The purpose of this study was to 1) compare the functional result and muscle strength between patients who underwent reconstruction by isolated posterior cruciate ligament (PCL) and combined PCL-posterolateral corner sling (PLCS) reconstruction. Nineteen (Group I: isolated PCL reconstruction) and 30 (Group II: combined PCL-PLCS reconstruction) were compared. The clinical results and isokinetic muscle strength were compared between groups. The clinical results were comparable between groups and posterior stability was not different between the two groups, either. The isokinetic strength test result was not significantly different between the two groups, although absolute values of the flexion strength in Group I was higher than those in Group II. The HQ ratio of the affected side in Group I was similar to that of the contralateral side. Isokinetic muscle strength, especially flexion, was not fully recovered as compared with the contralateral side, although clinical and stability results were improved. However, the isolated PCL reconstruction group that was managed with the accelerated rehabilitation protocol showed an HQ ratio similar to that of the contralateral side. Therefore, an earlier active strengthening program would be also necessary in PCL-PLCS reconstructed groups, and justification for prevention of early weight bearing in PCL-PLCS reconstruction should be re-evaluated because weight bearing is helpful for muscle strengthening.

**Keywords:** Knee; posterior cruciate ligament; reconstruction; Rehabilitation; Isokinetics.

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**INTRODUCTION**

The keys to successful posterior cruciate ligament (PCL) reconstruction are to identify and treat all pathologies, use strong graft material, use an accurate surgical technique, ensure strong graft fixation, and use an appropriate rehabilitation program. Posterolateral rotatory instability (PLRI) is frequently combined with PCL injury, and recognition and proper treatment of PLRI is important because it may affect the gait pattern, result in subjective complaints, and cause of failure of concomitant ligamentous reconstruction. Posterolateral corner sling (PLCS) reconstruction

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for PLRI is frequently performed because it has several advantages, although the optimal technique for the treatment of PLRI has not yet been established.(9,10) An adequate rehabilitation protocol that is not harmful to stability is important for functional recovery. Traditional rehabilitation protocols after PCL or combined PLCS for PLRI reconstruction are not as well established as those for anterior cruciate ligament (ACL) reconstruction. In contrast to ACL rehabilitation, accelerated PCL postoperative rehabilitation is generally undesirable, and most surgeons and physical therapist are using more conservative methods than those used for ACL reconstruction.(7,8) Delayed PCL postoperative rehabilitation can result in diminished hamstring activity due to the reduced demand on the PCL, much like diminished quadriceps activity reduces the demand on the ACL.(27,33) The negative aspects of these methods imply that it is possible to cause dysfunction to patients.

Muscle strength becomes critical for assessment of reconstructed ligaments and a rapid, uneventful return to pre-injury activities.(30) Quadriceps muscle strength has been shown to correlate with good outcomes after ACL reconstruction, but it is not well established for PCL or PLCS patients.(19) Evaluation of muscle strength can be accomplished using functional tools (hop test) or single-joint evaluation tools.(22,23) One of the most commonly used reliable tools to assess single-joint muscle strength is isokinetic dynamometry.(1,4,5)

Relatively more accelerated rehabilitation protocol as compared with other authors was used in this study (Tables 1 and 2).(26) After isolate PCL reconstruction, strengthening was encouraged within low grades of flexion and that early weight-bearing is started for co-contraction and proprioception, but range of motion (ROM) was similar to that of other protocols.(7,8,16,26) However, weight bearing and strengthening were delayed about 3 weeks after PCL-PLCS reconstruction although ROM and proprioceptive training were performed with similar protocol as like isolated PCL reconstruction. The purposes of this study were to 1) compare the functional result and muscle strength between patients who underwent reconstruction by isolated PCL and combined PCL-PLCS reconstruction and 2) to evaluate the efficacy of our relatively accelerated rehabilitation protocol and reevaluate the program according to the outcomes of this comparison. Our hypotheses were that 1) patients who underwent PCL-PLCS reconstruction would show a lower functional recovery and muscle strength than patients who underwent isolated PCL reconstruction and that 2) the more accelerated rehabilitation program would be needed in patients who underwent PCL-PLCS reconstruction.

MATERIALS AND METHODS

The study population comprised 171 patients who underwent primary PCL reconstruction between March 2006 and May 2011. The isolated PCL reconstruction was included as a case group and combined PCL-PLCS reconstructed group was included as a control group. PCL reconstruction was performed in the subacute (after about 3 weeks) or chronic stage because it was difficult to assess the instability in the acute stage. Patients had to be followed up for more than 2 years and had to agree to undergo clinical and muscle strength examinations. The exclusion criteria were an associated combined ACL injury, infection, revision surgery, combined lower extremity fracture, and prior surgery on the affected knee. Multi-ligament reconstructed patients such as combined ACL+PCL, ACL+PCL+PLCS, PCL+medial collateral ligament (MCL) repair or reconstruction were also excluded. However, meniscal injury that was treated as a meniscectomy or repair was included in this study. Institutional review board approval was obtained, and all patients provided informed consent for participation. The clinical results were evaluated in terms of Lysholm score, International Knee Documentation Committee (IKDC) subjective knee score, Tegner activity score, and side-to-side differences (KT-2000 arthrometer; MEDmetric, San Diego, CA) by an independent experienced 3rd party.

Isokinetic muscle strength measurements were performed with a dynamometer (Biodex System 3; Biodex Medical Systems, Shirley, NY) at
postoperative 16.9 ± 7.3 months. Isokinetic muscle strength tests were performed at the common angles classified as 0° to 90°. Isokinetic muscle strength tests were performed in the concentric mode. For the evaluation of quadriceps and hamstring strength in the sitting position, patients were seated on the Biodex testing device with the chest, pelvis, and thigh immobilized with straps (figure 1). After measurement of the ROM of the knee joint in flexion and extension, the flexion angle of the knee joint was adjusted to 90°. Before starting the testing session, each patient completed a standardized stretching exercise program over a period of approximately 10 minutes. Two warm-up repetitions were then performed before measurement. After the patient had warmed up and was familiarized with the procedure, the measurements were repeated four times with an angular velocity of 60°/s. This angular velocity (60°/s) was used to evaluate muscle peak torque. Measurements were first taken on the contralateral side, then on the affected side. The peak torque value (the maximum value during the four repetitions) of the extensor and flexor muscles was assessed, and the measured value of the involved knee was compared with that of the contralateral knee. Isokinetic strength measurements were peak torque of the total range and the torque at 80° (strength of deep flexion). The hamstring-quadriceps (HQ) ratio was also calculated. Finally, for evaluation of recovery, the peak torque of the affected and contralateral sides was compared.

Demographic data, scores, and isokinetic strength tests were compared between the two groups using independent-sample t tests. The flexor peak torque between the affected versus contralateral sides was compared using a paired t test. All statistical analyses were performed using SPSS software (SPSS for Windows, release 18.0; SPSS, Chicago, IL). Significance was set at p < 0.05.

Under regional anesthesia, the patient was placed in the supine position. Instability of the knee joint was checked by the posterior and posterolateral drawer tests. If there was significant posterolateral rotation, PLCS reconstruction was performed simultaneously to correct the PLRI. The affected knee was hung free at the edge of the table in a 90° flexed position. The opposite limb was placed in a well-leg support with the knee and hip flexed, abducted, and externally rotated. A tourniquet was applied to the affected leg.

As the first step of the posterior trans-septal portal preparation, the posteromedial portal was made under direct arthroscopic visualization. Using the transillumination technique, the exact location for the posteromedial portal was marked by an 18G needle. By making a minimal skin incision and expanding the portal with a straight hemostat, the posteromedial portal was established. The posterolateral portal was made in a similar fashion. To create the trans-septal portal, a switching stick was inserted through the posteromedial portal to push the septum laterally and carefully create a hole. An arthroscope was inserted through the posteromedial portal. A motorized shaver was inserted through the posterolateral portal to widen the septum.

When using a Tibialis tendon allograft for PCL reconstruction, an assistant simultaneously prepared the allograft at a side table. The diameter was 8 to 9 mm. At the end of the tendon, No. 5 Ethibond (Ethicon, Somerville, NJ) was used to place whipstitch sutures.

A transtibial tunnel for the PCL graft, which was usually between 8 and 9 mm in diameter, was made depending on the diameter of the graft, while taking care not to damage the remnant PCL stump. Care was taken to protect any neurovascular structures
during the process of drilling and reaming with the guide pin. For a graft passage, a new accessory portal was made below the anterolateral portal. A wire loop was inserted through the tibial tunnel and taken out to the accessory portal.

The retained anterolateral bundle of the PCL femoral attachment was detached with the shaver so that the central portion was exposed. This location is 7 mm posterior to the distal border of the articular cartilage of the medial femoral condyle, which is at the 1-o’clock position in the right knee and the 11-o’clock position in the left knee. The femoral tunnel was formed in an inside-out fashion. After formation of the femoral tunnel, the guide frame was inserted into the femoral socket and two pinholes were drilled, leaving two sleeves for the insertion of the cross-pins (RIGIDfix System; Mitek, Johnson & Johnson, USA).

While keeping the knee in a reduced position, the graft was fixed to the tibial tunnel with two bioabsorbable interference screws and an additional staple fixation was performed for firm fixation of the graft. After the graft fixation, instability of the joint was checked again by the posterolateral drawer tests. If there was significant posterolateral translation after the PCL reconstruction, a PLCS reconstruction operation was performed simultaneously to correct the PLRI.

The indication for PLCS reconstruction for PLRI was determined by thorough physical examination, examination under anesthesia, and arthroscopic examination. We performed PLCS reconstruction if PLRI of grade II or more was detected. Two femoral tunnels were made just proximal to the anatomical locations. The fibular head tunnel was directed from the anterior–inferior superficial aspect to the posterior–superior deep location and was made at the distal portion of the anatomical insertion sites, 6 mm in diameter. A commercially prepared tibialis anterior allograft was prepared as graft material.

Detailed rehabilitation protocols are described in Tables 1 and 2. The main differences between Groups I and II were in the strengthening exercise (immediate vs. postoperative 6 weeks) and weight bearing (immediate full vs. 6 weeks full). A delayed approach was recommended if associated PLRI was present because external rotation of the tibia could occur to compensate for foot pronation. Brace was usually maintained for the first postoperative 6 weeks and the determination of the brace-off was dependent on the status of the patient.

| Table I. — Rehabilitation of isolated PCL reconstruction |
|---------------------------------|------------|------------|-------------|-------------|
| **Weight bearing**              | 1-3 weeks | 4-6 weeks | 6-12 weeks  | 12-24 weeks |
| - Tolerable or Full weight bearing with crunch |            |            |            |
| **ROM**                          | 1-3 weeks | 4-6 weeks | 6-12 weeks  | 12-24 weeks |
| Immediately CPM in prone position |          | To 90 degrees | To 120 degrees |
| **Strength**                     | 1-3 weeks | 4-6 weeks | 6-12 weeks  | 12-24 weeks |
| Q-set, SLR                       | CKC & OKC | Isotonic exercise without hamstring curl | Light Hamstring curl exercise start |
| Calf-raise                       |           |           |             |
| Mini squat (0~30deg)             |           |           |             |
| **Proprioception**               | 1-3 weeks | 4-6 weeks | 6-12 weeks  | 12-24 weeks |
| Muscle coordination              |            |            |            |
| balance                          |            |            |            |
| **Return to sports**             | 1-3 weeks | 4-6 weeks | 6-12 weeks  | 12-24 weeks |
| Allow light running within muscle deficit 30% | Allow sports specific activation within muscle deficit 15 % | | |
Forty-nine patients fulfilled the above-mentioned criteria. For comparison, we divided the patients into two groups. The total numbers of patients were 19 (Group I: isolated PCL reconstruction) and 30 (Group II: combined PCL-PLCS reconstruction). The ratio of male:female patients was 27:3 in Group I and 18:1 in Group II. The mean follow-up period was 28.9 months (range, 20–48 months). In the comparison between preoperative and final follow-up clinical results, Lysholm, IKDC, and Tegner knee scales were significantly improved at the last follow-up as compared with preoperative values (p < 0.05). In the comparison of the last follow-up clinical results between Groups I and II, there were statistically significant differences in the Lysholm (94.6 ± 5.4 vs. 87.5 ± 10, p = 0.007) and IKDC (88.5 ± 10 vs. 79.7 ± 14.1, p = 0.014) scores, but there were no statistically significant differences in the Tegner activity score (5.6 ± 1.6 vs. 4.9 ± 1, p = 0.117) and side-to-side difference on the KT-2000 arthrometer (4.5 ± 3 vs. 4.7 ± 2.7, p = 0.76).

Isokinetic muscle strength was not significantly different in any of the variables, although Group I showed higher flexion strength on both the affected and contralateral sides as compared with Group II (Table 3). The flexion strengths of the affected and contralateral sides showed no statistical differences in either low-grade 30° flexion (flexion peak torque) or deep flexion (80° flexion) between both groups (Table 3). The affected sides showed statistically significant lower strengths than the contralateral sides (Table 4). Groups I and II showed no statistically significant difference in the HQ ratio (Table 3). However, the HQ ratio of the affected side in Group I was not statistically significantly different from that of the contralateral side, although the HQ ratio of the affected side in Group II was significantly higher than that of the contralateral side (Table 4).

**DISCUSSION**

The principle findings of this study were that 1) the clinical results were comparable between groups and posterior stability was not different between the two groups, either; 2) the isokinetic strength test result was not significantly different between the two groups, although absolute values of the flexion

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**RESULTS**

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**DISCUSSION**

The principle findings of this study were that 1) the clinical results were comparable between groups and posterior stability was not different between the two groups, either; 2) the isokinetic strength test result was not significantly different between the two groups, although absolute values of the flexion
similar to that on the contralateral side. This may imply that the isolated PCL reconstruction group had higher quadriceps strength than the PCL-PLCS reconstruction group.

Muscle strength after PCL reconstruction is not well established as compared with ACL reconstruction.\(^{(1,19,29)}\) In a previous motion analysis of patients who underwent PCL-PLCS reconstruction, the patients were reluctant to engage in, or lacked strength for, daily activities at 6 months postoperatively.\(^{(27)}\) Goudie et al.\(^{(12)}\) evaluated the function of 23 patients who underwent PCL reconstruction (4 isolated and 19 combined) and reported good clinical results. However, muscle function remained abnormal in the reconstructed knee at both 12 and 24 months following surgery, and peak torque in both flexion and extension was significantly worse in the reconstructed knee than in the uninjured knee at both follow-up times. These results correspond well with those in a study by Chen et al.\(^{(6)}\) and are in contrast to the commonly held opinion that functional recovery is complete at 12 months.\(^{(11)}\) They concluded that muscle function in the reconstructed knee demonstrated a trend of gradual recovery over a 2-year period.\(^{(12)}\)

In the common postoperative rehabilitation protocol after PCL reconstruction, hamstring strengthening is initiated at 3 months because of static stability.\(^{(17,18,24)}\) This implies that the hamstrings may be weak, leading to a delay in hamstring muscle activation. These results in reduced co-contraction between the quadriceps and hamstring muscle because the quadriceps activation that provides a net flexor moment required to

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group I</th>
<th>Group II</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contralateral FPT*/BW†</td>
<td>126.6 ± 27.4</td>
<td>120.6 ± 36.5</td>
<td>0.546</td>
</tr>
<tr>
<td>Affected FPT*/BW†</td>
<td>108.2 ± 22.9</td>
<td>96.2 ± 38.6</td>
<td>0.177</td>
</tr>
<tr>
<td>Contralateral FPT*/BW† (80°)</td>
<td>67.6 ± 22.6</td>
<td>55.6 ± 24.1</td>
<td>0.112</td>
</tr>
<tr>
<td>Affected FPT*/BW† (80°)</td>
<td>50.1 ± 22.4</td>
<td>39.4 ± 19.8</td>
<td>0.109</td>
</tr>
<tr>
<td>Contralateral H/Q‡ ratio</td>
<td>52.6 ± 6</td>
<td>50.7 ± 7.7</td>
<td>0.377</td>
</tr>
<tr>
<td>Affected H/Q‡ ratio</td>
<td>53.7 ± 21.8</td>
<td>59.9 ± 18.7</td>
<td>0.247</td>
</tr>
</tbody>
</table>

*: flexor peak torque, †: body weight, ‡: hamstring/quadriceps. These data are mean ± standard deviations.
perform movement would also decrease.(14,15) However, the vector of the hamstring is not directed posteriorly within 30 degrees flexion. Therefore, hamstring exercise is possible within this angle using a calf-raise or minisquat. It could also support the early weight bearing because it could be a different kind of co-contraction and proprioceptive training.(21,25,26) The ideal HQ ratio for an ACL reconstruction may be the HQ ratio of the opposite healthy extremity, and the ideal absolute value of the HQ ratio is between 50% and 80%.(26) Our HQ ratio results were within the ideal absolute value, and the HQ ratio of the patients who underwent isolated PCL reconstruction was similar to that of the contralateral side. We believe that our relatively accelerated rehabilitation protocol contributed to these HQ ratios.

Nevertheless, our study has some weaknesses. First, the period of isokinetic testing was a bit variable (18–32 months), and some mismatches existed between clinical follow-up and isokinetic testing. Second, it could not be stated definitely that the improved muscle strength originated from the relatively accelerated rehabilitation program. Third, reconstructed patients were only considered and conservative treatment could be considered as a valid alternative control group. However, this study focused on the postoperative rehabilitation and used isolated PCL reconstruction as a case and PCL-PLCS reconstruction as a control.

CONCLUSION

Isokinetic muscle strength, especially flexion, was not fully recovered as compared with the contralateral side in both groups, although clinical and stability results were improved. However, the isolated PCL reconstruction group that was managed with the accelerated rehabilitation protocol showed an HQ ratio similar to that of the contralateral side. Therefore, an earlier active strengthening program would be also necessary in PCL-PLCS reconstructed groups, and justification for prevention of early weight bearing in PCL-PLCS reconstruction should be re-evaluated because weight bearing is helpful for muscle strengthening.

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