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Posterior cruciate ligament reconstruction with the quadriceps tendon in chronic injuries

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Abstract We reviewed 18 patients (knees) operated on because of chronic PCL insufficiency. Preoperatively all the patients were severely disabled and showed a posterior drawer of 10 mm or more. A quadriceps tendon autograft was implanted using an open technique, direct posterior approach, and fixation to the tibia. A free semitendinosus graft was used to reconstruct the lateral collateral ligament in six knees and the medial collateral ligament in two. The patients were reviewed with a mean follow-up of 3.5 years (range 2–5.5) using the IKDC form. Stability was evaluated by stress radiography using the Telos device. The mean side-to-side difference in posterior tibial displacement at 70° of knee flexion at follow-up was 4.8 mm; the side-to-side difference was less than 5 mm in 77% of cases. A side-to-side difference less than 2 mm in lateral joint line opening was found in five of six knees with a lateral collateral ligament reconstruction. Posterior tibial translation was similar in the knees with and those without collateral ligament reconstruction. Only one patient complained of significant pain and giving-way at follow-up. Patellofemoral crepitation was present in nine knees at follow-up although it was symptomatic only in one. The results of this series suggest that posterior cruciate ligament reconstruction using an autologous quadriceps tendon is a valuable option to reconstruct these severe injuries.

Keywords Posterior cruciate ligament · Quadriceps tendon autograft · Posterior tibial approach · Direct tibial fixation

Introduction

Surgical treatment of chronic posterior cruciate ligament (PCL) injuries remains controversial. The indication to reconstructive procedures in acute isolated PCL injuries has been the subject of debate since several authors [10, 14, 37, 41, 45] showed that good results can be achieved in the short to medium term with conservative treatment. However, results tend to deteriorate with increasing follow-up due to the development of pain and degenerative changes [5, 11, 27]. Acute combined PCL injuries require surgical treatment to repair or reconstruct the PCL, the anterior cruciate ligament (ACL), and the peripheral structures. Symptomatic chronic PCL injuries frequently present with combined ligamentous injuries and often require surgical reconstruction.

Reconstruction of a chronic PCL injury is less frequent than reconstruction of an ACL. The surgical technique is demanding and risks several possible complications. The final result in terms of objective stability has been found to be less consistent than in ACL reconstructions [1, 30, 34].

Several autografts have been used for PCL reconstruction, including the patellar tendon [8, 28, 32, 46], the semitendinosus and gracilis [30, 38, 48], and the quadriceps tendon [7]. Achilles tendon and the patellar tendon allografts have also been used, mainly in the United States

[13, 34, 35]. Numerous surgical techniques have been proposed using open [8, 30] and arthroscopy-assisted [13, 21, 32, 35] procedures, single or double femoral tunnel [2, 31], and tibial tunnel [13, 21] or direct fixation [3, 9, 26] of the graft on the tibial side.

In 1994 we started a prospective study on PCL reconstruction in chronic injuries using the autologous quadriceps tendon and a direct posterior approach to the tibia. Combined ligamentous injuries were reconstructed at the time of PCL reconstruction. The purpose of the present study was to evaluate the results in a group of 18 knees with a minimum follow-up of 2 years.

Material and methods

Patients

Between November 1994 and February 1998 we operated on 18 patients (18 knees) at the First Orthopedic Clinic of the University of Florence because of chronic PCL injury. The study group included 11 men and 7 women; their average age at surgery was 26.7 years (range 16–36). The PCL lesion was caused by a motor vehicle accident in 15 patients and by a sport injury in 3. Associated injuries of the muscoloskeletal system included contralateral tibial fracture in 3 patients, ipsilateral diaphyseal femoral fractures in 4, and fracture of the wrist and of the metacarpals in one patient each.

Before the injury 9 patients participated in pivoting-contact sports (level I activities), one in pivoting noncontact sports (level II), 7 in running activities (level III), and one in activities of daily living (level IV). The average injury-surgery interval was 4.3 years (range 6 months to 19 years). Preoperatively 14 patients complained of pain, 4 of swelling and 13 of giving-way. Preoperatively 5 patients participated in level II activities, 7 in level III and 6 were limited to activities of daily living (level IV).

Measurements

The preoperative and follow-up clinical evaluation was performed according to the International Knee Documentation Committee (IKDC) form [23]. Subjective assessment, symptoms (pain, swelling, and giving-way), range of motion and objective stability are classified as normal, nearly normal, abnormal, and severely abnormal. The worst result achieved in each category determines the final result. A normal or nearly normal result is considered satisfactory. Preoperative and follow-up radiography included anteroposterior 30×40 cm weight-bearing view, lateral view, and axial view.

Posterior tibial translation at follow-up was measured on stress radiographs obtained with the Telos device (SAMO, Bologna, Italy). The knee was flexed 70° as measured with two lines tangent to the posterior femoral and tibial cortices. A posteriorly directed force of 15 kg was applied to the tibial tuberosity using a dynamometer [35]. A lateral radiograph of the normal and injured knee was obtained using the image amplifier to achieve superimposition of the femoral condyles. Posterior displacement was measured separately in the medial and lateral compartments. The medial femoral condyle was identified because of its convex distal contour and a flat terminal sulcus located anterior to the intercondylar roof [43]. The lateral femoral condyle was distinguished by its biconvex distal profile and a deeper triangularly shaped terminal sulcus located in the projection of the intercondylar roof. The medial tibial plateau was identified because of its concave profile and squared off posterior contour. The lateral plateau was distinguished by its convex or flat profile and sloping posterior contour. A line was drawn tangent to the tibial plateau. Two lines were drawn, perpendicular to the tibial plateau line and tangent to the most posterior aspect of the corresponding femoral condyle and tibial plateau. The distance between these two lines express the amount of posterior tibial displacement (Fig. 1). The difference in posterior displacement between operated and normal knee were calculated for the medial and lateral compartment separately. A posterior tibial displacement was also calculated averaging the displacements of the medial and lateral plateaus. All the measurements were corrected according to the magnification.

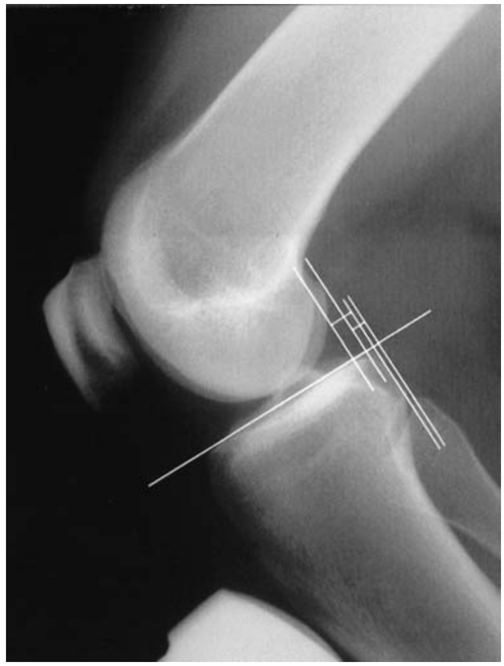

Fig. 1 Measurement of posterior tibial displacement in the medial and lateral compartment. The knee was flexed 70° and a posterior force of 15 kg was applied to the tibial tuberosity. Lateral radiography was performed. The medial and lateral femoral condyles and corresponding plateaus were identified. A tangent to the tibial plateau was drawn. Two lines perpendicular to the plateau line were drawn, tangent to the most posterior aspect of each femoral condyle and tibial plateau. The distance between these two lines was measured in millimeters and corrected according to the magnification

The Telos device was employed to measure medial and lateral joint line opening in the knees which had a medial or a lateral collateral ligament reconstruction. The knee was stressed in varus or valgus applying a laterally or medially directed force of 15 kg (Fig. 2). The measurements of posterior tibial translation and joint line opening were compared to the opposite normal knee. A side-to-side difference of 0–2 mm was considered normal, 3–5 nearly normal, 6–10 mm abnormal, and more than 10 mm severely abnormal [23].

Preoperative posterior tibial displacement was 10 mm or more in all the knees, as measured clinically. With the knee flexed at 90° the tibial plateaus were flush or posterior to the femoral condyles in each case. An associated ACL injury was present in four knees as evidenced by an increased anterior tibial translation at the Lachman test and by a positive pivot shift, which was 2+ (jerk) in two knees and 1+ (glide) in two. Increased medial joint line opening was appreciated at the valgus stress test in four knees. It was 3–5 mm in two knees and 6–8 mm in the other two. Increased lateral joint line opening was confirmed at the varus stress test in six knees, 3–5 mm in two cases, and 6–8 mm in four. Increased external tibial rotation (over 10°) at 30° and 90° was present in four knees.

Fig. 2 Measurement of lateral joint line opening. The knees were flexed 10°. A laterally directed force of 15 kg was applied at the medial joint line level. The minimum distance between lateral femoral condyle and tibial plateau was measured in millimeters

The reverse pivot shift was 1+ (glide) in five knees and 2+ (jerk) in ten.

Preoperatively there were not cases with loss of motion. Four patients had knee hyperextension (recurvatum) between 3° and 5° compared to the opposite normal knee. Patellofemoral crepitation was present preoperatively in seven knees, moderate in six, and symptomatic in one patient.

Statistical evaluation was performed using Fisher's test. The minimum level of significance was set at $P<0.05$.

Surgical technique

The patient was placed supine on the operating table with the foot supported by a bolster and the knee in 70–80° of flexion. A pneumatic tourniquet was used routinely. A medial parapatellar skin incision was made, beginning at the joint line level and proceeding proximally up to 3 cm proximal to the base of the patella. A 10- to 12-mm-wide full thickness strip of quadriceps tendon was sculptured with a trapezoidal bone block from the base of the patella. The bone block was 25 mm long and 2 mm wider distally than proximally. Number 2 nonabsorbable Ethibond sutures (Pomezia, Italy) were placed through drill holes in the bone block. A Bunnel-type stitch was placed at the proximal end of the quadriceps tendon. The defect at base of the patella was filled with bone debris collected while drilling the femoral tunnel. The defect in the quadriceps tendon was sutured.

The joint was entered through a limited subvastus approach [24]. This approach was advantageous since detachment of the vastus medialis from the patella was avoided and simultaneously access to the femoral metaphysis was gained to drill the femoral tunnel. Exploration of the joint was performed. Meniscal and cartilage pathology was recorded and treated as needed. There was a lesion of the lateral meniscus in two knees and of both menisci in one. Cartilage lesions were present in nine patients, involving the medial femoral condyle (seven knees), medial tibial plateau (four knees), lateral femoral condyle (four knees), and patella (six knees). These lesions were characterized by fissuring or deep fibrillation of the cartilage. There were no cases with large areas of exposed subchondral bone representative of early osteoarthritis. The mobile fragments of cartilage were removed.

A C-guide was used to introduce a K-wire in the medial femoral condyle. We aimed at a point located 5 mm from the articular cartilage at the junction between roof and wall of the notch (1 o'clock position for the right knee). The K-wire was overdrilled with a 10–11 mm cannulated drill bit. The femoral tunnel was enlarged with a conical reamer to achieve interference fit with the patellar bone block.

The quadriceps tendon graft was introduced with its ligamentous end into the femoral tunnel. It was advanced until the trapezoidal bone block was firmly engaged and its tip was flush with the wall of the notch. If the press fit fixation was not firm enough, an interference screw was added or the sutures were tied around a screw and washer on the medial aspect of the femoral metaphysis.

The graft was pulled in the posteromedial compartment using a suction drain with a curved needle. With the knee in around 90° of flexion, the needle was inserted into the notch and pushed to exit from the posteromedial compartment. The sutures were recovered and pulled posteriorly out of the skin. We have found that pulling the graft into the posteromedial compartment greatly enhances recovery of the graft from the posterior approach. The tourniquet was released, hemostasis was achieved. The wound was sutured as routinely.

The patient was turned in the prone position and a sterile field was prepared again. A J incision was used [6] with the horizontal limb at the level of the popliteal crease and the vertical limb along the medial margin of the gastrocnemius. The medial head of the gastrocnemius was displaced laterally. A posterior capsulotomy was performed along the lateral margin of the medial femoral condyle. The incision was prolonged distally over the tibia until proximal to the inferomedial genicular vessels. Then the incision was turned medially toward the posteromedial corner of the tibia (Fig. 3). The graft was recovered from the posterior compartment. The posterior intercondylar area of the tibia was sharply exposed using a knife and a periosteal elevator. The capsular flap was lifted from the posterior tibia until sufficient exposure was achieved. Retraction was enhanced by use of two Steinman pins inserted into the tibia.

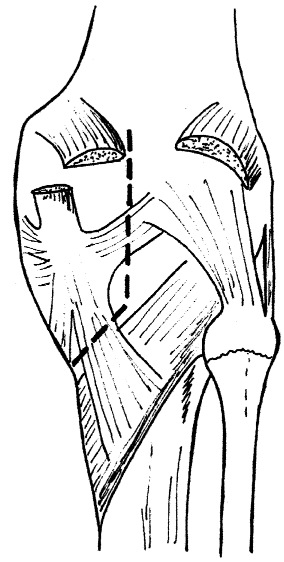

Fig. 3 Posterior capsulotomy. The incision parallels the lateral margin of the medial femoral condyle and proceeds distally to the upper limit of the popliteus muscle. Here the incision turns medially to the posteromedial corner of the tibia. The lower limb of the incision runs parallel and proximal to the inferomedial genicular vessels

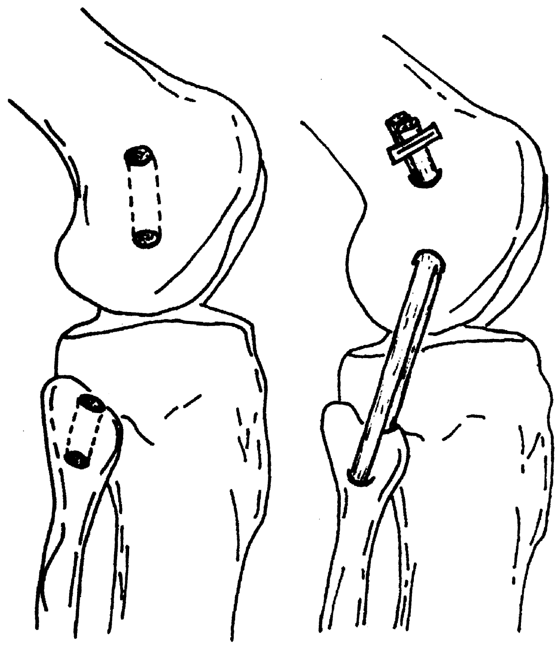

Fig. 4 Lateral collateral ligament reconstruction using a free semitendinosus tendon graft (see text for explanation)

The graft was pulled distally and fixed in the central part of the fovea. Graft angulation against the lateral margin of the medial femoral condyle was carefully avoided. The posterior intercondylar area was fish-scaled with a sharp osteotome. With the knee in 40–50° of flexion the graft was tensioned and fixed to the back of the tibia with two teethed staples (Richards, Memphis, Tenn., USA) or with a staple proximally and a screw and soft tissue washer distally. While inserting the staples, care was taken to angle the device distally to avoid penetration of the joint. The capsular incision was closed, the tourniquet was released, and hemostasis was achieved. The wound was closed as routinely over a suction drain.

If increased lateral joint line opening was present, we performed a lateral collateral ligament (LCL) reconstruction. It was performed with the patient in the supine position. We harvested a free semitendinosus (ST) graft through a prolonged anterior skin incision using a tendon stripper. A 15-cm lateral skin incision was centered on the Gerdy's tubercle. The ileotibial band was split longitudinally just anterior to the intermuscular septum to have access to the lateral femoral epicondyle. The peroneal head was exposed protecting the peroneal nerve. A 4.5-mm tunnel was drilled in the peroneal head, starting in front of the styloid and exiting 2 cm distally at the level of the neck. The graft was introduced into the tunnel and sutured to itself and to the soft tissues around the proximal exit of the peroneal tunnel (Fig. 4). The ileotibial band was elevated and the graft was rerouted deep to the ileotibial band to reach the area of the lateral femoral epicondyle. The lateral epicondyle was located by finger palpation. The remnants of the LCL can be also used as a guide. A 2.5-mm K-wire was introduced into the lateral femoral epicondyle. The ST graft is pulled tight around this wire. The knee was flexed from 0° to 120° while maintaining the tibia reduced underneath the femur. Length changes in the LCL graft were observed. We aimed at a 3- to 4-mm graft shortening toward flexion. If this was not the case the K-wire was repositioned. The K-wire was overdrilled with a 6 mm cannulated drill bit. A second hole was drilled in the distal femoral metaphysis to create a bone tunnel. The graft was introduced into the tunnel and tensioned with the knee in 20° of flexion. Fixation was achieved with two staples in a belt buckle fashion or with a screw and soft tissue washer in the femoral metaphysis.

In two cases we performed a medial collateral ligament reconstruction using a ST tendon graft. The ST tendon was harvested leaving it attached distally. A bone tunnel was produced into the medial femoral condyle, starting at the epicondyle. The position of the hole at the epicondyle was checked with a K-wire, as described for the LCL. We aimed at a ligament which was isometric within 2 mm in the arc of motion between 0° and 120°.

Postoperatively the knee was placed in a hinged brace in extension. Flexion was started on the second postoperative day using a continuous passive motion machine. Passive flexion exercises were gradually introduced hanging the leg over the edge of the bed. Alternatively a physical therapist flexed the knee pulling forward on the calf. Active flexion with contraction of the hamstrings was avoided. Quadriceps contraction and strengthening was encouraged in the range from 0° to 70° of flexion. It was our goal to achieve 90° of flexion at the end of the first postoperative month, 120° by the end of the second, and full flexion within 3 months. Weight bearing was started as soon as tolerated, and it was progressed from partial to full during the second postoperative month.

If a lateral reconstruction had been performed, we avoided the last 20° of extension in the first postoperative month. We encouraged the patients to slowly regain full extension during the second postoperative month. In these cases weight bearing was allowed 6 weeks postoperatively.

Results

The patients were reviewed at an average follow-up of 3.5 years (range 2–5.5). There were no perioperative complications in this series. Two patients developed a hematoma postoperatively which resolved with conservative treatment. One knee was manipulated under anesthesia 1 month after the operation because of flexion loss.

Subjectively all the patients described their knee as satisfactory (normal or nearly normal; Table 1). Symptoms evaluation was satisfactory in 17 patients for pain and giving-way, and in all of them for swelling. One patient complained of patellofemoral pain and giving-way. At follow-

Table 1 Results at follow-up according to the IKDC evaluation form

	Normal	Nearly normal	Abnormal	Severely abnormal
Subjective evaluation	8	10	–	–
Symptoms				
Pain	11	6	1	–
Swelling	12	6	–	–
Giving-way	14	3	1	–
Range of motion				
Extension loss	16	2	–	–
Flexion loss	9	8	1	–
Ligament examination				
Posterior drawer	3	11	4	–
Reverse pivot shift	16	2	–	–
Lachman test	11	7	–	–
Pivot shift	16	2	–	–
Medial joint line operation (valgus rotation)	15	3	–	–
Lateral joint line operation (varus rotation)	15	3	–	–
Patellofemoral crepitation	9	8	1	–
Harvest site pathology	18	–	–	–
Final result	3	9	6	0

up 5 patients participated regularly in level II activities, 12 in level III, and one in level IV activities. None of the patients reported that he was limited to activities of daily living because of knee problems.

There were no knees with an extension loss at follow-up evaluation. Knee recurvatum was corrected in all the 4 cases in which it was present preoperatively. A flexion loss of 20° was present in one knee.

The average posterior tibial displacement using the Telos device was 4.6 mm (range 1.6–8) in the lateral compartment and 5.1 mm (range 1.6–9.6) in the medial compartment. The posterior displacement of the tibial plateau was 4.8 mm on average. The average displacement was 0–2 mm in 3 knees, 3–5 mm in 11, 6–7 mm in 2, and 8–10 mm in 2. The tibial step-off, evaluated with the knee at 90° of flexion, was similar that in to the opposite knee in 3 cases, decreased in 8, and absent in 7. The reverse pivot shift at follow-up was absent in 16 and 1+ in the other 2 knees.

The posterior tibial displacement was 4.7 mm in the 10 knees with an isolated PCL reconstruction, 4.5 mm in the 6 knees with a lateral compartment reconstruction, and 6.4 mm in the 2 knees with a medial reconstruction (n.s.).

In the 6 knees with a lateral reconstruction, lateral joint line opening, evaluated with the Telos device, was within 2 mm in 5 knees and 3–5 mm in one. An increased external tibial rotation at 30° and 90° of flexion persisted in 2 knees. In the two knees with a medial reconstruction, stress radiography revealed an increased medial joint line opening of 2 mm in the first knee and of 5 mm in the second.

Patellofemoral crepitation at follow-up was moderate in 8 knees and symptomatic in one. There were no cases with pain or tenderness along the upper margin of the patella suggesting donor site morbidity.

The final result, according to the IKDC form, was satisfactory in 12 knees and unsatisfactory (abnormal) in 6 knees, because of symptoms (one knee), flexion loss (one knee) and increased posterior tibial displacement (4 knees). A satisfactory final result was achieved by 7 of 10 knees with an isolated PCL reconstruction (70%) and by 5 of 8 knees with an associated PCL and medial or lateral compartment injury and reconstruction (62.5%; n.s.).

Discussion

The results of this series of PCL reconstructions have been satisfactory and represent an improvement over our previous experience [1]. We routinely employed a quadriceps tendon autograft which was implanted with an open technique and a direct posterior approach and fixation to the tibia. In this group of severe chronic injuries a satisfactory posterior stability (posterior tibial displacement within 5 mm of the opposite normal knee) was restored in 14 of 18 knees (78%).

The choice of the autologous quadriceps tendon has several reasons. Its length, which is 8.6 cm on average, was always adequate for this operation and compares favorably with an average length of 5.2 cm for the patella tendon [44]. The mean cross-sectional area of a 10 mm wide quadriceps tendon graft was 64 mm^2, significantly larger than the 37 mm^2 of the patellar tendon. Gross anatomy observations confirm that the quadriceps tendon is thicker, longer, and wider than the patellar tendon [22]. The ultimate failure load of the quadriceps bone-tendon complex was 2173±618 N compared to 1953±325 N of the bone–patellar tendon–bone complex [44]. Therefore the anatomical and structural properties make it a suitable graft for PCL reconstruction.

Harvesting of the quadriceps tendon is easily for surgeons familiar with harvesting of the patellar tendon. Donor site morbidity appears to be less than using the patellar tendon graft. Our patients did not complain of donor site pain or increased patellofemoral pain and/or crepitation compared to the preoperative status. Favorable results have been reported in the literature when the quadriceps tendon graft was employed to reconstruct the ACL [16, 42]. Finally allograft tissues as the patellar or Achilles tendon are not readily available in our country.

Arthroscopic assisted PCL reconstruction has been recommended and performed with success [12, 13, 21, 28, 38]. This is an advanced arthroscopic procedure which may be difficult for the surgeon who performs it occasionally. Accurate placement of the tibial tunnel is demanding. Drilling of the tibial tunnel should be performed with caution to avoid injury to the popliteal vessels [25]. The use of a transtibial tunnel unavoidably causes an acute turn in the course of the graft. This increases the difficulties of graft passage and may lead to recurrent instability if tunnel widening or graft abrasion occur [26]. Finally if a quadriceps tendon graft is used the length of the graft is not enough to exit from the tibial tunnel. Distal fixation is achieved with nonabsorbable sutures tied around a post screw, which is less than optimal.

To overcome the disadvantages reported above a direct posterior tibial approach and fixation has been used [3, 9, 26]. A direct posterior tibial approach and fixation avoids the potential problems of proximal or medial tibial tunnel placement, tunnel widening and graft abrasion. On the other hand, the procedure is more traumatic than an arthroscopic assisted operation. The dissection is limited using the approach described by Burks and Schaffer [6] which avoids sectioning the tendon of the medial gastrocnemius. Laboratory evaluation of PCL reconstruction using the patellar tendon graft was performed comparing the standard tibial tunnel technique to the direct posterior tibial fixation with lag screw (the so-called "tibial inlay" technique) [4]. Twelve pairs of human knees were used. The increase in posterior tibial translation was 4.7 mm on average in the tibial tunnel group and significantly less (1.8 mm) in the direct tibial fixation group.

Although our technique with a direct posterior tibial approach and fixation has achieved a satisfactory objective stability, its use is not without disadvantages. The main difficulty in our experience is related to positioning of the patient. The procedure may be performed in two steps, as we did, placing the patient supine first and then prone. In this case the graft is tensioned and fixed in the prone position with the knee flexed 45–60°. Evaluation of the step-off and posterior drawer is virtually impossible in this position. Tensioning of the graft at 45° may be suboptimal; since high tensile forces are developed in the PCL at 90° of flexion [15] graft tensioning should be performed close to this degree of flexion. Finally, working in the prone position is a disadvantage in associated injuries. In these knees the best sequence would be to accurately reduce the tibia with the knee at 90° of flexion reproducing a normal step off, followed by tensioning and fixation of the PCL graft and by tensioning and fixation of the posterolateral structures and/or ACL. The alternatives involve working with the patient in the supine [9] or lateral decubitus position [3]. The posterior approach to the tibia is somewhat more difficult in both these positions than in the prone position, especially for the surgeon who is not familiar with it.

Accurate positioning of the PCL graft on the femoral side is of crucial importance to restore an optimal posterior stability. Laboratory studies have shown that the forces in the PCL increase with increasing flexion to reach maximum tension at 90° [15]. There is a general agreement today that reconstruction of the main anterolateral bundle should be the focus of the procedure. To reproduce the anterolateral bundle the Kirschner wire must be placed in the anterior part of the femoral foot print, in a "shallow" position. This "anatomical" femoral positioning has been shown to give better results than a deeper, so-called "isometric" positioning in terms of objective stability in a cadaver model [17]. Variations in graft positioning on the femoral side have a larger effect on the graft tensioning pattern than variations on the tibial side [20]. Double-tunnel techniques have been proposed [2] to reproduce more accurately the complex anatomy and function of the PCL. Laboratory studies [31, 36, 39] suggest that a two-bundle PCL reconstruction improves objective stability. The effectiveness of these procedures in the clinical setting remains to be confirmed.

A final consideration involves the treatment of associated injuries. It has been shown that the posterolateral [18, 19] and the posteromedial [40] structures cooperate with the PCL to control posterior tibial displacement. A satisfactory result requires reconstruction of both the PCL and of the medial or posterolateral structures.

Our LCL reconstruction using a free semitendinosus graft was effective in restoring a normal varus tibial rotation in five of six knees. The anatomical insertions of the LCL on both the femur and the fibula should be duplicated to achieve a ligament which is tight in extension and slackens in flexion. Laxity in flexion is necessary to accommodate the greater mobility of the lateral tibial plateau. In the knees with an increased external tibial rotation over 10° at 30° and 90° of flexion, a reconstruction of the popliteofibular ligament [33, 47] has been suggested since this structure is better oriented to control external tibial rotation. A reconstruction with these characteristics has been described by Larson [29] with reported good results.

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