Anatomic Reconstruction of the Posterolateral Corner of the Knee: A Case Series With Isolated Reconstructions in 27 Patients

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Purpose: This study presents clinical results of a case series of isolated reconstruction of the posterolateral corner (PLC) with a new technique that aims to reconstruct the lateral collateral ligament (LCL), popliteus tendon, and popliteofibular ligament. Methods: From 1997 to 2005, 27 patients available for follow-up with isolated posterolateral instability were treated with primary reconstruction of the LCL and PLC. The median age was 28 years, and there were 16 male patients. Of the patients, 26% had remaining instability after anterior or posterior cruciate ligament reconstruction. All underwent reconstruction with a novel technique addressing both the LCL and the PLC by use of hamstring autografts. Follow-up was more than 24 months, and patients were examined by an independent observer using the International Knee Documentation Committee objective measures and subjective Knee Injury and Osteoarthritis Outcome Scores. Results: In our series 95% of patients with isolated lateral rotatory instability had rotatory stability after PLC reconstruction. On the basis of International Knee Documentation Committee scoring, 71% were normal or nearly normal. Subjective Knee Injury and Osteoarthritis Outcome Scores were comparable to scores in patients after meniscectomy. One patient had a deep infection, but none had any peroneal nerve injury. Conclusions: This case series presents a new method for combined reconstruction of the LCL and the PLC. Despite the extensiveness of procedure, complications were low. The technique restores lateral stability clinically at 2 years' follow-up. Level of Evidence: Level IV, therapeutic case series.

Injury to the posterolateral ligament structures of the knee is uncommon and frequently related to high-energy trauma and knee dislocations. Isolated injuries are rare and seen in only 2% of all knee ligament injuries. Among combined knee ligament injuries, posterolateral injuries are more common and are seen in 60% of cases with posterior cruciate ligament (PCL) injury.2 Overlooked injuries to the posterolateral complex in patients with multiligament injuries have been seen to lead to failure of reconstructed anterior cruciate ligaments (ACLs) and PCLs.3,4 Conservative treatment of posterolateral injuries has been shown to lead to residual posterolateral laxity clinically.5 The lateral and posterolateral complex (lateral collateral ligament [LCL]/posterolateral corner [PLC]) consists of numerous structures and has been divided into the iliotibial tract, long and short heads of the biceps femoris muscle, fibular collateral ligament (LCL), midthird lateral capsular ligament, fabellolublar ligament, posterior arcuate ligament, popliteus muscle complex, lateral coronary ligament, and posterior capsule.6 Knee instability due to lesions of the lateral and posterolateral structures causes increased
load on the ACL during varus loading and internal rotation and increased load on the PCL during varus loading and external rotation.\(^4\)\(^,\)\(^7\) Tibial internal rotation is restrained by the medial and posteromedial structures, whereas tibial external rotation is restrained by the lateral and posterolateral structures.\(^8\)\(^,\)\(^9\)

Early anatomic repair has been advocated for acute injuries with significant clinical instability. The repair needs to be performed within 2 weeks of injury to be able to identify anatomic structures. Repair of the LCL-PLC structures has been reported to fail in 37\% of cases and with a higher failure rate than with PLC reconstructions performed nonacutely.\(^10\) In addition, there is a risk of treating lesions that could have healed with conservative treatment.

Several reconstructive procedures have been described. These techniques typically aim to reconstruct the LCL without addressing posterolateral structures or use combined techniques that address both the LCL and PLC. Biceps tenodesis with release of part of the biceps tendon and fixation of the free end to the LCL attachment at the femoral condyle is an isolated LCL reconstruction.\(^11\)\(^,\)\(^12\) Similarly, several loop procedures using a tendon graft through the fibular head and fixation to the LCL attachment at the femoral condyle have been described.\(^13\)\(^-\)\(^16\) Finally, combined LCL-PLC reconstruction has been described by LaPrade et al\(^17\) and other authors.\(^18\)\(^,\)\(^19\) Studies presenting clinical results with the different techniques are very limited. In a case series with 22 patients, 15 with multiligament injuries and 8 with isolated PLC injuries, 83\% of patients with multiligament injuries and 88\% of those with isolated PLC injuries obtained normal or nearly normal results according to International Knee Documentation Committee (IKDC) scoring after reconstruction with a modified sling technique.\(^10\) A recent study compared PLC reconstructions using fibular and tibial canals and found better rotational stability with the fibular technique in 47 patients with multiligament injuries.\(^20\) No clinical studies have presented clinical results after isolated PLC injuries treated with combined LCL-PLC reconstructions.

The aim of this study is to present clinical results of a retrospective case series after isolated PLC reconstruction using a novel PLC reconstruction technique that addresses both LCL and popliteal tendon ligaments.

**METHODS**

**Patients**

From October 1997 to April 2005, a total of 40 patients with isolated lateral and posterolateral insta-

--IMAGE-
they were relatively young, with a mean age around 28 years.

**Demographics**

Twenty-seven patients underwent follow-up for more than 24 months postoperatively. The median follow-up was 46 months (range, 24 to 86 months). There were 11 female patients and 16 male patients. The median age was 28 years, with a range from 13 to 57 years. Causes of initial injury were traffic accidents in 25% of cases and sports in 53%. Seven patients had remaining varus and rotatory instability after ACL or PCL reconstruction. One patient had a PCL reconstruction, and the remainder (6 patients) had ACL reconstruction. There was no significant difference in gender, age, body mass index, time from injury to surgery, and frequency of other previous surgeries between all operated patients and the patients available for follow-up (Table 1). Only 3 patients had a body mass index between 30 and 35, so obesity was not frequent in this patient material.

**Evaluation**

All patients with a minimum of 2 years’ follow-up were seen for follow-up in 2007. Objective examination was performed by an independent observer who was an experienced physiotherapist.

Patients were evaluated by preoperative and follow-up IKDC objective scores. At follow-up, a subjective Knee Injury and Osteoarthritis Outcome Score (KOOS) profile was obtained. The follow-up KOOS profiles were compared with published profiles from normal subjects, ACL-reconstructed subjects, and subjects who had undergone meniscectomy. Anterior-posterior instability was objectively assessed by KT-1000 testing (MEDmetric, San Diego, CA) because it has been recognized that the PLC also plays a role in anterior-posterior stability.

Any complications and reoperations were registered. Range-of-motion evaluation was based on objective IKDC scores. Patients were asked to describe any problems with pain.

**Surgical Technique**

The semitendinosus and gracilis tendons are harvested at the pes anserinus. Tendons are prepared with No. 2 FiberWire baseball suture (Arthrex, Naples, FL) at 1 end. Lateral structures are exposed through a hockey-stick incision. The peroneal nerve is exposed distal to the fibular head for visual nerve protection during drilling. An incision above the biceps tendon insertion enables palpation of the posterolateral aspect of the tibial condyle. A tibial tunnel is then drilled from the anterior aspect of the lateral tibial condyle at the level of the fibula head to the posterior corner of the lateral tibial condyle. The drill hole should exit 10 mm below the tibial plateau posteriorly at the center of the popliteus muscle. The tunnel diameter is the size of the semitendinosus graft, which typically will be 6 mm. An oblique tunnel is drilled through the proximal fibula at the insertion site of the LCL, heading toward the posterior tip of the fibula. The iliotibial tract is split over the lateral femoral condyle to expose the insertion sites of the LCL and popliteus tendon. Two femoral tunnels are then drilled at the LCL and popliteus tendon femoral insertion sites sized according to the measured diameter of the double looped tendon grafts. The semitendinosus tendon is passed from posterior through the tibial condyle hole. Then, it is passed from anterior through the fibular hole and subsequently under the fascia to the femoral insertion site of the popliteus tendon, creating a double looped

| TABLE 1. Epidemiologic Data in All Patients Operated on With Isolated Lateral Reconstruction, Patients With More Than 24 Months’ Follow-Up, and Patients With Previous Cruciate Ligament Reconstruction |
|-----------------|-----------------|-----------------|
| Number          | All Patients    | Patients With >24 mo Follow-Up | Patients With Previous Cruciate Ligament Reconstruction |
| Gender (F/M)    | 40              | 27              | 1/6 |
| Median age (range) (yr) | 29 (13-57)     | 28 (13-57)     | 36 (23-46) |
| Chronic cases   | 42.5%           | 29.6%           | 100% |
| *Time from injury to surgery (mo) | 36               | 32              | 50  |
| Previous surgery| 32.5%           | 25.9%           | 100% |
| *Body mass index | 25.1           | 25.6            | 26.8 |

NOTE. A chronic case is defined as more than 12 months from injury to surgery. *Data are presented as mean.
PLC reconstruction with tendon strand coming from the posterior tibial condyle and posterior fibular head. The gracilis graft is passed through the fibular tunnel and passed under the fascia as a sling to the femoral LCL insertion (Fig 2).

The other end of the grafts are measured and cut according to femoral drill holes, with 15 to 20 mm over length, and the free end is sutured with a No. 2 FiberWire. The graft ends are then passed into the femoral tunnels with a Bio-Tenodesis screwdriver (Arthrex) and fixed with Bio-Tenodesis screws with a diameter equal to the diameter of graft and bone tunnel with the knee in 60° of flexion, neutral rotation, and valgus stress. LCL sling graft is fixed in the same manner with the knee in near extension, neutral rotation, and valgus stress.

The LaPrade technique entails a single-strand LCL and popliteal tendon reconstruction. In addition, the popliteofibular ligament is reconstructed from the posterolateral aspect of the tibia to the posterior aspect of the fibula. Our technique entails double-stranded LCL reconstruction with a sling technique and a single-stranded popliteal tendon reconstruction. In addition, a popliteofibular ligament is reconstructed but in a more anatomic manner, going from the posterior aspect of the fibula to the popliteal tendon insertion on the femur.

For an experienced surgeon, the procedure is estimated to take approximately 60 minutes.

Rehabilitation
We used a hinged brace with 0° to 90° of motion for the first 2 weeks and partial weight bearing. Starting in week 2, continued brace use is recommended, with unlimited degrees of range of motion and weight bearing during standing and walking. After 6 weeks, unrestricted activity was allowed. Controlled sports activities after 3 months and contact sports after 6 months were allowed.

Statistics
Demographic data were compared between responders and nonresponders with the Student t test and $\chi^2$ test. Preoperative and postoperative IKDC values were compared with the $\chi^2$ test. KOOS data were compared between isolated LCL-PLC—operated patients and those with previous cruciate ligament reconstructions with the Student t test.

RESULTS

Objective IKDC Score
Rotatory instability evaluated by the dial test was abnormal in 60% of patients preoperatively and in only 5% of patients at follow-up ($P < .05$). A similar outcome was found for varus stability. The overall objective IKDC score improved, with an abnormal score of C or D in 60% of patients preoperatively and in 28.6% of patients at follow-up ($P < .05$) (Table 2).

On the basis of KT-1000 measurements, there was no
significant change in anterior-posterior stability, with normal scores in 88% of patients preoperatively and 94% of patients at follow-up. Of the 27 patients, 4 had flexion deficits. Two patients had a 10° deficit, and two had a 5° deficit. When we compared the patients who had previous cruciate ligament reconstruction with the patients with true isolated LCL-PLC injury, objective rotational and varus instability was not significantly different between groups. Both groups had only 1 patient with IKDC grade B varus and external rotational instability; the remainder were grade A.

KOOS Profile

The KOOS profile showed that the ability to perform sports/recreational activities and quality of life were the subscores that were most affected after PLC reconstruction (Table 3). When we compared the KOOS profile with published results after other procedures, PLC-reconstructed patients were similar to patients after meniscectomy and had a moderately poorer outcome compared with patients who had undergone ACL reconstruction.23,24 When we compared the patients who had previous cruciate ligament reconstruction with the patients with true isolated LCL-PLC injury, the KOOS was significantly worse for patients with previous cruciate ligament reconstruction, with subscores for activities of daily living, sports and recreation, and quality of life that were 17, 26, and 30 points lower, respectively.

Return to Sports

Tegner score at follow-up was 4.6 (2.2). Of 27 patients, 3 had Tegner scores of 1 and 2, indicating poor function level. Seven patients returned to a high level of sports participation, and the remainder returned to recreational sports. Of the 27 patients, 13 had a higher level of sports function after reconstruction than preoperatively.

Complications

There was 1 major complication, which was a deep infection along the tibial drill tunnel. The infection was treated successfully with intravenous antibiotics, and the reconstruction was preserved. One patient had deep knee pain that was treated with arthroscopic partial synovectomy without success. Two patients complained of moderate function related knee pain, and one patient had rotatory pain during examination.

### Table 2. Patients Divided Into Groups Preoperatively and at Follow-up Based on IKDC Rotational Instability and Overall Score

<table>
<thead>
<tr>
<th>IKDC Level</th>
<th>Rotational Stability Preoperatively (%)</th>
<th>Follow-up (%)</th>
<th>Varus Stability Preoperatively (%)</th>
<th>Follow-up (%)</th>
<th>Anterior-Posterior Stability Preoperatively (%)</th>
<th>Follow-up (%)</th>
<th>Overall Preoperatively (%)</th>
<th>Follow-up (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (%)</td>
<td>—</td>
<td>76</td>
<td>—</td>
<td>89</td>
<td>52</td>
<td>62</td>
<td>—</td>
<td>14</td>
</tr>
<tr>
<td>B (%)</td>
<td>40</td>
<td>19</td>
<td>15</td>
<td>7</td>
<td>36</td>
<td>33</td>
<td>40</td>
<td>57</td>
</tr>
<tr>
<td>C (%)</td>
<td>48</td>
<td>5</td>
<td>67</td>
<td>4</td>
<td>12</td>
<td>5</td>
<td>48</td>
<td>29</td>
</tr>
<tr>
<td>D (%)</td>
<td>12</td>
<td>—</td>
<td>13</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>12</td>
<td>—</td>
</tr>
</tbody>
</table>

### Table 3. KOOS at Follow-up in Present Study Compared With ACL-Reconstructed Patients After 1 Year and Partial Meniscectomy After 15 Years*

<table>
<thead>
<tr>
<th>KOOS Subscale</th>
<th>Isolated LCL-PLC</th>
<th>ACL/PCL Reconstruction</th>
<th>ACL Reconstruction in Danish ACL Registry</th>
<th>Long-Term Results of Partial Meniscectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>75 (39-100)</td>
<td>60 (39-86)</td>
<td>61</td>
<td>84</td>
</tr>
<tr>
<td>Symptoms</td>
<td>77 (42-100)</td>
<td>62 (42-75)</td>
<td>84</td>
<td>86</td>
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<tr>
<td>Activities</td>
<td>83 (38-100)</td>
<td>66 (38-87)**</td>
<td>89</td>
<td>88</td>
</tr>
<tr>
<td>Sports/recreation</td>
<td>55 (0-100)</td>
<td>29 (0-55)**</td>
<td>63</td>
<td>64</td>
</tr>
<tr>
<td>Quality of life</td>
<td>59 (15-100)</td>
<td>29 (13-56)**</td>
<td>60</td>
<td>71</td>
</tr>
</tbody>
</table>

NOTE. Data are presented as median (range).
*Based on data from references 23 and 24.
**Significantly different from isolated LCL-PLC group.
DISCUSSION

Though a rare condition, isolated symptomatic LCL-PLC insufficiency exists and may require surgical treatment. Our series of 40 isolated PLC reconstructions was part of a total of 2,293 ligament reconstructions performed in the inclusion period, resulting in isolated LCL-PLC reconstructions being performed in only 1.7% of all ligament reconstructions at our university clinic. This correlated well with previous findings of DeLee et al. The rareness of the condition can lead to injuries being overlooked because of the lack of a routine clinical instability examination that addresses the posterolateral structures. In addition, the rare need for surgical treatment may cause surgeons to be reluctant to perform a posterolateral reconstruction procedure because of the relatively advanced technique necessary and the extra time that the LCL-PLC procedure adds to other ligament reconstruction procedures.

In this study we present a new technique for combined LCL-PLC reconstruction. We found a good ability of the procedure to restore rotational stability and therefore considered the clinical outcome of the procedure acceptable. In addition, the complications were acceptable, with 1 deep infection and a few patients with postoperative knee pain, which in 1 patient was related to lateral structures.

Our case series included patients with isolated PLC instability after either ACL or PCL reconstruction. The injuries in these patients did not represent true isolated injuries but are surgical cases in which isolated PLC reconstruction is performed. The patients with previous surgery were older and had a longer period from injury to surgery than patients with isolated injuries. The clinical outcome based on the KOOS was poorer when previous surgery had been performed despite the fact that objective instability did not differ between the groups.

The knee stability obtained by the PLC reconstruction is relatively good, with more than 90% of the patients having good and excellent IKDC results. For the subjective KOOS profiles, the outcome of PLC reconstruction in patients without previous surgery was comparable to that in patients with primary ACL reconstruction. In contrast, the KOOS was significantly lower for patients who had had a previous cruciate ligament reconstruction.

Several reconstructive procedures for reconstruction of the lateral knee ligament structure have been described. Biceps tenodesis as shown by Bousquet et al. did not restore lateral stability because of femoral fixation performed too proximally. Biceps tenodesis alone with a fixation point located 1 cm anterior to the LCL insertion on the femur was effective at restoring external rotation and varus laxity in a cadaveric study, but biceps tenodesis is not an anatomic reconstruction, and the technique has no widespread clinical usage. Similarly, several loop procedures restore varus stability biomechanically and clinically, but they do not reconstruct the popliteal tendon and the popliteal fibular complex. A recent study showed that a single-loop allograft reconstruction passed through a drilled tunnel in the head of the fibula at a 45° angle and fixed in the femoral tunnel at the lateral epicondyle with a Bio-Tenodesis screw seems to restore LCL and popliteal ligament function, but similar to the sling techniques, this method does not address the popliteus tendon component.

A cadaveric study found that the posterolateral structures play an important role at full extension in intact knees and at all angles of flexion in PCL-deficient knees, and the popliteus muscle appears to be a major stabilizer under this loading condition. In addition, Suda et al. found that combined reconstruction of the PCL, LCL, and popliteus tendon is essential and adequate for treating severe chronic posterolateral rotatory instability. Although surgical reconstruction of the popliteal tendon will not be able to provide the dynamic stabilization of the popliteus muscle, the importance of an anatomic reconstruction including the popliteal tendon in an attempt to address the complete posterolateral complex seems evident. The clinical significance of reconstructing both structures has been shown in a study by Yoon et al. In their study comparing 2 case series using the sling technique and an anatomic reconstruction of both the LCL and the popliteus tendon with an Achilles tendon allograft, the anatomic reconstruction showed superior rotational and varus stability and a higher Lysholm score. The best documented technique biomechanically is that described by LaPrade et al. This technique combines LCL and PLC reconstruction using split Achilles tendon allograft. Through bone canals in the fibular head and lateral tibial condyle, the LCL and PLC are reconstructed to normal femoral attachments. This reconstruction has been shown to restore both varus and external rotational instability biomechanically. A recent report has described a posterolateral reconstruction technique that attempts the same combined LCL and popliteofibular ligament reconstruction by use of Achilles tendon allograft.
The technique presented in this study uses a sling technique for the LCL reconstruction and a second tendon graft from the posterolateral tibial condyles to the popliteal insertion on the femur for popliteal reconstruction. In addition, a fibular popliteal ligament reconstruction is included, with a tendon graft going from the posterior part of the fibular head to the popliteal insertion on the femur.

Despite the extensive exposure and the complex tendon reconstruction in multiple drill holes in both the lateral femoral and tibial condyles, we observed very limited postoperative morbidity that could be related to the procedure.

Peroneal nerve injury is an important complication that needs to be avoided when one is performing lateral knee procedures. In our technique we exposed the peroneal nerve early in the procedure where the nerve passes the fibular neck. This enables visual confirmation of nerve protection during the drilling procedures that most likely could cause nerve injury. In our series no nerve injuries were observed. However, in combined reconstructions for multiligament injuries, especially when the trauma is a knee dislocation, very careful nerve exposure must be performed because the nerve can be dislocated from its anatomic position, due to severe soft-tissue injury during the dislocation.

Only a few clinical studies have presented outcomes after PLC reconstruction. These studies are typically small case series with the majority of patients having multiligament injuries. Zhao et al. reported good objective stability in 95% of 28 PLC reconstructed patients. Noyes and Barber-Westin reported excellent objective knee stability in 13 patients, 12 of whom had multiligament injuries. Stannard et al. found no failures in 7 isolated PLC reconstructions, with generally good objective stability in a total of 22 patients who underwent reconstruction. A recent study by Schechinger et al. showed a follow-up subjective IKDC score of 80 in 16 patients with PLC reconstruction. Our data are difficult to compare with these studies because a majority of patients in our material had isolated PLC injuries compared with the previously mentioned studies. However, overall, the results are similar to PLC reconstruction, showing good objective stability for all patient types and a good clinical outcome overall for patients with isolated PLC injuries.

This study is limited by the fact that it is a retrospective case series. However, the rareness of postero-lateral injuries has thus far resulted in no published randomized studies that address lateral and postero-lateral ligament reconstructions. Another study weakness is the suboptimal follow-up completeness of 27 patients compared with the 40 patients who underwent the procedure. The main reason for this poor follow-up is that our clinic is a national referral center for advanced knee ligament reconstruction and, therefore, many patients live far from the clinic and did not want to travel for a study follow-up. This study is, to our knowledge, the largest case series published thus far and the only study to present clinical results after isolated LCL-PLC reconstructions. In the study we present a new technique for combined LCL-PLC reconstruction, but we lack in vitro biomechanical documentation to describe the degree to which the reconstruction restores normal knee biomechanics. Such a study is currently being performed and will enable comparison to other in vitro documented techniques such as the LaPrade technique. When one is performing posterolateral reconstruction, a popliteal tendon reconstruction is necessary. However, the normal muscle and tendon complex is a dynamic entity that is activated during rotation, and this dynamic function can never be restored with a static tendon reconstruction as presented.

CONCLUSIONS

This case series presents a new method for combined reconstruction of the LCL and the PLC. Despite the extensiveness of procedure, complications were low. The technique restores lateral stability clinically at 2 years’ follow-up.

REFERENCES

7. LaPrade RF, Muench C, Wentorf F, Lewis JL. The effect of


