

Temporal changes in posterior laxity after isolated posterior cruciate ligament injury

35 patients examined by stress radiography and MRI

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ABSTRACT We examined the temporal changes in posterior laxity and MRI findings in acute isolated posterior cruciate ligament (PCL)-injured knees. 35 patients with acute isolated PCL injuries who attended our clinic within 10 weeks of an injury underwent nonoperative treatment, and were chronologically evaluated for posterior laxity and MRI. We divided them in 3 groups, as regards the evolution of laxity and MRI findings. In 20 patients, the degree of posterior laxity was slight throughout the observation periods. In 9 patients, who had severe posterior laxity on their initial visit, the laxity had improved markedly 6 months after injury and did not deteriorate. In 6 patients the severe posterior laxity did not improve during the study. 4 patients whose PCL on MRI was seen as a continuous swollen band having high signal intensity and showed consistently good stability or even an improvement. We conclude that acute isolated PCL injuries with a continuous swollen band on MRI should be treated conservatively for at least 6 months after injury, even if the posterior laxity is severe initially.

There is no consensus on the treatment of a fresh PCL injury and the outcome of brace treatment is poorly documented (Dandy and Pusey 1982, Clancy et al. 1983, Parolie and Bergfeld 1986, Fowler and Messieh 1987, Torg et al. 1989, Keller et al. 1993, Boynton and Tietjens 1996). Parolie and Bergfeld (1986) and Fowler and Messieh

(1987) reported that patients with an isolated PCL injury do well when treated nonoperatively. In contrast, more recent studies with longer follow-ups have shown gradually worsening pain with time, eventually resulting in degenerative changes on radiographs (Keller et al. 1993, Boynton and Tietjens 1996). We prospectively examined the change with time in posterior laxity of acute or subacute isolated PCL-injured knees treated with a brace and assessed the relationship between temporal changes in posterior laxity and the MRI appearance of the PCL.

Patients and methods

All 35 patients (30 men) with isolated PCL injury who was seen in our clinic within 10 weeks of injury between 1994 and 1999 were eligible for the study. Their mean age at injury was 29 (12–48) years. The cause of the injury was sports in 16 patients, a traffic accident in 10, a fall from standing height in 6 and another injury in 3. The mean time from injury to first consultation was 6 (0–10) weeks.

In all patients, a soft brace was applied for at least 3 months after the injury. It had two metal supports with hinges, one on each side. During knee flexion, a posterior rubber strap pushed the proximal tibia forward. The PCL was not repaired or reconstructed for a minimum of 1.5 years. The

knees were evaluated with stress radiographs, the KT-2000 knee arthrometer (MED Metric Corporation, San Diego, California), and MRI at the first visit, at 6 and 12 months after injury, and at the last follow-up examination. The duration of the follow-up was 2.5 (1.5–5) years.

When first seen, a routine physical examination for a PCL injury was done. To assess posterolateral corner and posteromedial injuries, varus and valgus instability tests and the posterolateral and posteromedial drawer tests were also performed. We used the external rotation recurvatum test and the reversed pivot-shift test to evaluate posterolateral instability (Hughston and Norwood 1980). Patients having PCL injuries associated with a posterolateral corner injury or posteromedial injury were excluded; only those with an isolated PCL injury were included in the study.

At the first examination, a lateral radiograph of both knees flexed at 90 degrees was taken. A posterior load of 150 N or posterior manual maximum stress was applied to the proximal tibia to evaluate posterior laxity (Murase et al. 1983). The most anterior tip (A) and the most posterior tip (B) of the tibia were determined. Straight lines were drawn parallel to the baseline (AB) and tangential to the medial and lateral femoral condyles. From the points of contact on the femoral condyles, perpendicular lines were drawn to the baseline. From their feet on the baseline (M and L), the midpoint (C) was obtained. The difference, in mm, between AC in the contralateral normal knee and AC in the injured knee was calculated and corrected for magnification on radiographs (10%) (Figure 1).

We also did the KT-2000 knee arthrometer test on each patient in standard fashion. After applying a posterior load of 89 N and an anterior load of 133 N with the knee flexed at both 70 and 20 degrees, we measured total displacement at each degree, and the relative translation was calculated (mm) by subtracting the amount of translation of the contralateral normal knee from the injured knee.

The first MRI examination was done within 1 week of the first consultation, with a 1.5-Tesla MR unit (Gyrosan, Phillips, CA, USA or Signa, General Electric Milwaukee, WI, USA), using a cylindrical transmitting and receiving extremity coil. The knee was not rotated externally or internally.

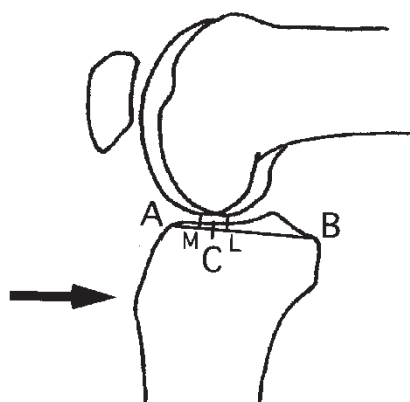


Figure 1. Posterior laxity, as measured by the midpoint of displacement on the posterior stress radiograph. The knee is flexed at 90 degrees with 150 N of applied posterior force. The most anterior tip (A) and the most posterior tip (B) of the tibia of the contralateral normal knee are visualized. Straight lines are drawn parallel to the baseline (AB) and tangential to the femoral condyles. From the points of contact on the lateral and medial femoral condyles, perpendicular lines are drawn to the baseline. From their positions on the baseline (M and L), the midpoint (C) is obtained. In the same way, the most anterior tip (A') and the midpoint (C') of the injured knee are obtained. Posterior laxity is expressed as $AC-A'C'$.

Spin echo (SE) sequences were employed, using proton density SE (TR 2,000 to 3,000 ms/TE 15 to 25 ms) and T2-weighted SE (TR 2,000 to 3,000 ms/TE 80 to 120 ms). Sagittal images were taken, using 3-mm slices, a 16-cm field of view, and a 256×256 or 356×512 matrix. In all patients, MRIs were performed at 6 months after injury, when possible, and at 1 year and at the final follow-up examinations.

We reviewed the MRIs, unaware of other patient data and divided the appearance of the injured PCL into 3 grades, according to its size, irregularity, and homogeneity.

Grade 1 was a continuous swollen band having mainly high signal intensity.

Grade 2 was a continuous irregular band having low signal intensity spotted with high signal intensity.

Grade 3 was a disrupted band (discontinuous at all slices).

Statistics

Differences in laxity between the first examination and 6 months after injury, 6 months and 1 year after injury, and 1 year after injury and the

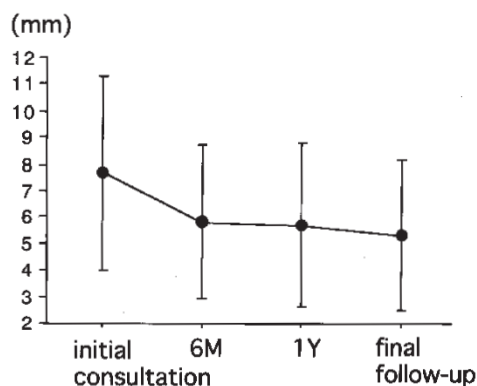


Figure 2. Changes in posterior laxity with time, as measured on stress radiographs. Although stability improved significantly between the initial visit and 6 months after injury ($p < 0.001$), no significant improvement occurred observed thereafter.

final follow-up were assessed, using the Wilcoxon signed-rank test. These differences were evaluated, using two-way repeated-measures ANOVA. All analyses were done on Statview™ (SAS Institute, Cary, North Carolina). P values of less than 0.05 were interpreted as statistically significant.

Results

The mean posterior laxity on the stress radiographs was 7.7 (2.6–14) mm on the initial examination, 5.8 (0.5–13) mm 6 months after injury, 5.7 (0.5–12) mm 1 year after injury, and 5.3 (1.4–12.0) mm at the final follow-up, which indicated an improvement with time (Figure 2). Laxity improved between the first examination and 6 months after injury ($p < 0.001$). The side-to-side difference in the total displacement at 70 degrees, measured by KT-2000, also improved during this period, but was not statistically significant. The side-to-side difference in the total displacement at 20 degrees showed no marked change with time.

By regarding 8 mm in the side-to-side difference in posterior laxity on the stress radiograph as being the cut-off point, we distinguished three groups (Figure 3). In group A ($n = 20$), the side-to-side difference on the initial examination was less than 8 mm, and the value remained the same throughout the study. In group B ($n = 9$), although the side-to-side difference on the initial examination was more

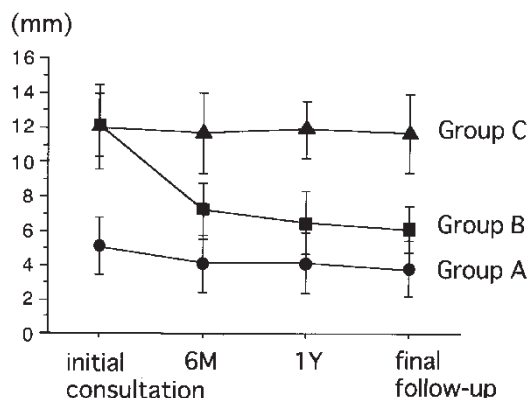


Figure 3. The change with time in the three groups was classified according to the changes in posterior laxity with time on the stress radiographs. Group A: The side-to-side difference on the initial consultation was less than 8 mm, and remained unchanged during the study. Group B: Although the side-to-side difference on the initial consultation was more than 8 mm, 6 months after injury, it had improved by more than 4 mm and remained constant thereafter. Group C: The side-to-side difference on the initial consultation was more than 8 mm, and the value did not improve during the study. The posterior laxity between the pairs of the three groups differed significantly ($p < 0.001$).

Relationship between magnetic resonance image grade and pattern of change in laxity with time among 29 patients with nonoperatively treated, isolated posterior cruciate ligament injuries

MRI injury Grade	Temporal pattern of change in side-to-side laxity ^a			Total
	A	B	C	
1	13	5	0	18
2	7	4	2	13
3	0	0	4	4
Total	20	9	6	35

^a See text for definitions of groups
MRI magnetic resonance imaging

than 8 mm, the difference 6 months after injury improved by more than 4 mm and did not change thereafter. In group C ($n = 6$), the side-to-side difference on the initial examination was more than 8 mm and showed no improvement during the study. These differences in the patterns of change in the posterior laxity of these groups were significant ($p < 0.001$).

On the first examination, all MRIs showed a band containing high and low signal intensities. No peel-off injury from the femoral insertion was

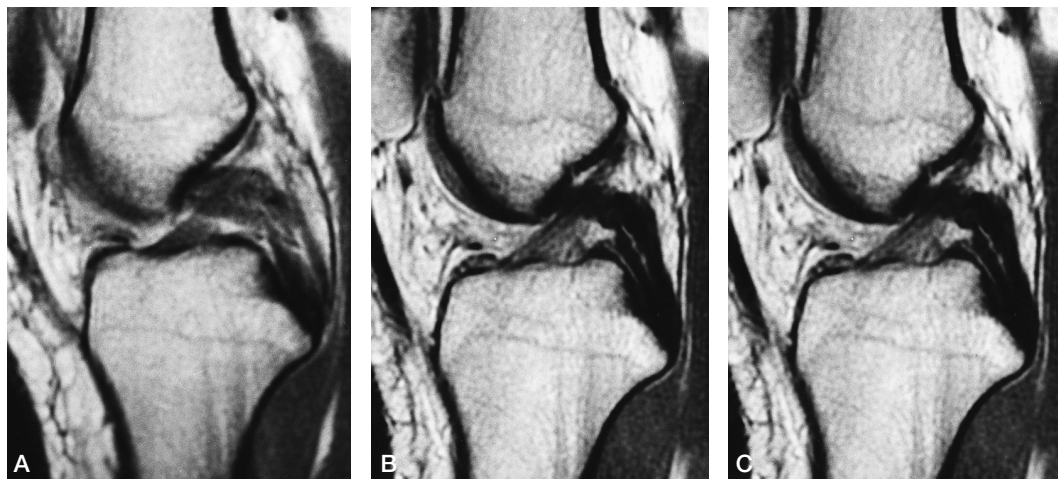


Figure 4. A knee in which the PCL was seen as a continuous swollen band having mainly high signal intensities on the first MRI examination 4 weeks after injury (A). 6 and 19 months after injury (B, C) this was seen as a continuous irregular band having mainly low signal intensities as well as partially high signal intensities. The side-to-side difference was 12.4 mm at 4 weeks after injury, 7.1 mm at 6 months and 6.8 mm at the final follow-up of 19 months after injury.

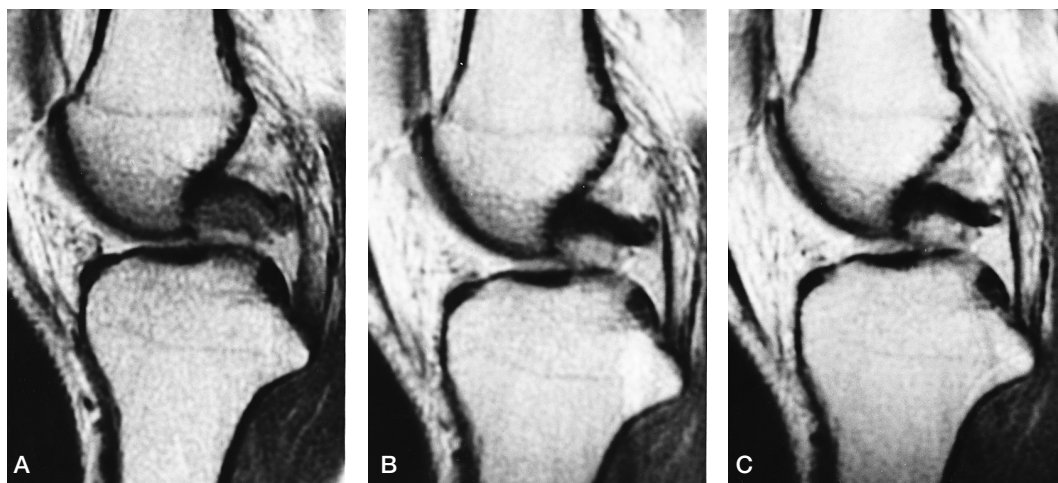


Figure 5. A knee in which the PCL was seen as a disrupted band at any slice of the MRIs taken at 10 weeks after injury and even at the final follow-up at 24 months. The side-to-side difference was 11.7 mm 10 weeks after injury (A), 10.8 mm at 6 months (B), and 10.8 mm at the final follow-up of 24 months after injury (C).

apparent on MRI. In group C, none of the MRIs had a grade 1 appearance and grade 3 was found only in group C (Table).

With time, high intensity signals on the first examination tended to decrease to a low signal intensity, similar to that in a normal PCL. However, the irregularity of the PCL shape persisted to some extent, even at the final follow-up examination. At the final follow-up, only in 10 of the 31 patients classified as grade 1 or 2 at the first examination the PCL was depicted as a band with no high signal

intensity, resembling a normal PCL, while in 21 of these 31 cases, certain parts of the PCL were seen as a band with high signal intensity (Figure 4). The 4 cases classified as grade 3 showed a disrupted PCL, even at the final examination (Figure 5).

Discussion

We found that posterior laxity in all knees, as measured by the stress radiographs, was statisti-

cally significantly reduced at 6 months after injury, whereas the side-to-side difference of the total displacement, as measured by the KT-2000 knee arthrometer, also improved 6 months after injury, although not significantly. Hewett et al. (1997) reported that stress radiography is better than the KT-1000 arthrometer in determining the amount of posterior tibial translation in knees with an isolated PCL injury. As they pointed out, one advantage of stress radiography is that it eliminates errors resulting from compliance of the soft tissues that occur when measurements are performed with the knee arthrometer.

We defined 8 mm in the side-to-side difference of posterior laxity as the cut-off point because we consider it to be the limit for nonoperative treatment. We believe that no orthopedic surgeon recommends PCL reconstruction when the posterior laxity is less than 8 mm since it has been shown that PCL reconstruction improves posterior laxity by approximately 4 mm (Berg 1995).

We defined our three temporal patterns on stress radiography. In group A, the degree of posterior laxity was slight during the observation period of 18 months. This group might represent PCLs with a partial rupture, as suggested by Harner et al. (1995), Harner and Hoher (1998) and Hewett et al. (1997). Our results in this group accord with the findings of Parolie and Bergfeld (1986) and Fowler and Messieh (1987), who showed that the results of nonoperative treatment are good. A slight improvement at 6 months after injury in this group might be due to tissue repair with support from the remaining intact portion of the PCL and the synovial cover and vascularity, which are greater in the PCL than the ACL.

Since an isolated PCL injury with slight posterior laxity may have been misdiagnosed as a simple contusion of the tibia at a local hospital, and because patients with such laxity were not seen in our hospital, the true percentage of group A patients with PCL injury may be higher. Unlike an ACL injury, most PCL injuries are usually partial. It is uncertain whether application of a soft brace for 3 months could improve stability. No treatment may result in similar stability. Ihara et al. (1996) showed that the injured ACL heals by itself with early protective mobilization and a controllable knee brace. Although the type of brace we used

in our study differed from theirs, we studied early mobilization with the view that protection against gravity and overstress during daily activity for 3 months can promote repair of the partially torn PCL.

In the early stage, we divided the patients with severe posterior laxity into two groups, B and C, based on the amount of improvement with time. The patients with severe posterior laxity may have combined PCL injuries, such as a posterolateral corner injury. We excluded a combined PCL injury from our series, not only in the early stage, but also at 6 and 12 months after injury. Therefore, we are reasonably sure that we included only patients with isolated PCL tears. Hewett et al. (1997) found that the mean posterior translation of cadaveric knees with completely transected PCLs was 12 mm—i.e., the same as the mean value of 12 mm in groups B and C on the initial visit. Group B improved markedly 6 months after injury and showed no change thereafter. Group C showed no improvement in the follow-up period. However, even in group C, we found no gradual worsening of posterior laxity resulting from secondary stress or damage to the posterolateral or posteromedial corner, although it has been reported that overstress or understress of other ligaments secondary to PCL insufficiency can induce morphological and mechanical changes in other ligaments (Murao et al. 1997, Ochi et al. 1999). The soft brace may have prevented an increase in posterior laxity, or the duration of our follow-up may have been too short to observe a secondary progress of the posterior laxity. We found no clear differences between groups B and C as regards the degree of laxity and the injured part of the PCL on the MRI.

Group C included 4 patients who had a grade 3 injury with a disrupted band on the MR image, while a grade 1 injury was present only in groups A and B. Tewes et al. (1997) reported that 3 of 13 patients whose PCL tear had been documented within 10 weeks of acute injury had discontinuous MR images taken at least 5 months after the MRI for their acute tear. However, since it is not clear how many of the 13 patients corresponded to our grade 3 injury (a disrupted band on the initial MR images), we cannot compare our findings with theirs. Although the sample size is limited and additional data must be collected, MRI grade 1

probably indicates a good prognosis and grade 3, a poor one. If so, surgical reconstruction of a knee with an isolated PCL injury should not be performed until at least 6 months after injury, despite such severe posterior laxity soon after injury, because 9/15 with severe findings improved in 6 months. However, meniscal or chondral lesions secondary to PCL injury are indications for surgery, regardless of the degree of posterior laxity. As Shino et al. (1995) pointed out, severe chondral damage does not always increase with time after PCL injury; it is often caused by the initial PCL injury. Such an injury requires special attention, regardless of the presence of posterior laxity.

No competing interests declared.

- Berg E E. Posterior cruciate ligament tibial inlay reconstruction. *Arthroscopy* 1995; 11: 69-76.
- Boynton M D, Tietjens B R. Long-term follow-up of the untreated isolated posterior cruciate ligament-deficient knee. *Am J Sports Med* 1996; 24: 306-10.
- Clancy W G, Shelbourne K D, Zoellner G B, Keene J S, Reider B, Rosenberg T D. Treatment of knee joint instability secondary to rupture of the posterior cruciate ligament. Report of a new procedure. *J Bone Joint Surg (Am)* 1983; 65: 310-22.
- Dandy D J, Pusey R J. The long-term results of unrepaired tears of the posterior cruciate ligament. *J Bone Joint Surg (Br)* 1982; 64: 92-4.
- Fowler P J, Messieh S S. Isolated posterior cruciate ligament injuries in athletes. *Am J Sports Med* 1987; 15: 553-7.
- Harner C D, Hoher J. Evaluation and treatment of posterior cruciate ligament injuries. *Am J Sports Med* 1998; 26: 471-82.
- Harner C D, Xerogeanes J W, Livesay G A, et al. The human posterior cruciate ligament complex: an interdisciplinary study. Ligament morphology and biomechanical evaluation. *Am J Sports Med* 1995; 23: 736-45.
- Hewett T E, Noyes F R, Lee M D. Diagnosis of complete and partial posterior cruciate ligament ruptures. Stress radiography compared with KT-1000 arthrometer and posterior drawer testing. *Am J Sports Med* 1997; 25: 648-55.
- Hughston J C, Norwood L A Jr. The posterolateral drawer test and external rotational recurvatum test for posterolateral rotatory instability of the knee. *Clin Orthop* 1980; 147: 82-7.
- Ihara H, Miwa M, Deya K, Torisu K. MRI of anterior cruciate ligament healing. *J Comput Assist Tomogr* 1996; 20: 317-21.
- Keller P M, Shelbourne K D, McCarroll J R, Rettig A C. Nonoperatively treated isolated posterior cruciate ligament injuries. *Am J Sports Med* 1993; 21: 132-6.
- Murao T, Ochi M, Jitsuike J, Ikuta Y. The adverse effects of sectioning the posterior cruciate ligament in rabbits. Changes in the structural and morphological properties of the femur-anterior cruciate ligament-tibia complex. *Arch Orthop Trauma Surg* 1997; 116: 1-5.
- Murase K, Kumano K, Bannoji T, et al. Radiographical measurement of anteroposterior instability of the knee joint (Japanese). *Tokyo Knee Soc* 1983; 4: 179-86.
- Ochi M, Murao T, Sumen Y, Kobayashi K, Adachi N. Isolated posterior cruciate ligament insufficiency induces morphological changes of anterior cruciate ligament collagen fibrils. *Arthroscopy* 1999; 15: 292-6.
- Parolie J M, Bergfeld J A. Long-term results of nonoperative treatment of isolated posterior cruciate ligament injuries in the athlete. *Am J Sports Med* 1986; 14: 35-8.
- Shino K, Horibe S, Nakata K, Maeda A, Hamada M, Nakamura N. Conservative treatment of isolated injuries to the posterior cruciate ligament in athletes. *J Bone Joint Surg (Br)* 1995; 77: 895-900.
- Tewes D P, Fritts H M, Fields R D, Quick D C, Buss D D. Chronically injured posterior cruciate ligament: magnetic resonance imaging. *Clin Orthop* 1997; 335: 224-32.
- Torg J S, Barton T M, Pavlov H, Stine R. Natural history of the posterior cruciate ligament-deficient knee. *Clin Orthop* 1989; 246: 208-16.