral PTS multiplied by 10, it was revealed that a 10° increase in the medial and lateral PTS would result in an increase in postoperative ATT of 3.3 mm and 2.3 mm, respectively. This result was consistent with that of Dejour and Bonnin,[2] but the measurements were slightly lower than those reported by Giffin et al[5] and Shelburne et al.[17] This discrepancy may be attributable to the axial force in the Giffin et al[5] study, rather than the maximum manual displacement of the present study, and the choice of human participants, rather than a computer model or cadaveric knees in the studies by Giffin et al[5] and Shelburne et al.[17]

However, all of the above studies only regarded the correlation between PTS and primary ACL injuries. To our knowledge, there have been only a few studies[8,21,22] concerning the association between PTS and the clinical outcome of ACL-reconstructed knees. Consistent with the present study, Webb et al[21] reported that an increased PTS was associated with an increased odds of a further ACL injury after ACLR in a prospective study of 200 consecutive participants and that ACL injuries after reconstruction were increased by a factor of 5.2 with a PTS ≥12° using lateral radiographs. According to a binary logistic regression, they concluded that PTS influences both primary ACL injuries and those that occur after ACLR.

Zaffagnini et al[22] observed a significant positive correlation (r = 0.64, P = .04) between PTS and manual maximum displacement with a KT-1000 arthrometer of the indexed knee at final follow-up. Nevertheless, the authors only emphasized the absolute value of the indexed knee rather than the measurement of the side-to-side difference, which is a better representation of knee stability. Moreover, Zaffagnini et al[22] evaluated PTS in the setting of high tibial osteotomy and ACLR, which was a different population from those of the present study and the Webb et al[21] study. In the present study, a significant but moderate correlation was detected between PTS and postoperative ATT (medial: r = 0.41, P = .01; lateral: r = 0.40, P = .01).

Interestingly, Hohmann et al[8] reported that among 24 patients who underwent ACLR, those with a higher PTS had more functional knees according to the Cincinnati Knee Rating Scale. From their perspective, it is conceivable that an increase in PTS lengthens the hamstrings and enables them to operate over a more efficient portion of their length-tension relation and therefore improve knee joint stability. Although the Cincinnati Knee Rating Scale consists of the side-to-side difference measurements with a KT-1000 arthrometer, the relationship between ATT and PTS was not reported in the literature. The mechanism and a more detailed relationship should be further investigated.

To provide an insight into the relationship between PTS and ATT ≥5 mm, a further analysis was conducted in the present study. To our knowledge, there is no published literature investigating the correlation between PTS and ATT or describing the threshold of PTS as a risk factor for ATT ≥5 mm.

In the present study, the calculation indicated that the medial or lateral PTS were risk factors for ATT ≥5 mm with an OR of 1.76 and 1.68, respectively, which were comparable with the results of an intensive study conducted by Hashemi et al,[6] who discovered that a 1° increment of the lateral PTS increased the risk of ACL injuries 1.17 times.

Moreover, the calculation of the threshold and efficacy of PTS as a predictor of postoperative ATT was also performed. Based on our findings, both the medial and lateral PTS were shown to be good predictors for ATT ≥5 mm. Furthermore, based on the Hudek et al[11] measurement, the ROC curve analysis revealed that the threshold of 5.6° for the medial PTS (with a sensitivity of 77.8% and a specificity of 77.4%) and 3.8° for the lateral PTS (with a sensitivity of 100% and a specificity of 58.1%) demonstrated the equivalence in the predictive ability of ATT ≥5 mm ($P < .05$). The risk for ATT ≥5 mm was 3.5 times higher in patients with a medial PTS >5.6° than a lateral PTS ≤5.6°. Similarly, Webb et al[21] reported that a threshold of 12° increased the odds of further ACL ruptures by a factor of 5.2 using lateral radiographs.

The rate of ATT ≥5 mm was 22.5%, which appeared to be high. However, it is necessary to mention that (1) no clinical instability was identified in the present study; (2) among 9 of 40 patients with ATT ≥5 mm, the ATT was 5 mm in 6 patients and 6 mm in the remaining 3 patients (7.5%); (3) only 4 patients had a 1+ pivot-shift grade; and

(4) no graft ruptures were documented among the 40 patients at final follow-up. Second, according to the IKDC guidelines[7] in which an abnormal ATT is defined as being >5 mm, the rate of an abnormal ATT was only 7.5%. Last, the present sample size was relatively small, so it may not be an ideal representation of the whole population.

There were several limitations in this study. First, this study was a retrospective case-control study with a relatively small sample size of 40. However, according to the a priori power analysis, a sample size of 40 was large enough for a power of 80%. Second, the mean follow-up time was 27.5 months postoperatively, which is relatively short for the evaluation of midterm to long-term knee stability. Third, it was the initial MRI scans instead of the MRI scans at final follow-up that were used for measuring PTS. As a result, the assumption had to be made that PTS remained unchanged during the follow-up time. However, from our experience, the anterior border of the tibia is harder to recognize on postoperative MRI because of the drilled tunnel. If MRI scans at final follow-up were used, the measurement of PTS would probably be less reliable. In addition, the inclusion of medial meniscus injuries, the relatively low reproducibility of KT-1000 arthrometer measurements, and the absence of functional outcomes were also limitations of this study.

The clinical relevance of this study was (1) the identification of PTS as a risk factor for postoperative static anterior knee instability and (2) a steeper PTS resulting in greater graft laxity, which suggests that patients with a steep PTS should follow a more conservative rehabilitation protocol. However, it should be noted that although the correlation was statistically significant, it was relatively moderate. The clinical significance should be evaluated in further studies with a longer follow-up time and patient-oriented outcome scores.

CONCLUSION

There was a significant but moderate correlation between PTS and postoperative static anterior knee stability in this study. Patients with a steeper medial or lateral PTS were found to have a higher risk of ATT $\geq$5 mm at a threshold of 5.6° and 3.8°, respectively.

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