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ORIGINAL ARTICLE

Posterior Cruciate Ligament Reconstruction in Patients with Generalized Joint Laxity

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Abstract Generalized joint laxity has been considered a risk factor causing late failure of reconstructed anterior cruciate ligaments, although it is unknown whether that is the case for reconstructed posterior cruciate ligaments. We hypothesized patients with generalized joint laxity, compared with those without laxity, would have similar postoperative knee stability, range of motion, and functional scores after posterior cruciate ligament reconstruction. The Beighton and Horan criteria were used to determine generalized joint laxity. We enrolled 24 patients with generalized joint laxity (Group L) and 29 patients without any positive findings of joint laxity (Group N) matched by gender and age. The average side-by-side differences of posterior tibial translation were 4.72 mm in Group L and 3.63 mm in Group N. We observed no differences in posterior tibial translation with differing graft materials or combined procedures. In Group L the International Knee Documentation Committee score was normal in 12.5% and nearly normal in 45.8% whereas in Group N, 24.1% were normal and 55.2% nearly normal. Patients with generalized joint laxity showed more posterior laxity than patients without joint laxity. Generalized joint laxity therefore appears to be a risk factor associated with posterior laxity after posterior cruciate ligament reconstruction.

Level of Evidence: Level III, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

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Introduction

As a result of improvements in various surgical techniques, some authors have reported favorable outcomes of posterior cruciate ligament (PCL) reconstruction [14, 22]. However, the most common complication after PCL reconstruction is residual posterior laxity [21]. Several factors may lead to unsuccessful outcomes with PCL reconstruction. These include a failure to recognize and treat associated ligament instabilities, incorrect tunnel placement, and inappropriate postoperative rehabilitation programs [24, 27, 30]. Generalized joint laxity is reportedly a risk factor associated with late failure of a reconstructed anterior cruciate ligament (ACL) [1], but it is unknown whether laxity influences the outcomes of PCL reconstruction.

We therefore hypothesized patients who had generalized joint laxity, compared with those with normal joint laxity, would have similar outcomes regarding postoperative knee stability, range of motion, and functional scores after PCL reconstruction.

Materials and Methods

We retrospectively reviewed all 154 patients with symptomatic PCL injuries who underwent arthroscopic PCL reconstruction between March 1999 and April 2005. We included patients with PCL injury with or without concomitant posterolateral corner injuries and more than 24 months of followup. We excluded 21 of the 154 patients with concomitant ACL injury (n = 9), total meniscectomy (n = 8), articular cartilage erosion greater than Grade II according to the Outerbridge classification [25] (n = 7; of these patients, four had total meniscectomy concomitantly), and posterolateral instability greater than Grade II (increased external rotation 10° or greater without a firm end point [10, 11]) after surgery (n = 1). There were no patients with abnormal connective tissue disorders. Thirteen of the 154 patients had less than 24 months followup. We then had 26 patients with generalized joint laxity according to the Beighton and Horan criteria [3]; the comparison group (Group N) was matched by gender and age and composed of patients without any findings of joint laxity. We did not include male patients older than 30 years in Group N so as not to achieve a major difference in gender between the groups. We also excluded female patients older than 32 years in Group N to obtain similarity in age between the two groups. Five patients (two patients with laxity, three patients without laxity) were lost to followup. We were not able to contact these patients because three declined to visit our hospital because of distant location and lack of time to visit the hospital, and two had incorrect telephone numbers. The average age of the 24 patients with laxity (Group L) at the time of surgery was 28.7 years, and the minimum followup was 24 months (average, 30.6 months; range, 24–50 months). The average age of the 29 patients without laxity (Group N) at the time of surgery was 30.6 years, and the minimum followup was 24 months (average, 36.2 months; range, 24–62 months) (Table 1). We applied the Beighton and Horan criteria [3] for evaluation of generalized joint laxity before surgery: (1) passive dorsiflexion of the little fingers beyond 90°; (2) passive apposition of the thumbs to the flexor aspects of the forearms; (3) hyperextension of the elbows beyond 10°; (4) hyperextension of the knees beyond 10°; and (5) forward flexion of the trunk with the knees straight so the palms of the hands rest easily on the floor. The patients who were considered to have generalized joint laxity had four or five positive findings of these criteria, including hyperextension of the contralateral knee.

Thirty-nine patients (17 of 24 in Group L, 22 of 29 in Group N) had combined posterolateral rotatory instability. For reconstruction of the posterolateral corner structure, two different techniques were used: the modified biceps rerouting technique [15] and the anatomic reconstruction of the popliteus tendon and lateral collateral ligament technique [16]. A modified biceps rerouting technique was performed in seven patients in Group L and nine in Group N. An anatomic reconstruction technique was performed in 10 patients in Group L and 13 in Group N. In Group L, three patients (12.5%) had medial meniscus injuries, and all patients received partial meniscectomy. In Group N, four (13.8%) patients had medial meniscus injuries, and one (3.4%) patient had concomitant medial and lateral meniscus injuries. Four patients with medial meniscus injuries underwent partial meniscectomy, and one patient with medial and lateral meniscus injuries underwent partial meniscectomy for a medial meniscus tear and meniscus repair for a lateral meniscus tear.

Table 1. Patient demographics

Demographic	Group L	Group N
Number of patients	24	29
Male/female	14/10	21/8
Age (years)*	28.7 (20–32)	30.6 (23–32)
Mechanism of injury		
Sports	7 (29.2%)	5 (17.3%)
Traffic accident	13 (54.2%)	21 (72.4%)
Fall	4 (16.6%)	3 (10.3%)
Combined PLRI	17 (70.8%)	22 (75.9%)
Duration (months)*	10.9 (3–27)	13.3 (5–37)
Followup (months)*	30.6 (24–50)	36.2 (24–62)

* Values expressed as means with ranges in parentheses; Group L = patients with generalized joint laxity; Group N = patients with normal joint laxity; PLRI = posterolateral rotatory instability.

The PCL reconstruction was performed using the arthroscopic one-incision and anterolateral tibial tunnel technique [13]. All procedures were performed by the senior author (S-JK). Three arthroscopic portals were used [12]: a parapatellar anteromedial portal, a lateral anterolateral portal, and a proximal posteromedial portal.

We used two different types of graft: Achilles tendon-bone (ATB) allograft and bone-patellar-tendon-bone (BPTB) autograft. In Group L, ATB allografts were used in 17 (70.8%) cases and BPTB autografts were used in seven cases (29.2%). In Group N, ATB allografts were used in 21 cases (72.4%) and BPTB autografts were used in eight cases (27.6%). There was no difference (p = 0.899) in graft sources between the two groups. For BPTB autografts, the patellar and tibial bone block were harvested in the usual manner: a trapezoidal shape 25 mm in length, 8 mm in depth, and 11 mm in width. For ATB allografts, a rectangular-shaped bone plug with a width of 11 mm and a length of 25 mm was designed along with the attached Achilles tendon. The tendon portion was 60 mm long and 11 mm wide. The Achilles tendon (30 mm) was sutured by using a whipstitch technique from the tip of the tendon, and a 9-mm-diameter EndoPearl® (Linvatec, Largo, FL) was attached.

To prepare the tibial tunnel, a 2-cm longitudinal skin incision was made just lateral to the tibial tuberosity. The tibialis anterior muscle was stripped off and retracted laterally to expose the starting point of the tibial tunnel at the anterolateral tibial cortex. Careful posterior dissection of the muscle from the anterior border was needed to the extent of approximately 2 cm to prevent slippage of the guidewire beyond the lateral interosseous border of the tibia. Then the PCL guide was inserted through the high parapatellar anteromedial portal and passed through the intercondylar notch. The drill guide was oriented 45° to the longitudinal axis of the tibia, to the posterior flat spot of the tibia 1.5 cm below the articular margin, and just lateral to the midline. The tibial tunnel was made through the anterolateral tibial cortex located 2 cm posterolateral to the tibial tuberosity and in the same position as the tibial PCL insertion (Fig. 1). After adjusting the distance from the anterior tibial cortex to the tip of the guide at the tibial insertion site of the PCL (to prevent past-point drilling), the tibial tunnel was made with a reamer over the guide pin. The final step of reaming was performed with manual handling of the reamer to avoid damage to the neurovascular structures in the popliteal space. Then chamfering of the upper edge of the posterior aperture was completed with a rasp to reduce the acute angle turn created at the entry point of the tunnel into the joint [4]. The femoral socket was made 8 mm posterior to the articular junction at the 1:30 o'clock position on the right knee. A 10-mm-diameter reamer with a plastic sheath was introduced through the lateral anterolateral portal toward the femoral socket site. Then the femoral socket was prepared with a cannulated head reamer with 110° knee flexion. The femoral socket then was reamed to a depth of approximately 35 mm. The plastic sheath covering the reamer shaft prevented damage to the articular surface of the lateral femoral condyle. Chamfering of the edge of the femoral socket, especially the posterior half, was important for reducing femoral acute angle turn.

The graft passed from the tibial tunnel to the femoral socket. Femoral fixation was obtained with an 8 × 25-mm bioabsorbable interference screw (Linvatec) through the

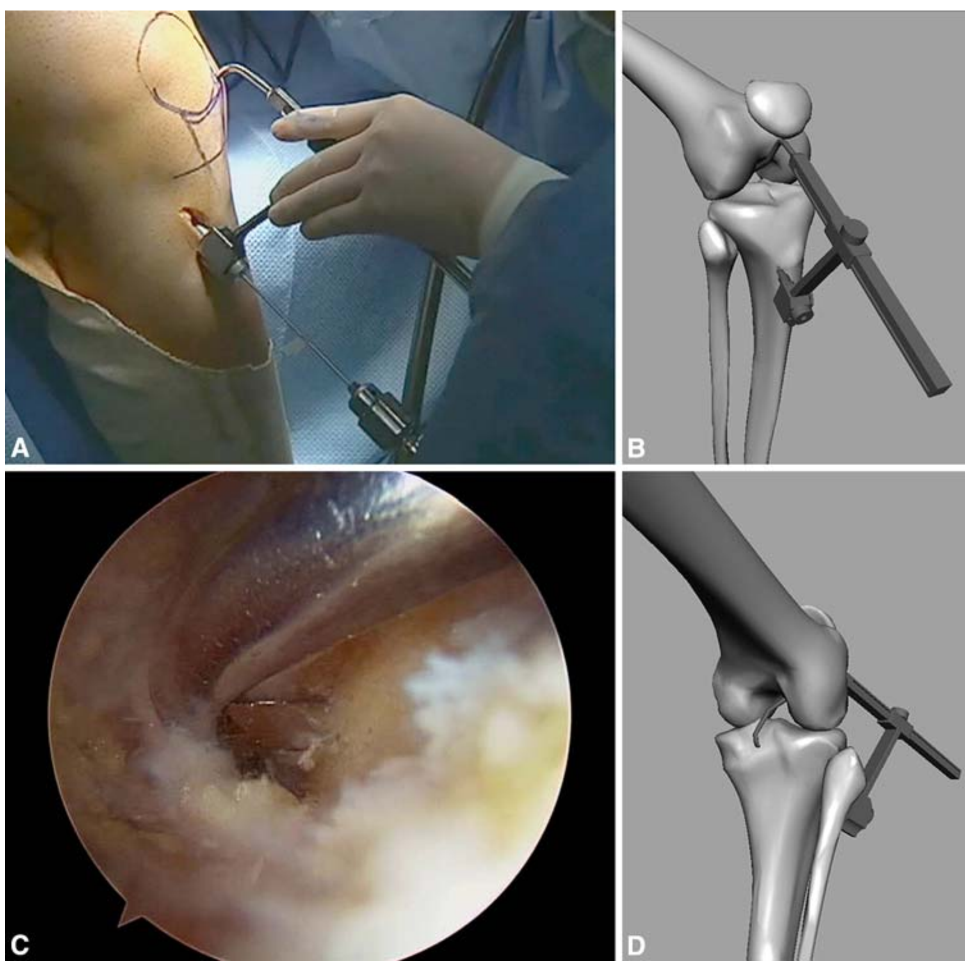

Fig. 1A–D (**A**) A skin incision is made lateral to the tibial tuberosity and the tibialis anterior muscle is stripped off to expose the (**B**) starting point of the tibial tunnel at the anterolateral tibial cortex. The tip of the PCL guide is placed on the PCL fossa, which is located 1.5 cm below the articular margin and just lateral to midline. (**C**) An arthroscopic view from the high posteromedial portal and (**D**) graphic view show overviews of the posterior aspect of the knee.

lateral anterolateral portal with the knee in 110° flexion. Tension was applied on the graft in the tibial tunnel while moving the knee 10 times through a full range of motion. The distal bone peg was secured by a 9 × 25-mm absorbable interference screw (Linvatec) with the knee in 70° flexion while applying anteriorly directed force to maintain the normal anterior tibial step-off.

The rehabilitation protocol was identical for both groups. The surgically treated knee was immobilized with a standard hinged knee brace in full extension for patients with PCL surgery or 30° flexion for patients with PCL and posterolateral corner surgery for 2 to 4 weeks; this varied according to the amount of combined surgery. After 2 to 4 weeks, protected range of motion exercises were started and ambulation with partial weightbearing using crutches was permitted. The brace was locked during ambulation. The brace was unlocked after 3 to 5 weeks and range of motion exercises instituted. At 6 to 8 weeks, the brace was removed and closed-chain kinetic exercises were started. At 10 to 12 weeks, stationary bicycle, stair stepping, swimming, and single leg stance were initiated. At 3 to 4 months, jogging in a pool and swimming were permitted. At 5 to 9 months, the patients were encouraged to return to full activity, including sports.

Clinical assessment for posterior knee stability and functional outcome was performed postoperatively. Manual examination was performed by the senior author (S-JK). Ligament stability was examined by the posterior drawer test and by Telos® (Telos GmbH, Marburg, Germany) stress radiographs. The posterior drawer test was categorized as Grade 0 (normal tibial step-off), 1 (+10 to +5 mm tibial step-off), 2 (+5 mm to tibia flush with condyles), or 3 (translation of the proximal tibial eminence posterior to the distal femoral condyle) [5]. The interobserver agreement for the grade of PCL injury in the posterior drawer test, which included palpation of the tibia-femur step-off, was reported as 81% [28].

All patients received posterior stress radiographs using the Telos® Stress Device with 15-kPa posterior load applied to the proximal tibia at 90° knee flexion. The posterior displacement was measured between the femoral and tibial vertical midpoint lines using a computerized radiographic system (Centricity® Enterprise Web v 2.0; GE Medical Systems, Waukesha, WI). A vertical midpoint was a crossing point of the two lines, a line parallel to the tibial plateau and a vertical line at the midpoint of two lines drawn from the most posterior medial and lateral condyles of tibia and femur (Fig. 2) [20, 29, 31, 32].

To enhance the reliability of the side-by-side difference (SSD) of postoperative Telos® stress radiographs, each stress view was measured three times by two orthopaedic surgeons (S-BJ, J-HC). The average of the two individual mean values was used in assessing the final SSD of posterior tibial translation. The SSDs of posterior translation measured with Telos® stress radiographs were categorized into four levels according to the ligament evaluation session of the International Knee Documentation Committee (IKDC) evaluation form [8]: Grade 0 (0 to 3 mm), Grade 1 (3 to 5 mm), Grade 2 (5 to 10 mm), and Grade 3 (greater than 10 mm). The intraclass correlation between testers was 0.860.

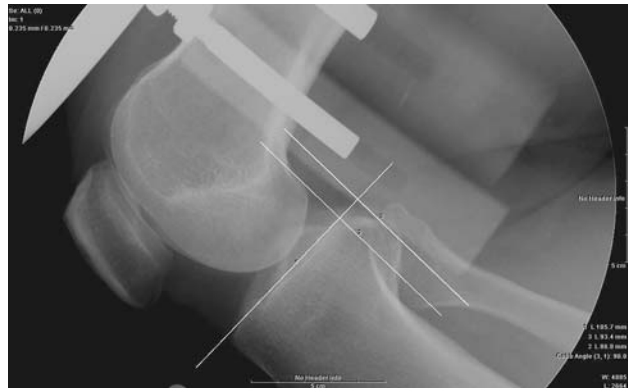

Fig. 2 The radiograph shows measurement of posterior tibial translation in 90° flexion. Three lines are drawn: a line across the tibial plateau and perpendicular lines tangential to the midpoint between the most posterior contours of the medial and lateral femoral condyles and tibial plateaus. The distance between femoral and tibial vertical midpoint lines is calculated to determine tibial translation of the knee.

The IKDC score [8] and Lysholm knee scoring scale [19] were used to evaluate the functional outcome.

We compared SSD of posterior translation and range of motion between Groups L and N using an unpaired Student's t test and differences in the Lysholm scores using the Mann-Whitney test. Differences in the posterior drawer test and the IKDC scores were analyzed with the chi square test. To detect a difference in postoperative SSDs of posterior translation between the patients with and without posterolateral instability, the analysis of variance test was used. To assess the reliability of SSDs of posterior tibial translation, we used intraclass correlation among testers. We performed all analyses using SPSS® software (Version 13.0; SPSS Inc, Chicago, IL).

Results

One patient in each group had considerable loss of flexion greater than 15°. The two patients had surgery for posterolateral corner injuries concomitantly using a modified biceps rerouting technique. No patients had vascular complications, postoperative wound infections, or graft failures.

The postoperative SSD of posterior tibial translation was larger (p = 0.019) in Group L (mean, 4.72 mm; standard deviation [SD], 1.61 mm; range, 2.17–7.39 mm) than in Group N (mean, 3.63 mm; SD, 1.63 mm; range, 0.99–6.32 mm). In the posterior drawer test, all patients had Grades 3 and 4 instability preoperatively, which was translation of the proximal tibial eminence posterior to the distal femoral condyle. Postoperatively, 37.5% of patients with generalized joint laxity had SSDs of posterior translation measured with stress radiographs greater than 5 mm compared with 20.7% of patients with normal joint laxity (Table 2).

Table 2. Posterior translation measured by stress radiographs

SSD	Group L	Group N
Less than 3 mm	3 (12.5%)	9 (31.0%)
3 to 5 mm	12 (50.0%)	14 (48.3%)
Greater than 5 mm	9 (37.5%)	6 (20.7%)

SSD = side-to-side difference; Group L = patients with generalized joint laxity; Group N = patients with normal joint laxity.

Table 3. Lysholm functional knee score

Status	Group L*	Group N*	p Value
Preoperative	62.1 ± 6.4	63.4 ± 4.4	0.288
Postoperative	89.2 ± 5.8	87.7 ± 5.1	0.277

* Mean ± standard deviation; Group L = patients with generalized joint laxity; Group N = patients with normal joint laxity.

At last followup, there was no difference (p = 0.465) in the SSDs of flexion loss between Group L (mean, 5.79°; SD, 3.83°; range, 1°–16°) and Group N (mean, 6.24°; SD, 3.50°; range, 2°–16°). No patient had an extension deficit at final followup.

Preoperatively, average Lysholm scores of Group L (62.1; range, 54–83) were similar (p = 0.288) to those of Group N (63.4; range, 58–73). At final followup, the average Lysholm scores were 89.2 (range, 66–100) and 87.7 (range, 69–100) in Groups L and N, respectively (Table 3). According to the IKDC score, the two groups had similar strenous activities preoperatively. At the postoperative evaluation, in Group L, 12.5% (three of 24) were graded as A (normal), 45.8% (11 of 24) were graded as B (nearly normal), and 41.7% (10 of 24) were graded as C (abnormal). In Group N, 24.1% (seven of 29) were graded as A, 55.2% (16 of 29) were graded as B, and 20.7% (six of 29) were graded as C (Table 4). There was no difference (p = 0.214) in IKDC scores between groups.

There were no major differences in the SSDs of posterior tibial translation between the groups in graft materials and combined procedures (Table 5).

Discussion

Although numerous surgical techniques have been developed for PCL injuries, the outcomes of PCL reconstruction

Table 4. IKDC functional knee score

Status		A	B	C	D	p Value
Preoperative	Group L	0	0	14 (58.3%)	10 (41.7%)	0.566
	Group N	0	0	9 (31.0%)	20 (69.0%)	
Postoperative	Group L	3 (12.5%)	11 (45.8%)	10 (41.7%)	0	0.214
	Group N	7 (24.1%)	16 (55.2%)	6 (20.7%)	0	

IKDC = International Knee Documentation Committee; Group L = patients with generalized joint laxity; Group N = patients with normal joint laxity.

Table 5. KT-2000 arthrometric data

Graft material/procedure	Group L	Group N
ATB allografts	4.66 ± 1.59 mm (n = 17)	3.67 ± 1.55 mm (n = 21)
BPTB autografts	4.86 ± 1.79 mm (n = 7)	3.56 ± 1.93 mm (n = 8)
	p = 0.759	p = 0.879
Intact PLC	4.51 ± 1.65 mm (n = 7)	3.55 ± 2.08 mm (n = 7)
Modified biceps rerouting technique	4.86 ± 1.25 mm (n = 7)	3.68 ± 1.39 mm (n = 9)
Anatomic reconstruction of PT and LCL	4.77 ± 1.94 mm (n = 10)	3.66 ± 1.65 mm (n = 13)
	p = 0.920	p = 0.986

Group L = patients with generalized joint laxity; Group N = patients with normal joint laxity; ATB = Achilles tendon-bone; BPTB = bone-patellar tendon-bone; PLC = posterolateral corner; PT = popliteus tendon; LCL = lateral collateral ligament.

remain less favorable than those of ACL reconstruction. Several factors related to abnormal posterior laxity after PCL reconstruction have been suggested, including improper diagnosis, untreated combined ligament injuries, lower extremity malalignment, and incorrect placement of PCL grafts [24]. We asked whether (1) generalized joint laxity leads to increased instability after PCL reconstruction; and (2) patients with generalized joint laxity have a similar clinical performance compared with patients without joint laxity.

There were some inherent limitations to this study that warrant review before definite conclusions can be drawn. First, we assumed generalized joint laxity would not affect knee stability or physical performance at more than 2 years followup. Second, we included patients with combined ligament injuries. Of 53 patients, 73% had posterolateral reconstruction. However, it is difficult to obtain the outcomes of isolated PCL injuries as a result of the low incidence. Between 50% and 90% of PCL injuries involve associated injury to other structures with the posterolateral corner being the most frequent [6]. Third, we used two reconstruction techniques, the modified biceps tenodesis and anatomic reconstruction of the popliteus tendon and lateral collateral ligament. Perhaps owing to the complexity of the posterolateral corner structure injuries and inconsistent results of reconstruction we do not sense a consensus in the literature on the best techniques. Therefore, we have developed different techniques to restore the posterolateral corner more anatomically and hopefully provide more satisfactory outcomes. In this study, the proportion of each type of case with posterolateral reconstruction was similar between the two groups, and subsequently the influence of posterolateral reconstruction on overall outcomes could be minimized. Fourth, the number of cases in subgroups was insufficient to assess any influence of graft materials or combined operations on knee stability. Finally, we provided relatively short-term clinical data and restricted outcome measures. Therefore, we could not draw clinical inferences regarding generalized joint laxity except for postoperative ligament instability.

At a mean followup greater than 30 months after PCL reconstruction our data suggest increased posterior translation on stress radiographs in patients with generalized joint laxity. More patients with generalized joint laxity had SSDs larger than 5 mm than patients with normal joint laxity. In other assessments, including range of motion, we did not find any differences between the generalized and normal joint laxity groups. It appears, in daily life, a certain degree of posterior laxity can be tolerated as long as knees do not give way. However, the activity scale was not fully evaluated in our study. Therefore, it is possible limitations in knee function could be masked by an involuntarily low activity level.

Several factors make it difficult to compare our analysis of postoperative laxity with analyses in published studies. We included cases in which two different types of grafts were used and posterolateral corner injuries were combined. In addition, the one-incision and anterolateral tibial tunnel technique was adapted in PCL reconstruction instead of the conventional two-incision and anteromedial tibial tunnel technique. Reported percentages of cases with abnormal posterior laxity greater than 5 mm postoperatively are 21% for BPTB autografts [22] and 29% [7] and 33% [18] for allografts. We found no differences in posterior laxity according to the graft materials in a within-group comparison. However, to provide more reasonable outcomes, a larger number of study patients should be enrolled in both groups. As for surgical technique, to reduce tibial graft angulation at the exit of the tibial tunnel, we used the anterolateral tibial tunnel technique instead of the conventional anteromedial tibial tunnel technique [13]. Based on biomechanical studies [9, 17], the stress concentration of the graft around the entry point of the tunnel through the anteromedial approach area was much higher than in the anterolateral approach. Also, to avoid damage to the extensor mechanism, the one-incision technique was used. As previously described, to reduce graft-femoral socket divergence, the proximal tibia is pushed backward during knee flexion to approximately 110°. In 1999, we reported no difference in posterior laxity between the one- and two-incision techniques [14].

Previous studies have focused on the effect of generalized joint laxity in patients with ACL injury. ACL injuries may increase in the absence of sufficiently taut ligaments and tendons that surround the lower extremity to stabilize the knee and absorb ground reaction force [23]. However, the mechanism of PCL injury (a posteriorly directed force applied to the proximal tibia) is different from that of ACL injury (deceleration, lateral pivoting, or landing); it is unclear whether generalized joint laxity influences PCL tears. A previous investigation indicated a trend toward increased laxity after ACL reconstruction in female patients in which generalized joint laxity was considered one of the causative factors [2]. The reason for the inferior results of patients with generalized joint laxity may be because of the inherent connective tissue extensibility of the secondary restraint that is determined by the composition of connective tissue and orientation of the various soft tissue structures [1, 26]. In the same manner, it could be assumed the laxity of passive restraints (ligaments, tendons, and joint capsule) may affect the stability of the reconstructed PCL.

We found patients with generalized joint laxity had more posterior laxity after PCL reconstruction than patients with normal joint laxity. The data indicate generalized joint laxity should be considered a risk factor that may cause abnormal posterior laxity after PCL reconstruction.

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