

# Flexion Gap in the Isolated Posterior Cruciate Ligament-Injured Knee Affects Symptom Relief After Conservative Treatment

## A Case-Control Study

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**Background:** The posterior cruciate ligament (PCL) is a primary stabilizer of the knee in the posterior direction. However, PCL deficiency presents a clinical paradox because the outcome of PCL deficiency ranges from total disability to uninterrupted participation in competitive athletics.

**Purpose:** To investigate whether posterior laxity (PL) and the flexion gap (FG) influence the results of the conservative treatment of isolated PCL injuries.

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

**Methods:** A total of 27 patients (23 men, 4 women; mean age, 33 ± 14 years) with isolated PCL injuries between 2007 and 2013 were included in this study. All patients had been treated conservatively for more than 6 months. Nineteen patients achieved excellent relief of their symptoms (conservative treatment [C] group). Eight patients underwent PCL reconstruction owing to their symptoms (surgical treatment [S] group). Side-to-side differences of the FG and the PL were retrospectively measured on axial radiographs and on lateral radiographs with gravity sag views, respectively, and the degree of PCL injury was graded as I (PL, <5 mm) in 7 patients and II (PL, 5 to <10 mm) in 20 patients.

**Results:** The mean PL and FG were 6.9 ± 2.5 mm and 2.0 ± 1.8 mm, respectively. A mild positive correlation between the PL and the FG was observed ( $r = 0.47$ ,  $P = .02$ ). The mean PL and FG were 6.5 ± 2.9 mm and 1.2 ± 1.0 mm in the C group and 7.7 ± 1.3 mm and 3.8 ± 2.0 mm in the S group, respectively. The FG in the C group was significantly smaller than that in the S group ( $P < .05$ ), although there was no significant difference between the groups for PL. All patients with grade I injury belonged to the C group, for which the FG was less than 2 mm in all cases. Eight of the patients with grade II injury were in the S group, and their FG was more than 2 mm, except in 1 patient. The FG performed better with an area under the receiver operating characteristic curve of 0.924 (95% CI, 0.000-1.000) compared with 0.599 (95% CI, 0.388-0.809) for the PL. Discrimination between the C and S groups with a cutoff set at 2.30 mm for the FG and 7.45 mm for the PL showed a sensitivity of 75.0% and 75.0% and a specificity of 89.5% and 52.6%, respectively.

**Conclusion:** Considering that the FG affects the outcome of conservative treatment, it could be a factor in the indication for the surgical treatment of isolated PCL injuries.

**Keywords:** posterior cruciate ligament; epicondylar view; posterior laxity; flexion gap; lateral gravity sag view; axial radiograph; conservative treatment

The posterior cruciate ligament (PCL) is a primary stabilizer of the knee in the posterior direction.<sup>2</sup> However, PCL deficiency presents a clinical paradox because the outcome of PCL deficiency ranges from total disability to uninterrupted participation in competitive athletics. Some

authors have suggested that PCL injuries may fare better with conservative, nonoperative management than anterior cruciate ligament injuries because of a greater healing potential and supplemental function of surrounding structures.<sup>2</sup> Although good results after conservative treatment for isolated PCL injuries have been reported, surgeons often face difficult decisions on how to advise patients about treatment and when conservative management will be successful.

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The severity of injury to the PCL is typically graded by assessing static, nonweightbearing posterior sag with the knee in 90° of flexion: grade I (<5-mm posterior laxity [PL]), grade II (5- to < 10-mm PL), and grade III (≥10-mm PL).<sup>1</sup> However, this traditional grading has no correlation with the results of conservative treatment. Thus, another prognostic factor of conservative treatment aside from PL may exist.

Considering the sagittal alignment of the PCL at 90° of flexion and increasing the flexion gap (FG) after resection of the PCL in total knee arthroplasty (TKA),<sup>10,11,15,26</sup> we hypothesized that the PCL might play a role not only in posterior stabilization but also in maintenance of the FG. Previously, plain radiographs with the x-ray beam projected along the femoral shaft (axial radiographs)<sup>12,23</sup> evaluated the FG and revealed that the FG increased in an isolated PCL-injured knee.<sup>14</sup> Therefore, the purpose of this study was to investigate whether the FG and PL influence the results of conservative treatment for PCL injuries.

## METHODS

Included in this study were 27 patients (23 men, 4 women; mean age, 33 ± 14 years) with isolated PCL injuries between 2007 and 2013. We excluded patients with fractures, osteoarthritis, or other ligament lesions, such as those of the medial collateral ligament or posterolateral structures, as diagnosed through multiple radiographs, magnetic resonance imaging, and physical examinations: Lachman test, posterolateral drawer test, dial test, and varus/valgus stress test. All patients were treated conservatively after their injury for more than 6 months in our hospital or other clinics. Nineteen patients subsequently achieved excellent relief of their symptoms and returned to activities of daily life or sports (conservative treatment [C] group). Separate doctors performed PCL reconstruction in 8 patients (surgical treatment [S] group). The decision to operate was made on the basis of patients' accounts of pain and/or instability during daily and/or sports activities. The most common symptoms were instability and pain, especially while walking downstairs, as well as slowed acceleration, delayed responses, and delay in starting athletic activities.<sup>25</sup> Between the 2 groups, there was no significant difference in age, sex, body mass index, time from injury, meniscal damage, or bone marrow lesions (Table 1).

## Radiographic Evaluations for PL and FG

Radiographs were obtained before surgery in the S group and after conservative treatment in the C group. All

TABLE 1  
Patient Demographic Data<sup>a</sup>

	C Group (n = 19)	S Group (n = 8)	P Value
Age, y	30 ± 14	37 ± 11	.17
Sex, male/female, n	16/3	6/2	.63
Body mass index, kg/m <sup>2</sup>	23.9 ± 3.6	22.9 ± 4.2	.81
Time between injury and initial evaluation, mo	11.6 ± 25.8	7.4 ± 4.2	.40
Lysholm score at final evaluation	90.8 ± 5.6	53.3 ± 7.7	<.05
Meniscal injury, medial/lateral, n	2/0	3/1	.08
Bone marrow lesion, medial/lateral, n	2/0	5/1	.08

<sup>a</sup>Data are presented as mean ± SD unless otherwise specified. C, conservative treatment; S, surgical treatment.

patients underwent axial radiographs and lateral radiographs with gravity sag view. The radiographic evaluations were not considered as part of the decision for whether a patient went on to have surgical treatment.

The PL was evaluated on the gravity sag view.<sup>22</sup> The method for obtaining the gravity sag view was as follows (Figure 1A): The patient was positioned supine with both hips flexed at 45° and both knees at 90° of flexion. The x-ray beam projected from the lateral side. Side-to-side differences of the tibia-femur step-off were measured as posterior shift, and PL was calculated as the amount of posterior shift in the injured knee minus that in the contralateral uninjured knee. Seven patients had grade I injuries (PL, <5 mm), and 20 patients had grade II injuries (PL, 5 to < 10 mm).

The FG was evaluated using axial radiographs with the knee at 90° of flexion and the x-ray beam projected along the femoral axis, as reported in previous studies<sup>6,9,12,16</sup> (Figure 1B). This view can be used to evaluate the FG and rotational position of the femoral component after TKA. The method for obtaining axial radiographs in our study was based on previous studies as follows: Each patient sat on a table with his or her lower legs hanging and a 1.5-kg weight attached to the ankle. The marker used to calculate radiograph magnification (a 50 mm-diameter stainless steel disc) was attached to the lateral side of the knee. The patient was instructed to relax the leg muscles, especially the quadriceps, with relaxation confirmed by clinical palpation of the thigh. Then, axial radiographs of the injured and contralateral uninjured knees were obtained to evaluate the increment of the FG. The FG expressed the total of the medial and lateral vertical distances from the midpoint of each condyle to the tibial bony surface on the

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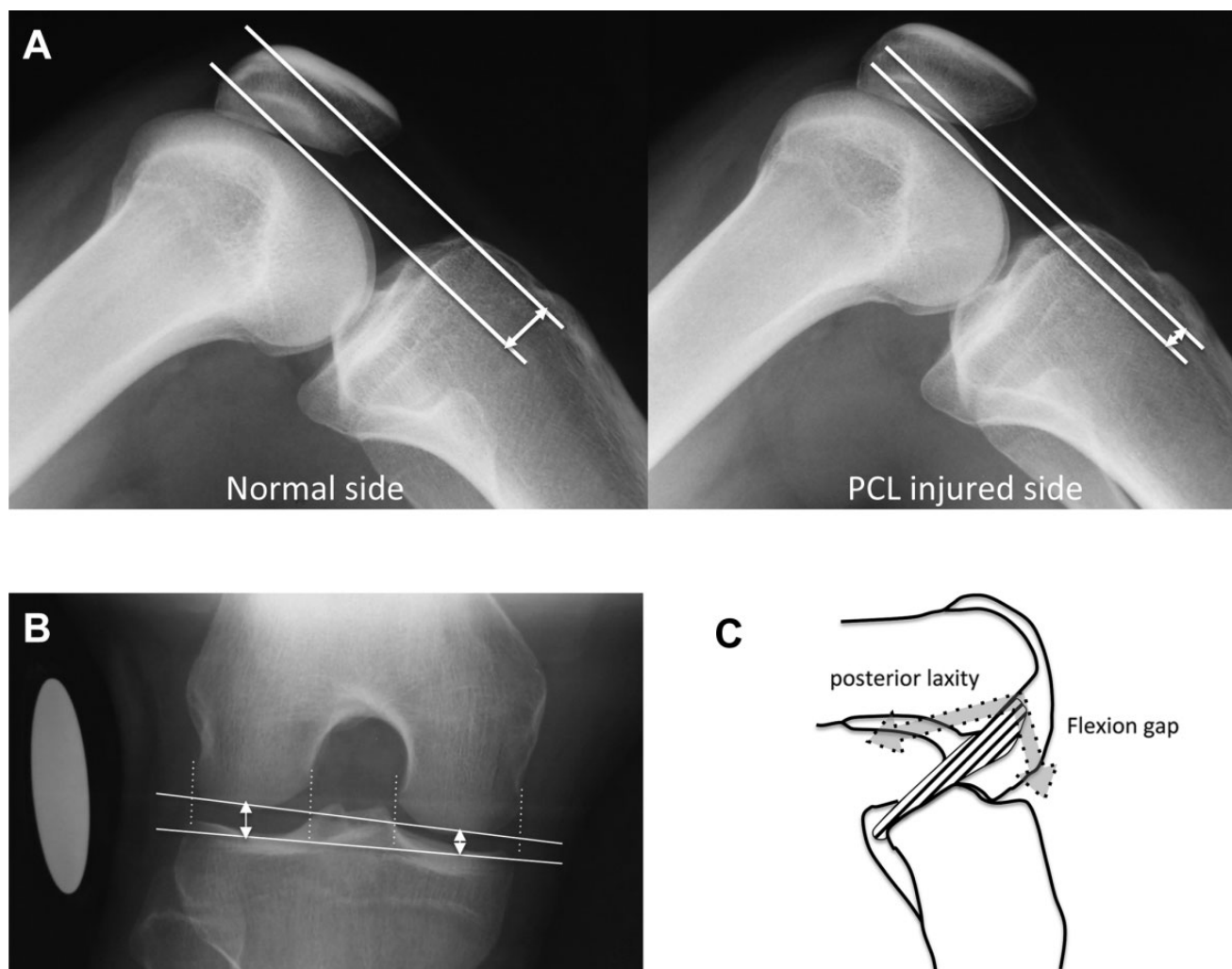
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Ethical approval for this study was obtained from the Osaka Rosai Hospital Ethics Committee (No. 28-47).



**Figure 1.** Radiographic evaluation. (A) Posterior laxity was evaluated on the gravity sag view of lateral radiographs. Side-to-side differences of the tibia-femur step-off were measured as posterior shift (arrows). (B) The flexion gap was evaluated on axial radiographs, with the knee at 90° of flexion. Side-to-side differences of the total medial and lateral vertical distances from the midpoint of each condyle to the tibial bony surface were measured (arrows). (C) Schema of the radiographic evaluation with the knee at 90° of flexion. The running pathway of the posterior cruciate ligament (PCL) can be divided into 2 factors: posterior laxity and flexion gap.

axial radiograph. Previous interobserver and intraobserver variability in measuring the FG on axial radiographs have shown intraclass correlation coefficients of 0.970 and 0.956, respectively.<sup>14</sup>

**Statistical Analysis**

The correlation between the side-to-side differences of the FG and PL was analyzed using the Spearman rank correlation coefficient test. The comparison in laxity between the 2 groups was analyzed using the Wilcoxon signed-rank test. The prediction of PCL reconstruction, measured by the area under the ROC (receiver operating characteristic) curve (AUC), was completed using SPSS. *P* < .05 was considered statistically significant. The power (0.58) was calculated using G\*Power on a web-based calculator.

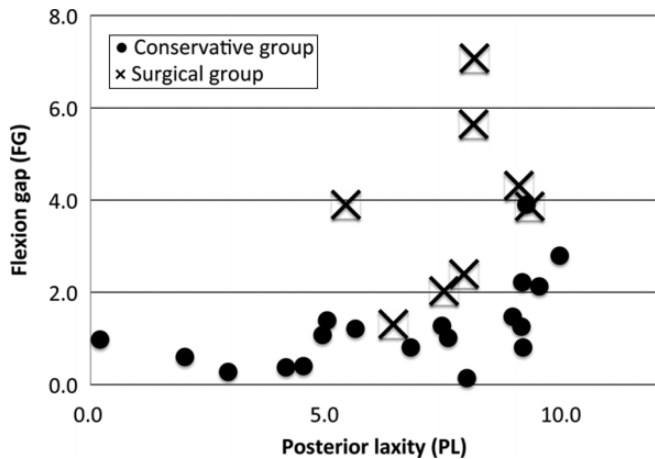
**TABLE 2**  
Posterior Laxity and Flexion Gap in the Study Groups<sup>a</sup>

	C Group	S Group	<i>P</i> Value
Posterior laxity, mm	6.5 ± 2.9	7.7 ± 1.3	.27
Flexion gap, mm	1.2 ± 1.0	3.8 ± 2.0	<.05

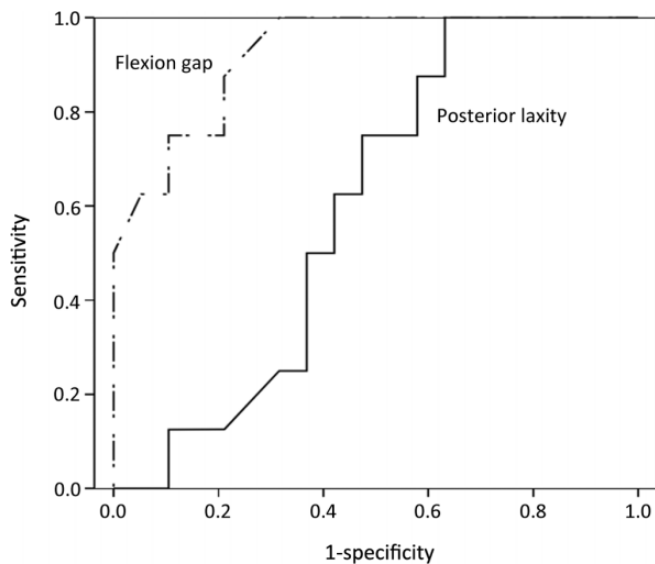
<sup>a</sup>Data are presented as mean ± SD. C, conservative treatment; S, surgical treatment.

**RESULTS**

The mean PL and FG were 6.5 ± 2.9 mm and 1.2 ± 1.0 mm in the C group and 7.7 ± 1.3 mm and 3.8 ± 2.0 mm in the S group, respectively. The FG in the C group was significantly smaller than that in the S group (*P* < .05), although



**Figure 2.** Scatter plot of flexion gap (FG) and posterior laxity (PL) in the patients who returned to their previous level after conservative treatment (black dot) and those who underwent posterior cruciate ligament reconstruction (X mark). The FG and PL were mildly positively correlated ( $r = 0.47$ ,  $P = .02$ ).



**Figure 3.** Receiver operating characteristic curves illustrating the ability to discriminate between the conservative treatment group and surgical treatment group for the following 2 factors: posterior laxity (black line) and flexion gap (dashed line).

there was not a significant difference in PL between the groups (Table 2). Moreover, a mild positive correlation between the PL and the FG was observed ( $r = 0.47$ ,  $P = .02$ ) (Figure 2).

All patients with grade I injury belonged to the C group, for which the FG was  $<2$  mm in all cases. Eight of the patients with grade II injury underwent PCL reconstruction, and their FG was  $>2$  mm in all but 1 patient (Figure 2).

The ROC curves illustrate the accuracy of the FG and the PL in discriminating between the C and S groups. The FG performed better, with an AUC of 0.924 (95% CI, 0.000-

1.000) compared with 0.599 (95% CI, 0.388-0.809) for the PL (Figure 3).

For discriminating between the C and S groups, with a cutoff set at 2.30 mm for the FL and 7.45 mm for PL, we found a sensitivity of 75.0% and 75.0% and a specificity of 89.5% and 52.6%, respectively (Table 3).

## DISCUSSION

The PCL is a strong stabilizer of the knee and provides posterior stability to the tibia. Previous reports have noted that athletes with PCL injuries functioned well despite obvious PL.<sup>8,17,18,24</sup> Moreover, some studies have indicated that there is no correlation between the amount of PL and clinical knee function.<sup>8,17,24</sup> Thus, a treatment decision can be difficult and is based on many factors. The sagittal alignment of the PCL at 90° of knee flexion suggests that the PCL might play a role not only in posterior stabilization but also in maintenance of the FG,<sup>14</sup> and some studies have revealed that the FG increased after resection of the PCL in TKA<sup>10,11,15,26</sup> (see Figure 1C). The present study showed a mild positive correlation between the PL and the FG. The FG in patients who required PCL reconstruction was significantly greater than in patients who had symptom relief after conservative treatment, while there was no significant difference in PL between the groups. Thus, the FG, and not the PL, might have an effect on the remaining symptoms after a PCL injury.

The majority of patients treated conservatively for PCL injury can expect to return to activity at the same or similar level. In one study, half of the 133 patients were able to make a full return in spite of a further 32% of patients returning at a lower level.<sup>18</sup> In a long follow-up study, 76% of 271 patients were able to return to sports or activity at a similar level.<sup>19</sup> Another study of conservative treatment after PCL injury found that 85% of sports injuries achieved a good result for returning to activity, compared with only 8% for motor vehicle accidents.<sup>5</sup> Despite cases of a successful return to activity, another report found that 74% of those who returned to sports thought that they had limitations.<sup>3</sup> Rugby players' athletic performance was reduced after a PCL injury, with high-speed running as the most affected skill.<sup>25</sup>

As for the severity of PL, rugby athletes with grade I injury tended to return earlier than those with grade II.<sup>25</sup> The severity of PL after an injury might affect the return time to a competitive level, in spite of some reports stating that the degree of laxity did not correlate with return to sports.<sup>18,19</sup> In addition to the severity of PL, other studies have reported that concomitant articular cartilage and meniscal damage might be an important factor influencing postinjury sports activity.<sup>7,21,25</sup> These previous studies, which investigated patients with grade I and II, not grade III injury, indicated that the discrepancy in results may be caused by differences in the types of sports participation and preinjury activity levels. In our series, concomitant meniscal and cartilage injuries did not significantly affect the clinical scores (see Table 1).

The surgical indication for a chronic isolated PCL injury remains controversial.<sup>13</sup> Studies have indicated that

TABLE 3  
Prediction of PCL Reconstruction<sup>a</sup>

	AUC (95% CI)	Cutoff Value	Sensitivity	Specificity
Posterior laxity	0.599 (0.388-0.809)	7.45	0.75	0.526
Flexion gap	0.924 (0.000-1.000)	2.30	0.75	0.895

<sup>a</sup>AUC, area under the receiver operating characteristic curve; PCL, posterior cruciate ligament.

patients with a grade III PCL injury, which is most often combined with another ligament injury, and isolated PCL injury with cartilage damage tend to undergo surgery.<sup>4,20,21,25</sup> Our study showed that the FG was related to knee function rather than PL because the specificity of PL was lower than that of FG. The cutoff value of 2.30 mm for FG and 7.45 mm for PL from statistical analysis among patients with grade I and II injuries indicated that those with grade I injury might have better results after conservative therapy but that those with grade II injury might be separated at these cutoff values.

The limitations of this study are that the number of patients was small and that this study was retrospective. Conservative treatment regimens were not completely identical because most patients in the S group underwent conservative treatment in another hospital. Therefore, future prospective research is needed using the same protocol for PCL rehabilitation. In addition, the cause of injury, level of activity, and type of sport were not the same among patients. The possibility of other associated injuries still remained, even if all patients were evaluated with a physical examination. Thus, in the future, it is necessary to investigate a large number of PCL injuries prospectively.

Considering that the FG affects the outcome of conservative treatment, it could be a factor, in addition to the PL, in the indication for surgical treatment of isolated PCL injuries.

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