Surgical Management of Knee Dislocations

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Surgical Technique

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INTRODUCTION

Our experience and techniques of surgical treatment of knee dislocations have produced satisfactory subjective and objective outcomes at two to six years postoperatively[1]. The purpose of this article is to present our technical approach to knee dislocations. This is a complex procedure, and our goal is to present, in detail, single-bundle reconstructions of the anterior cruciate ligament and posterior cruciate ligament, along with repair or reconstruction of the medial collateral ligament and posterolateral corner.

SURGICAL TECHNIQUE

Initial Evaluation

Knee dislocations can present as an isolated injury or, in many cases, in conjunction with multiple other injuries. Obviously, treatment of life-threatening morbidities takes precedence, but, as soon as the initial physician suspects a knee dislocation, a thorough neurovascular evaluation must be performed and plain radiographs made of the injured knee to prevent limb-threatening complications. In the case of a gross knee dislocation, which has not spontaneously reduced, the knee should be reduced immediately with use of gentle traction and countertraction, with the patient under conscious sedation, and the limb should be stabilized in a long leg splint. A postreduction neurovascular examination should be performed, and the reduction should be confirmed with radiographs. The routine use of angiography in this setting is justified by the relatively low morbidity of the test, the high prevalence of popliteal artery injury, and the potentially devastating consequences of any delay in the diagnosis of neurovascular injury[2,3].

Prior to surgical treatment, additional evaluation is necessary to characterize the pattern of injury. To determine the surgical approach, a thorough ligament examination is performed after survival of the limb is assured and the patient is stabilized. Because of the great magnitude of the injury, the preoperative ligament examination is often

ABSTRACT

BACKGROUND:
The evaluation and management of knee dislocations remain variable and controversial. The purpose of this study was to describe our method of surgical treatment of knee dislocations with use of a standardized protocol and to report the clinical results.

METHODS:
Forty-seven consecutive patients presented with an occult (reduced) or grossly dislocated knee. Fourteen of these patients were not included in this series because of confounding variables: four had an open knee dislocation, five had vascular injury requiring repair, three were treated with external fixation, and two had associated injury. The remaining thirty-three patients underwent surgical treatment for the knee dislocation with our standard approach. Anatomical repair and/or replacement was performed with fresh-frozen allograft tissue. Thirty-one of the thirty-three patients

continued

ABSTRACT | continued

returned for subjective and objective evaluation with use of four different knee-rating scales at a minimum of twenty-four months after the operation.

RESULTS:
Nineteen of the thirty-one patients were treated acutely (less than three weeks after the injury) and twelve, chronically. The mean Lysholm score was 91 points for the acutely reconstructed knees and 80 points for the chronically reconstructed knees. The Knee Outcome Survey Activities of Daily Living scores averaged 91 points for the acutely reconstructed knees and 84 points for the chronically reconstructed knees. The Knee Outcome Survey Sports Activity scores averaged 89 points for the acutely reconstructed knees and 69 points for the chronically reconstructed knees. According to the Meyers ratings, twenty-three patients had an excellent or good score and eight had a fair or poor score. Sixteen of the nineteen acutely reconstructed knees and seven of the twelve chronically reconstructed knees were given an excellent or good Meyers score. The average loss of extension was 1°, and the average loss of flexion was 12°. There was no difference in the range of motion between the acutely and chronically treated patients. Four acutely reconstructed knees required manipulation because of loss of flexion. Laxity tests demonstrated consistently improved stability in all patients, with more predictable results in the acutely treated patients.

continued

difficult to perform. In most cases, the extent (location and degree of injury) of the collateral ligament injury can be determined when varus and valgus stress is applied at 0° and 30°. It is not always possible to determine the degree of cruciate ligament involvement (especially the posterior cruciate ligament), so ancillary studies such as magnetic resonance imaging, and occasionally stress radiographs, are indicated. At this time, surgical and nonsurgical issues are discussed with the patient and the patient's family. The timing of surgery, graft selection, specific surgical techniques, risks, complications, and benefits are covered. Informed consent is obtained, and the patient is scheduled for surgery. In our practice, we schedule these complex cases in the morning at a facility where robust ancillary services, such as vascular surgeon support and intensive care units, are available.

Anesthesia

The choice of anesthesia is made in conjunction with the surgeon, the anesthesiologist, and the patient and depends on the age of the patient, the comorbid medical problems, and the history of the patient with regard to anesthesia. Most commonly, general anesthesia or an epidural anesthetic with concomitant intravenous sedation is chosen. If airway management is a concern, then general anesthesia is preferred. At our center, preoperative femoral and/or sciatic nerve blocks are routinely performed as an adjunct for postoperative pain relief. A Foley catheter is placed to help to monitor the fluid status during the procedure. Additionally, we recommend that a vascular surgeon be available during the procedure as unexpected injuries to the vessels may occur.

Decision to Repair or Reconstruct

The two most common injury patterns with knee dislocations are a combination of the cruciate ligaments and the medial collateral ligament or a combination of the cruciate ligaments, the lateral collateral ligament, and the posterolateral corner. Less commonly, the posterior cruciate ligament is intact or only partially torn and does not require reconstruction. At our institution, we attempt to preserve specific bundles of the posterior cruciate ligament that are not injured. In approximately one-third of patients with acute and chronic cases, the anterolateral bundle is ruptured, but the meniscofemoral ligament and the posteromedial bundle are intact. If this injury pattern is present, we preserve the intact portion of the posterior cruciate ligament and the meniscofemoral ligament and reconstruct the anterolateral component by means of a single-bundle technique.

The decision to repair or reconstruct the injured structures depends on numerous factors. Concerning the cruciate

FIG. 1

Overview of the setup.

ABSTRACT | continued

CONCLUSIONS:
Surgical treatment of the knee dislocations in our series provided satisfactory subjective and objective outcomes at two to six years postoperatively. The patients who were treated acutely had higher subjective scores and better objective restoration of knee stability than did patients treated three weeks or more after the injury. Nearly all patients were able to perform daily activities with few problems. However, the ability of patients to return to high-demand sports and strenuous manual labor was less predictable.

injuries, the majority are intrasubstance tears that are not amenable to surgical repair and are best treated with ligament reconstruction. However, we do recommend primary repair of anterior cruciate ligament and posterior cruciate ligament tibial avulsions. The primary repair can be accomplished by passing large nonabsorbable sutures into the osseous fragment (if present) and through bone tunnels in the tibia. Also, a primary repair of the posterior cruciate ligament insertion may be advocated in the case of a "peel off" or a soft-tissue avulsion of the posterior cruciate ligament from its femoral insertion by a similar technique.

Concerning the medial collateral ligament, lateral collateral ligament, and posterolateral corner, it has been our experience that primary repair is possible if performed within three weeks after the injury. Chronic injuries are limited by scar formation and soft-tissue contractures and often require ligament reconstruction. The medial collateral ligament can be directly repaired with intrasubstance sutures or with suture anchors if it is avulsed off the bone. Repair of the posterolateral corner structures and the lateral collateral ligament can be accomplished with direct suture repair or by repair to bone by means of drill-holes or suture anchors. If direct repair is not possible because of the quality of the tissue, then the acutely involved structures should be augmented with hamstring or biceps femoris tendons, the iliotibial band, or an allograft. If this does not suffice, then the involved structures should be reconstructed. In addition, concomitant injuries to the articular cartilage and menisci should be addressed at the time of surgery.

Surface Anatomy and Skin Incisions

The patient is seen in the preoperative holding area, and the surgeon, patient, and nurse identify the correct extremity. The selected extremity should correlate with the written consent, and, using an indelible marker, the surgeon then places his or her initials on the correct extremity with the word "yes." The marks should be strategically placed so that they are within the operative field.

A marker is used to identify the surface anatomy and the incisions that will be utilized during the procedure (Fig. 1). The important osseous landmarks include the patella, the tibial tubercle, Gerdy's tubercle, and the fibular head. The peroneal nerve is palpated, and its course is marked superficial to the fibular neck. The medial and lateral joint lines are identified. The anterolateral arthroscopy portal is placed adjacent to the lateral border of the patella proximal to the joint line. The anteromedial arthroscopy portal is placed approximately 1 cm medial to the patellar tendon at the same level. A superolateral outflow portal is placed proximal to the superior border of the patella and posterior to the quadriceps tendon. A posteromedial portal, if needed, is made under direct visualization with use of an inside-out technique and thus is not initially marked. A longitudinal 3-cm incision approximately 2 cm distal to the joint line and 2 cm medial to the tibial tubercle is drawn on the anteromedial aspect of the proximal part of the tibia for the anterior cruciate ligament and posterior cruciate ligament tibial tunnels. Also, a 2-cm incision is placed medial to the medial trochlear articular surface along the subvastus interval for the posterior cruciate ligament femoral tunnel. If there is a medial ligament injury, then the distal incision for the tibial tunnels is traced proximally to the medial epicondyle and extended to the level of the vastus medialis in a curvilinear fashion (Fig. 2). The incision for the lateral and posterolateral injuries is a curvilinear 12-cm incision that is drawn midway between Gerdy's tubercle and the fibular head and traced proximally just inferior to the lateral epicondyle while the knee is flexed 90°. The proximal extent of this incision parallels the plane between the biceps femoris tendon and the iliotibial band (Fig. 3). We prefer the above medial and lateral inci-

FIG. 2

Overview of the surface anatomy and skin incisions used for repair of a medial-side injury.

FIG. 3

Overview of the surface anatomy and skin incisions used for repair of a lateral-side injury.

sions as opposed to a midline incision because of the potential complications of skin breakdown over the patella and limited access to the collateral ligaments afforded by a midline incision. Finally, the dorsalis pedis pulse is palpated and marked.

Patient Positioning and Examination Under Anesthesia

The patient is placed in the supine position on the operating-room table. Our goal is to have a full, free range of motion of the knee during the procedure with the ability to have the knee statically flexed at 80° to 90° without any manual assistance. We accomplish this by placing a small gel pad bump under the ipsilateral hip and a post on the side of the bed just distal to the greater trochanter; a sterile bump of towels or drapes is wedged between the post and the thigh. The heel rests on a 10-lb (4.5-kg) sandbag that is taped to the bed during the initial positioning with the knee flexed to 90° (Figs. 1, 2, and 3). After a Foley catheter has been passed and the extremities carefully padded, an examination is performed with the patient under anesthesia. The laxity pattern is assessed, and this information, combined with the magnetic resonance imaging studies and arthroscopic evaluation, determines what ligamentous structures should be addressed. A tourniquet is not used in our current approach. Intravenous antibiotics are administered prior to the skin incision. The previously described skin incisions are drawn, and the pulses are once again palpated and marked. The extremity is prepared with alcohol and Betadine solution (povidone-iodine) and is draped in a meticulous fashion. The skin incisions are injected with 0.25% Marcaine (bupivacaine) with 1:100,000 epinephrine. A fluoroscope is in the operating suite and draped, as occasionally it is used to help to evaluate knee laxity.

Diagnostic Arthroscopy and Intra-Articular Preparation

A 30° arthroscope is introduced through the anterolateral portal, and gravity inflow irrigation (not a pump) is used. A superolateral outflow portal is also established. Care must be taken to avoid causing a compartment syndrome. Two factors that predispose to a compartment syndrome include an acute reconstruction (less than three weeks from the time of injury),

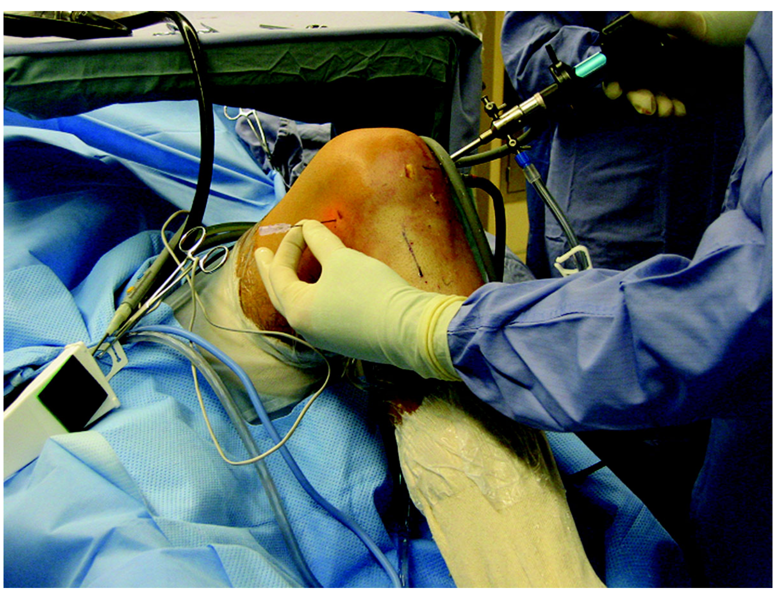

FIG. 4-A

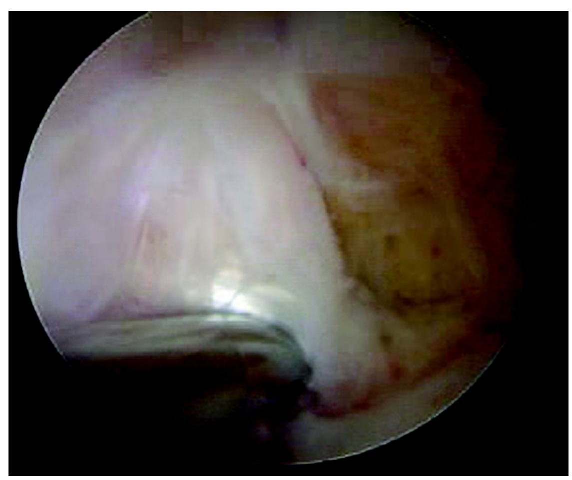

FIG. 4-B

Fig. 4-A Photograph demonstrating the posteromedial portal. **Fig. 4-B** Arthroscopic view from the posteromedial portal demonstrating the tibial insertion site of the posterior cruciate ligament.

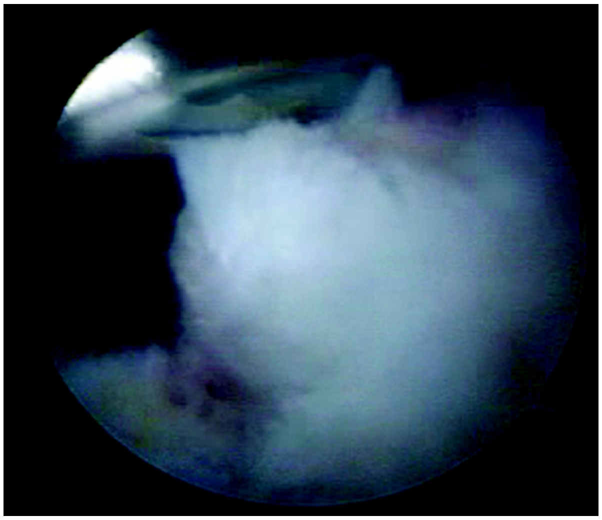

FIG. 5

Arthroscopic view from the posteromedial portal demonstrating débridement of the posterior cruciate ligament stump on the tibia and the proximity to the posterior capsule.

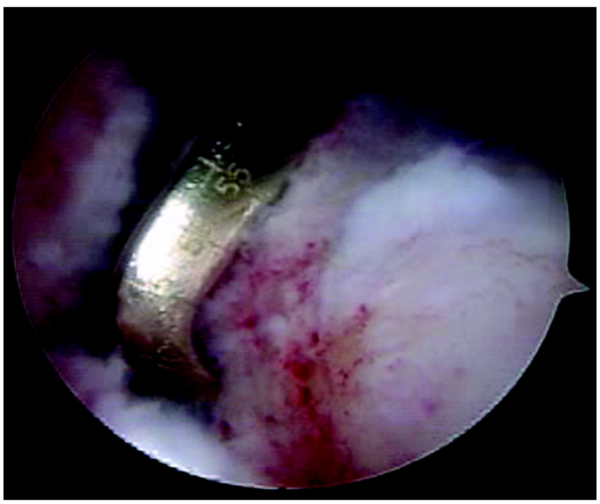

FIG. 6

Arthroscopic image demonstrating placement of the posterior cruciate ligament guide on the tibial insertion site.

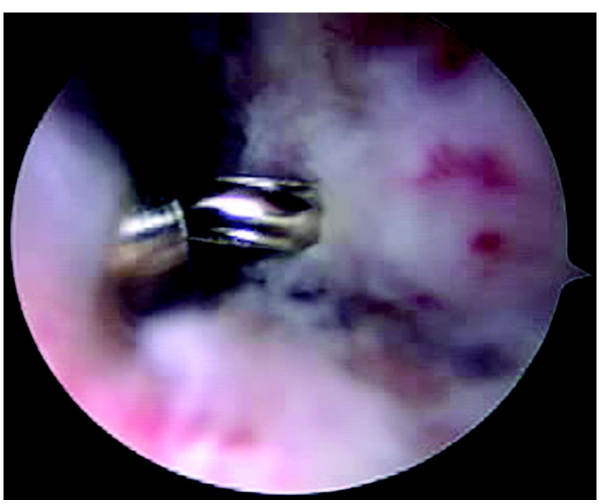

FIG. 7

Arthroscopic image demonstrating the Kirschner wire at the site of the tibial insertion of the posterior cruciate ligament.

in which the capsular healing is insufficient to maintain joint distention, and breeching the capsule iatrogenically during the procedure. If extravasation is noted and a compartment syndrome is suspected, then the arthroscopic technique should be abandoned and the remainder of the procedure should be performed by means of an open technique. However, the arthroscope can still be a valuable tool when used in a dry field by improving the visualization and magnification during the open procedure.

A quick diagnostic arthroscopy is conducted to assess the cruciate ligaments, menisci, and articular cartilage. This information is used to further determine what damaged structures should be reconstructed or repaired and how. After the three compartments are assessed with a 30° arthroscope, the posteromedial portal is established for visualization and as a work portal for the tibial insertion of the posterior cruciate ligament (Figs. 4-A and 4-B). At this time, a 70° arthroscope is placed through the anterolateral portal to visualize the tibial insertion site of the posterior cruciate ligament and a full radius resector is placed through the posteromedial portal to begin preparation (Fig. 5). Great care is taken to avoid extending beyond the capsule to minimize risk to the neurovascular structures, which lie approximately 1.5 cm from the tibial insertion. During preparation of the tibial insertion site, we often exchange

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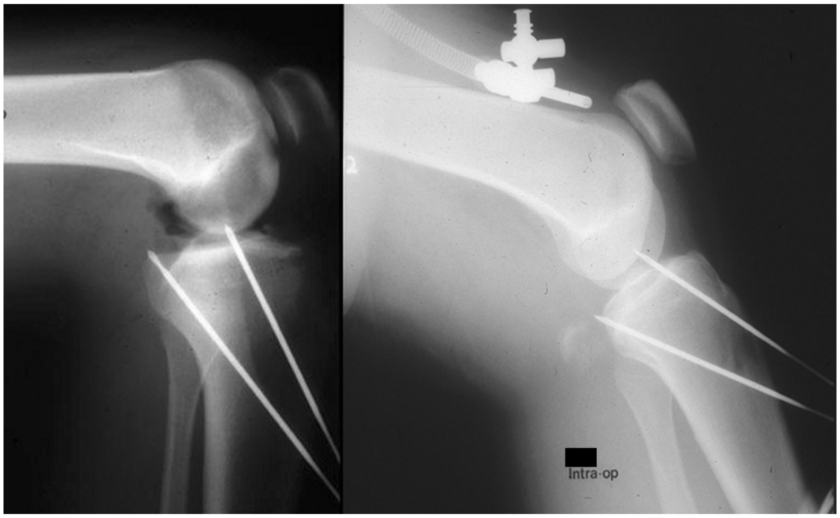


FIG. 8

Radiographic confirmation of the placement of the tibial guide wires for the anterior cruciate ligament and posterior cruciate ligament.

the 30° and 70° arthroscopes and exchange the anterolateral and posteromedial portals as viewing and working portals. This allows for excellent visualization and triangulation for the placement of the Kirschner wire and drilling of the tibial tunnel.

For the anterior cruciate ligament, we identify both the tibial and femoral insertion sites. We attempt to preserve the majority of the tibial footprint of the anterior cruciate ligament for its proprioceptive and vascular factors. A small notchplasty is often required to improve visualization and decrease the crowding of the instruments.

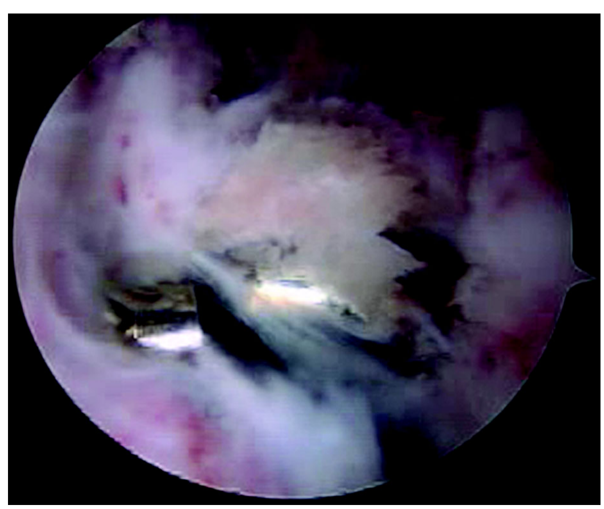
Once the intra-articular pathological disorder is confirmed, any concomitant articular cartilage or meniscal injury is addressed. Every effort is made to preserve the meniscal tissue. Peripheral meniscal tears are repaired by means of the inside-out technique, whereas central or irreparable meniscal tears are débrided to a stable rim. Should the meniscus require a repair, the sutures are tied down directly onto the capsule with the knee in 30° of flexion at the end of the procedure after the grafts have been passed and secured.

CRUCIATE TUNNEL PREPARATION

We prefer to address the tibial tunnel for the posterior cruciate ligament initially since it is the most challenging portion of the procedure. After arthroscopic visualization of the tibial tunnel has been established (see above), a commercially available 15-mm offset posterior cruciate ligament guide is set between 50° and 55° and placed through the anteromedial portal. The tip of the guide is placed as far distal and lateral as possible on the insertion site of the native posterior cruciate ligament (Fig. 6). A 4-cm skin incision is made on the proximal-medial aspect of the tibia as previously described. The starting point of the Kirschner wire is approximately 3 to 4 cm distal to the joint line. The Kirschner wire is passed (Fig. 7), and an intraoperative fluoroscopic image is obtained. Approximately 40% of the time, the wire is too proximal on the tibial insertion site of the posterior cru-

FIG. 9

Arthroscopic image demonstrating safe drilling of the tibial tunnel for the posterior cruciate ligament.



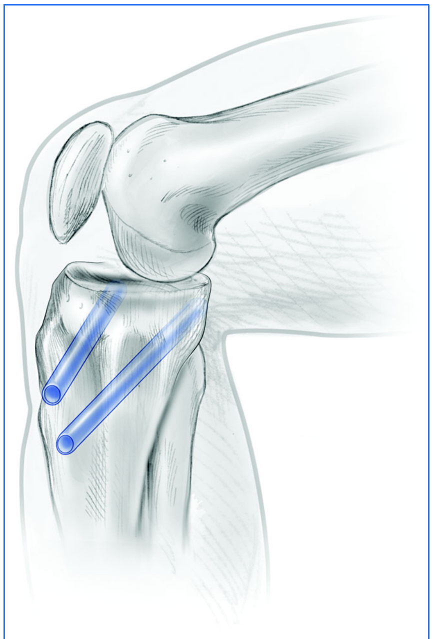


FIG. 10

Schematic of the tibial tunnels for the anterior cruciate ligament and posterior cruciate ligament.

ciate ligament and a 3-mm or a 5-mm parallel pin-guide is used to obtain the ideal placement of the tibial tunnel for the posterior cruciate ligament. The Kirschner wire for the tibial tunnel for the posterior cruciate ligament is left in place, and attention is then directed to the tibial tunnel for the anterior cruciate ligament. We prefer to pass both Kirschner wires prior to drilling.

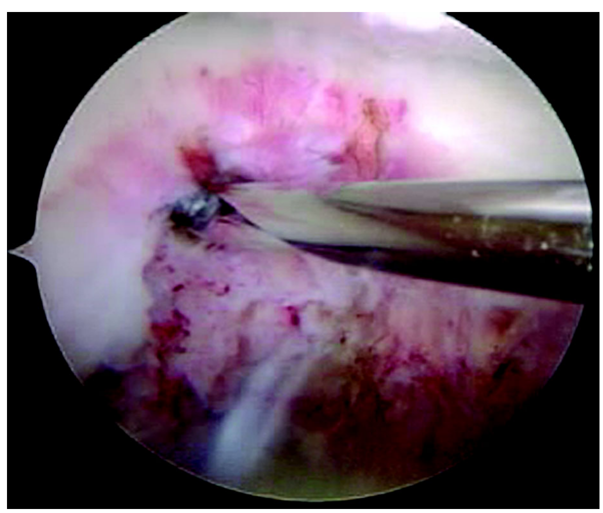
The anterior cruciate ligament tibial guide is set at approximately 45° and is introduced through the anteromedial portal. A 3/32-in (0.24-cm) guide wire is placed in the center of the tibial footprint of the anterior cruciate ligament. The location of the tibial tunnel for the anterior cruciate ligament is also confirmed on the full-extension lateral projection with intraoperative fluoroscopy. The guide wire should be just posterior to Blumensaat's line with the knee in full extension. The Kirschner wire for the posterior cruciate ligament should be 2 to 3 cm distal to the Kirschner wire for the anterior cruciate ligament (Fig. 8).

After acceptable placement of the tibial tunnel guide wires for the anterior cruciate ligament and the posterior cruciate ligament is confirmed, the posterior cruciate ligament tunnel is drilled. A curet is placed directly on top of the guide wire over the area of the drill site (Fig. 9). A compaction drill-bit is passed under direct arthroscopic visualization with a 30° arthroscope that is introduced through the posteromedial portal. The drill is started with pneumatic power, but, as soon as the initial cortex is breeched, drilling is finished by hand. At all times, the arthroscope visualizes the footprint of the posterior cruciate ligament with the curet over the tip of the Kirschner wire. We usually start with a drill that is 1 mm less than the desired tunnel width and dilate up in 0.5-mm increments. Next, the tibial tunnel for the anterior cruciate ligament is drilled and dilated in a similar manner. We prefer to have at least a 1 to 2-cm bone bridge between the anterior and posterior cruciate ligament tibial tunnels (Fig. 10).

Attention is then directed to the femoral tunnels for the anterior and posterior cruciate ligaments. For a single-bundle reconstruction of the posterior cruciate ligament, the insertion of the posterior cruciate ligament on the intercondylar notch is identified and a Kirschner wire is placed from the anterolateral portal to a point approximately 5 to 6 mm from the articular margin within the anterior portion of the femoral footprint of the posterior cruciate ligament (Fig. 11). The Kirschner wire is then overdrilled with a 9 or 10-mm compaction drill to a depth of approximately 25 to 35 mm.

FIG. 11

Arthroscopic image demonstrating the starting point of the femoral tunnel for the posterior cruciate ligament.



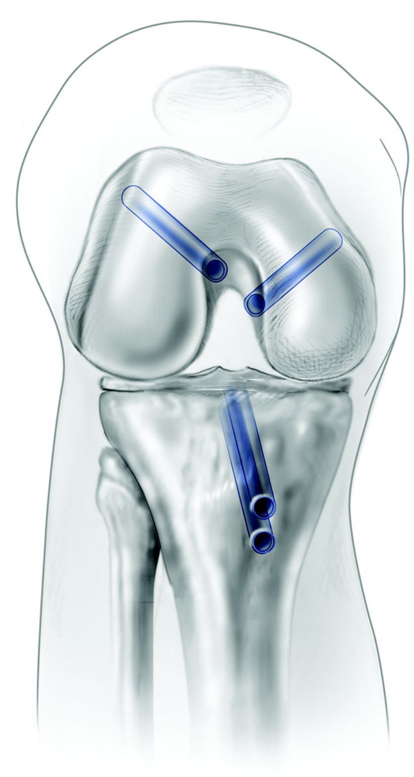


FIG. 12

Schematic of the femoral and tibial tunnels for the anterior cruciate ligament and posterior cruciate ligament.

Once again, the tunnel is dilated to the size of the graft by 0.5-mm increments. If a double-bundle reconstruction of the posterior cruciate ligament is chosen (this technique is used for chronic laxity of the posterior cruciate ligament), a second tunnel is drilled in the posterior footprint approximately 1 cm from the anterolateral tunnel. This tunnel is drilled to a diameter of 5 or 6 mm to accommodate the smaller posteromedial graft.

The femoral tunnel for theanterior cruciate ligament is established while the knee is flexed to 120°. The anteromedial portal is used to introduce the Kirschner wire into the desired position on the posterolateral portion of the intercondylar notch. The Kirschner wire is placed in the center of the anatomic insertion of the anterior cruciate ligament, which is approximately 6 mm anterior to the back wall or the over-the-top position of the femur and at the two or ten o'clock position for left and right knees, respectively. We prefer the medial portal technique to the traditional transtibial technique because the location of the femoral tunnel is not limited by the position or angulation of the tibial tunnel. The Kirschner wire is overdrilled with the compaction drill to a depth of 25 to 35 mm. This tunnel is then expanded with the dilators in 0.5-mm increments to the desired graft size. If there is any question about femoral tunnel placement, fluoroscopy is used for visualization (Fig. 12).

Graft Selection and Preparation

There are many options for graft selection for knees with multiple ligament injuries. Graft choice is based on the extent of the injury, timing of the surgery, and experience of the surgeon. Autograft tissue may be harvested from the ipsilateral or contralateral extremity and has the advantage of better graft incorporation and remodeling. At our institution, we prefer the use of allograft over autograft in multiple ligament reconstruction for the reasons listed below.

Anterior Cruciate Ligament

We prefer to use an allograft bone-patellar tendon-bone graft for our anterior cruciate ligament reconstructions. The bone-patellar tendon-bone allograft provides adequate biomechanical strength

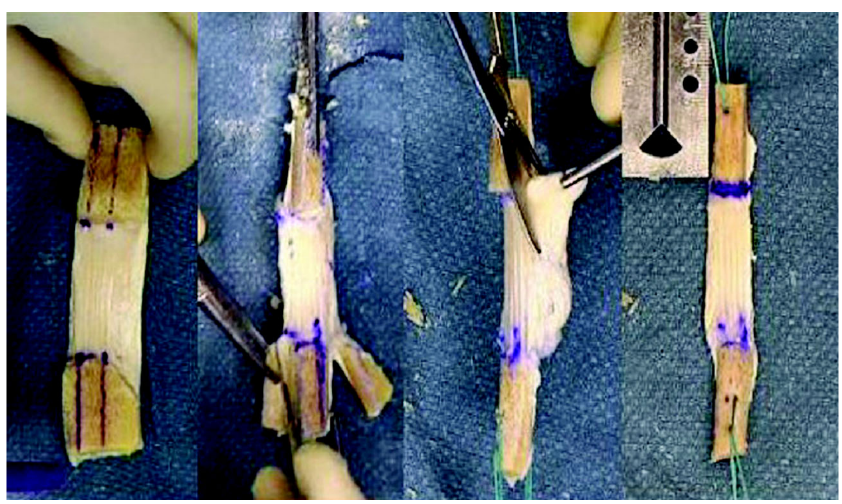


FIG. 13

Bone-patellar tendon-bone allograft for anterior cruciate ligament reconstruction.

with rigid osseous fixation at both the femoral and tibial attachment sites. We split the graft in half down the longitudinal axis; this is done so that we have an additional graft should something happen to the initial one. We prefer 11 × 25-mm cylindrical bone plugs with an 11-mm tendon width. The patellar bone plug is usually fixed in the femoral tunnel and is fashioned to have a slightly tapered leading edge to facilitate easy graft passage. Two number-5 nonabsorbable sutures are placed in both the patellar and tibial plugs through drill-holes (Fig. 13).

Posterior Cruciate Ligament

We recommend the use of Achilles tendon allograft for reconstruction of the posterior cruciate ligament. If a double-bundle technique is indicated, then an ipsilateral hamstring tendon (semitendinosus) autograft is harvested in addition. The allograft Achilles tendon is an attractive choice for reconstruction of the posterior cruciate ligament because it is a long graft, it has a substantial cross-sectional area, and it has a calcaneal bone plug that provides rigid fixation in the femoral tunnel. The central portion of the calcaneal bone plug is fashioned, with use of compaction pliers and a rongeur, such that it has a diameter of 11 mm and a length of 25 mm. Two number-5 nonabsorbable sutures are placed within the bone plug. Additionally, the tendon end is tubularized with use of a double-armed number-5 nonabsorbable suture. This is passed along the long axis of the tendinous portion in a "Chinese finger-trap" configuration so that the graft will not ball up during the graft passage (Fig. 14).

Lateral Collateral Ligament

The lateral collateral ligament is reconstructed with an Achilles tendon allograft with a 7 or 8-mm calcaneal bone plug. The

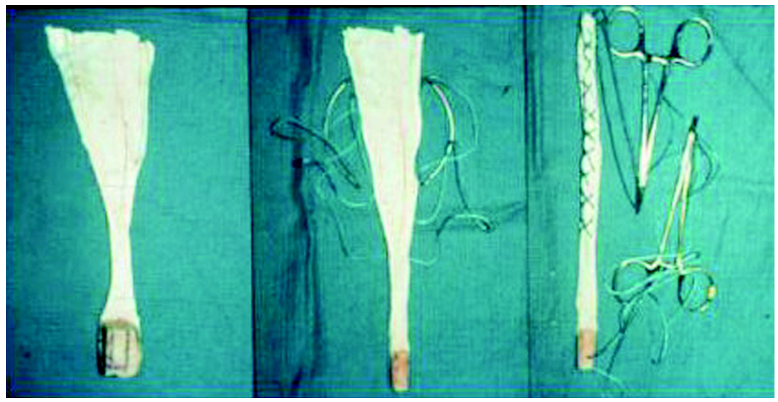


FIG. 14

Achilles tendon allograft for posterior cruciate ligament reconstruction.

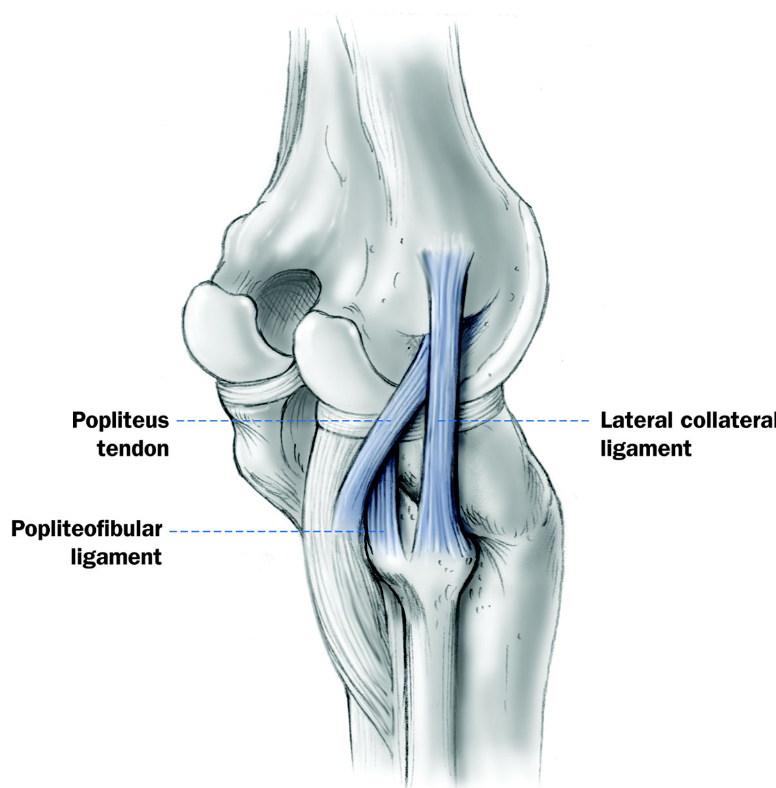


FIG. 15

Anatomic relationships of the structures on the lateral side of the knee.

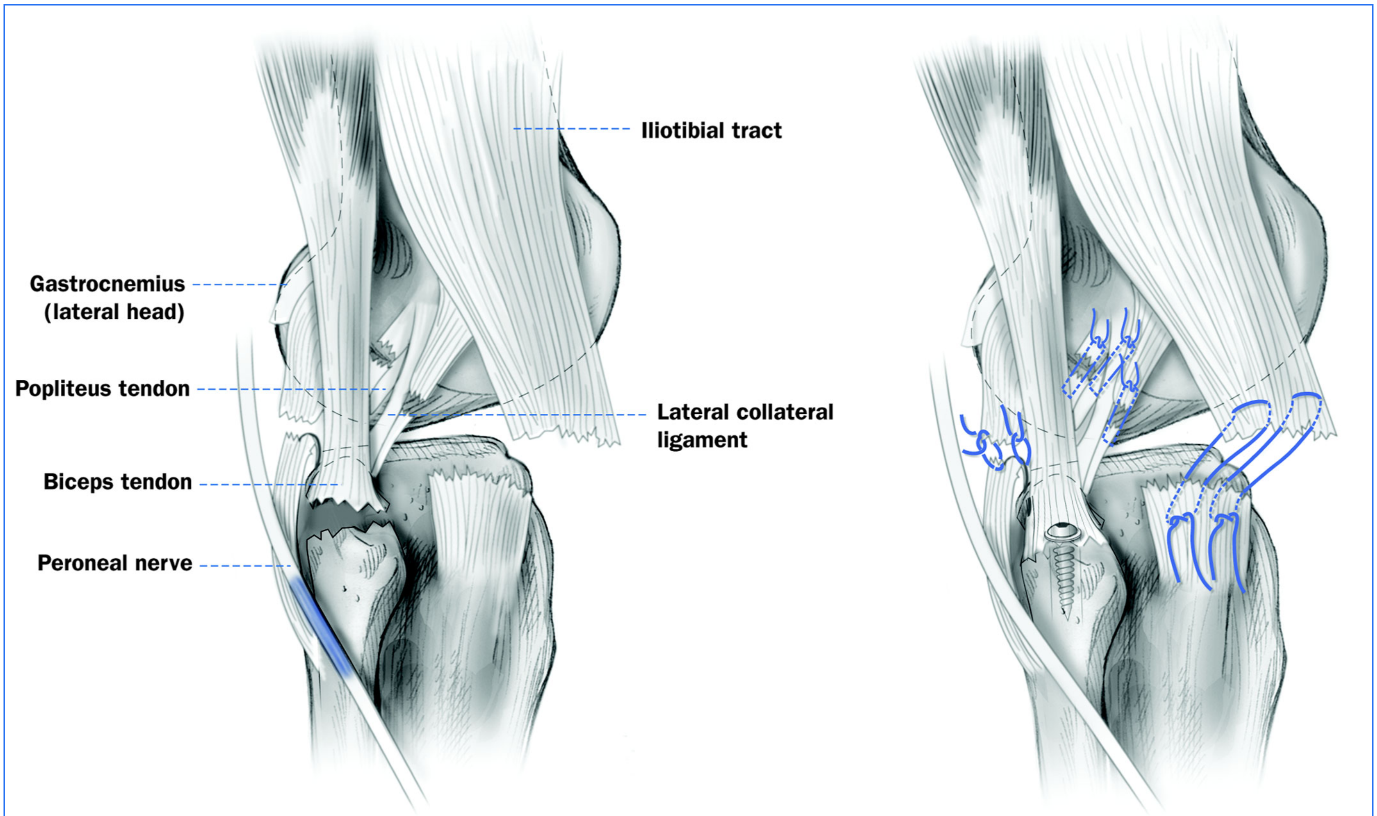


FIG. 16
Direct repair of the lateral structures.

bone plug can be fixed into the lateral collateral ligament insertion at the fibula through a bone tunnel. We do not tubularize the tendon as it is often reinforced to the native lateral collateral ligament tissue. Alternatively, the remaining bone-patellar tendon-bone allograft may be used for the lateral collateral ligament reconstruction.

Posterolateral Corner

Our graft choice for reconstructing the popliteofibular ligament is a tibialis anterior soft-tissue allograft or an ipsilateral hamstring (semitendinosus) autograft. These are fashioned with a whip-stitch on both ends with use of a number-2 braided nonabsorbable suture and usually fit into a 7-mm bone tunnel.

Cruciate Graft Passage and Femoral Fixation

The posterior cruciate ligament graft is passed first. An 18-gauge malleable wire is passed retrograde into the tibial tunnel for the posterior cruciate ligament and is retrieved out the anterolateral arthroscopy portal with a pituitary rongeur. Number-5 suture that has secured the tendon portion of the graft is shuttled into the joint with the looped 18-gauge wire by means of the anterolateral portal and is passed antegrade down the tibial tunnel for the posterior cruciate ligament to exit on the anteromedial aspect of the tibia. The calcaneal portion of the graft is passed out the anteromedial aspect of the femur by means of a Beath pin through the femoral tunnel for the posterior cruciate ligament and out the anteromedial part of the thigh. With arthroscopic assistance, a probe is used to direct the graft in the joint to facilitate its passage.

The anterior cruciate ligament graft is passed with use of the medial portal technique. The Beath pin, with a number-5 suture attached to the eyelet, is passed through the femoral tunnel by means of the medial portal. A pituitary rongeur is passed retrograde through the tibial tunnel, and the number-5 suture is retrieved with it. The graft is then passed from the tibial tunnel into the femoral tunnel with arthroscopic assistance.

The femoral fixation of the posterior and anterior cruciate ligament grafts is done at this time, but the cruciate grafts are not tensioned or fixed to the tibial side until the end of the procedure. The posterior cruciate ligament femoral grafts are fixed with a 4.5-mm AO screw and washer or they are tied and secured over a button. The anteromedial incision is extended proximally and distally adjacent to the exiting Beath pins. The vastus medialis obliquus is either split in line with its fibers or a small subvastus approach is used to gain access to the graft sutures and the bone. Alternatively, an interference screw may be used for femoral fixation of the calcaneal bone plug for a single-bundle reconstruction of the posterior cruciate ligament. For the femoral fixation of the anterior cruciate ligament, a 7 × 25-mm metal interference screw secures the femoral bone plug by means of the medial portal technique.

Lateral-Side Injury

After femoral fixation of the cruciate ligaments, a standard lateral hockey-stick incision is made. The plane between the posterior edge of the iliotibial band and the biceps femoris is incised longitudinally, and the insertion of the iliotibial band at Gerdy's tubercle is partially released to

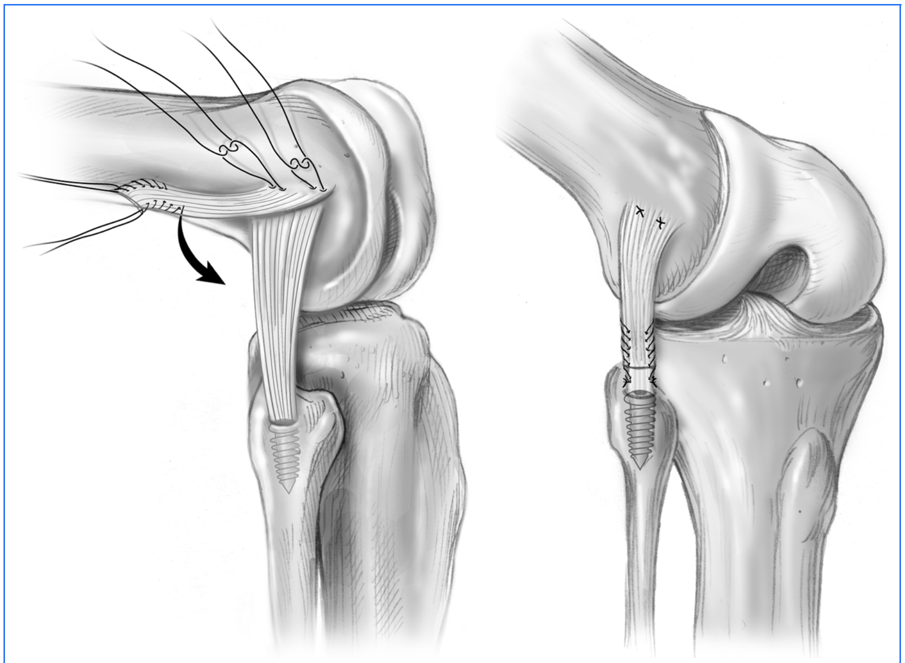


FIG. 17

Lateral collateral ligament reconstruction with Achilles tendon allograft.

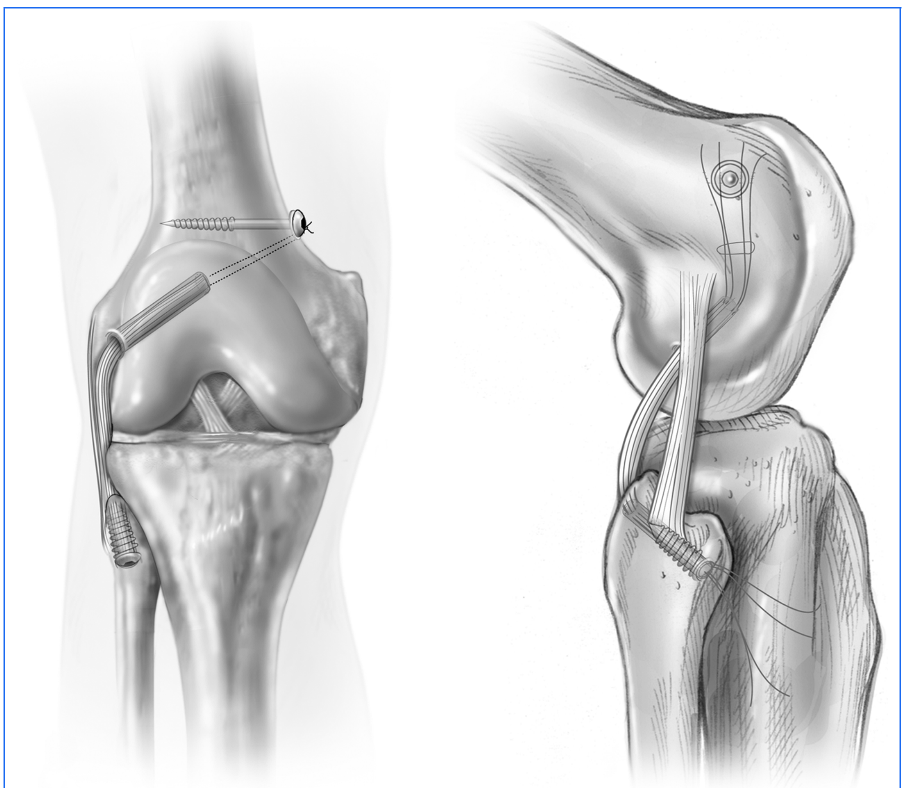


FIG. 18

Popliteofibular ligament reconstruction.

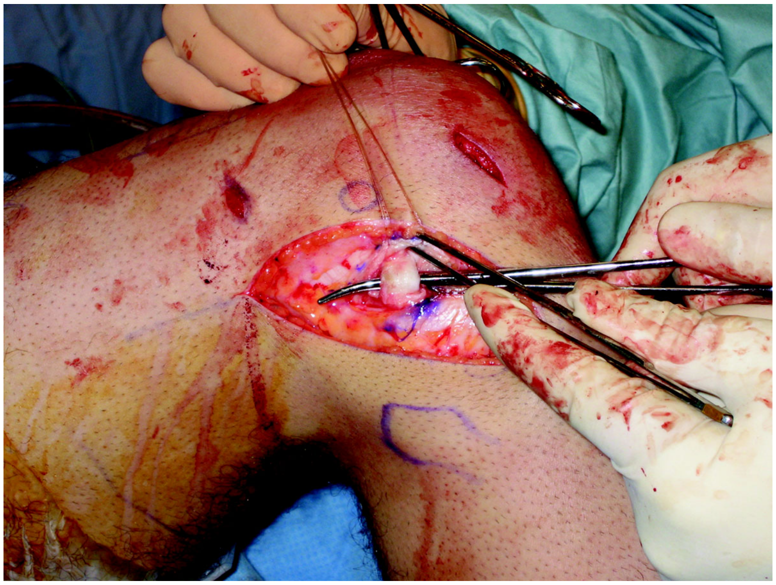


FIG. 19-A

FIG. 19-B

Figs. 19-A through 19-I Intraoperative photographs of lateral-side reconstruction. **Fig. 19-A** Dissection of the popliteus tendon. **Fig. 19-B** Detachment of the popliteus tendon.

increase visibility of the lateral collateral ligament and the popliteus insertions (Fig. 15). The peroneal nerve is identified proximally as it travels posterior to the biceps femoris and distally as it travels along the fibular neck and into the anterior tibialis muscle belly. A formal neurolysis is generally not performed unless there is evidence of compromise of the nerve at the time of surgery.

If repairable lateral meniscal tears or lateral capsular avulsions have been visualized during the diagnostic arthroscopy, a longitudinal capsular incision is made just posterior to the lateral collateral ligament. The meniscus is repaired with use of standard meniscal repair techniques depending on the type and location of the tear, while capsular avulsions are repaired with suture anchors.

Next, the lateral collateral ligament and the popliteofibular ligament are identified. If the injury is acute and tissue quality allows, avulsions of the biceps, iliotibial band insertion, lateral collateral ligament, or popliteus are directly repaired with number-2 braided nonabsorbable sutures (Fig. 16). However, for interstitial injury of these structures or if the injury is chronic, reconstruction is usually necessary.

Our preferred method for lateral collateral ligament reconstruction involves a 7 or 8-mm Achilles tendon allograft with an imbrication of the native lateral collateral ligament. The tendinous portion of the Achilles allograft is secured to the lateral collateral ligament insertion by means of drill-holes or suture anchors. The native lateral collateral ligament is then imbricated to the tendinous portion of the allograft with use of a whip-stitch. The injured lateral collateral ligament is dissected free from its distal insertion on the fibular head, and a tunnel is drilled along the longitudinal axis of the fibula. The allograft calcaneal bone plug is tensioned and secured in the tunnel with use of a metal interference screw (Fig. 17). Alternatively, the calcaneal bone plug can be fixed initially into the fibular tunnel and the tendinous portion can be recessed into the lateral femoral epicondyle by means of a small bone tunnel and tied over a post or a button on the medial aspect of the femur.

The goal of reconstruction of the popliteus complex is to recreate its static component, the popliteofibular ligament (Fig. 18). We prefer a tibialis anterior allograft, although hamstring au-

CRITICAL CONCEPTS

INDICATIONS:

- The majority of knees with multiple ligament injuries are currently treated surgically, with the goal of anatomic repair and reconstruction of all associated ligamentous and meniscal injuries.
- The timing of delayed repair and reconstruction is controversial, but, if possible, we prefer to approach these injuries within the first three weeks prior to excessive scar formation.
- Emergent surgery is indicated if knee dislocations are open, irreducible, or associated with vascular injury or a compartment syndrome.
- In open knee dislocations, wound management and achieving adequate soft-tissue coverage dictate the timing of ligament reconstruction, which should never be performed acutely.
- Irreducible dislocations, although uncommon, require prompt surgical reduction to avoid prolonged traction on the neurovascular structures. Although ligament reconstruction can be done at the time of the reduction, we prefer to delay the definitive reconstruction to allow for more complete knee imaging, planning, and stabilization of the patient.
- Popliteal artery injuries require emergent intervention by a vascular surgeon. The input of an orthopaedic surgeon as to the location of incisions is often helpful for future reconstructive efforts.

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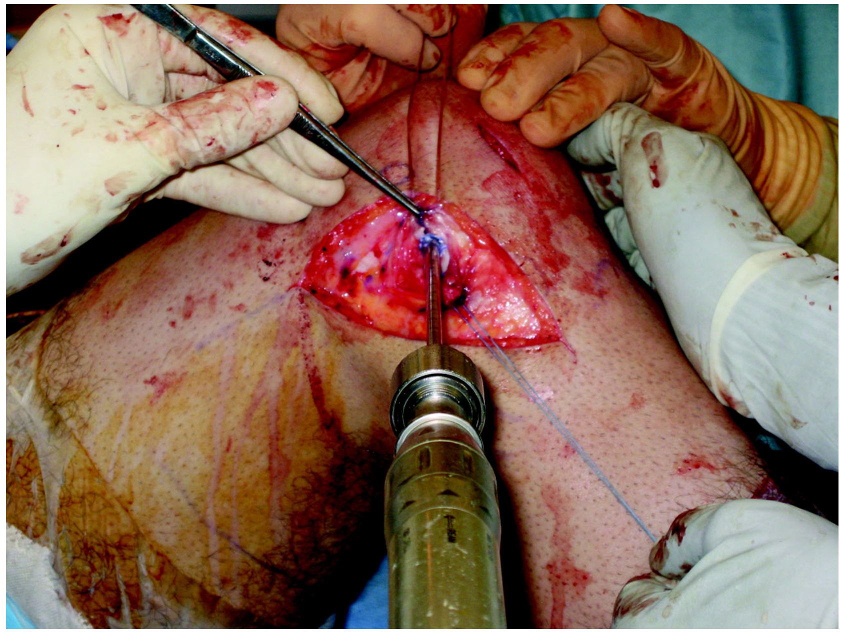

FIG. 19-C

Drilling of the femoral tunnel.

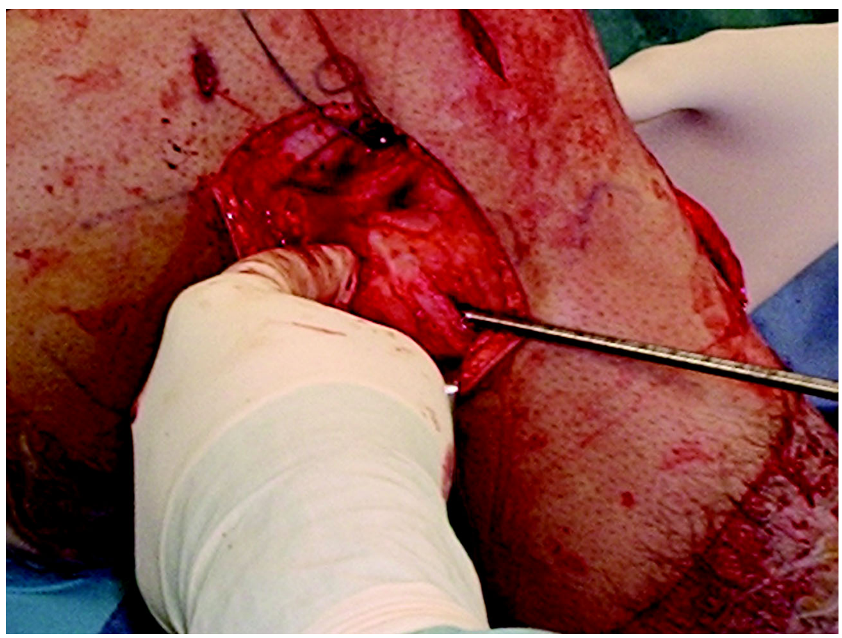

FIG. 19-D

Drilling of the fibular head tunnel.

tograft can be used. The lateral epicondyle of the femur is exposed, and the popliteus tendon is dissected off its anatomic insertion. A whip-stitch is placed in the popliteus tendon with a number-2 braided nonabsorbable suture. Correct placement of

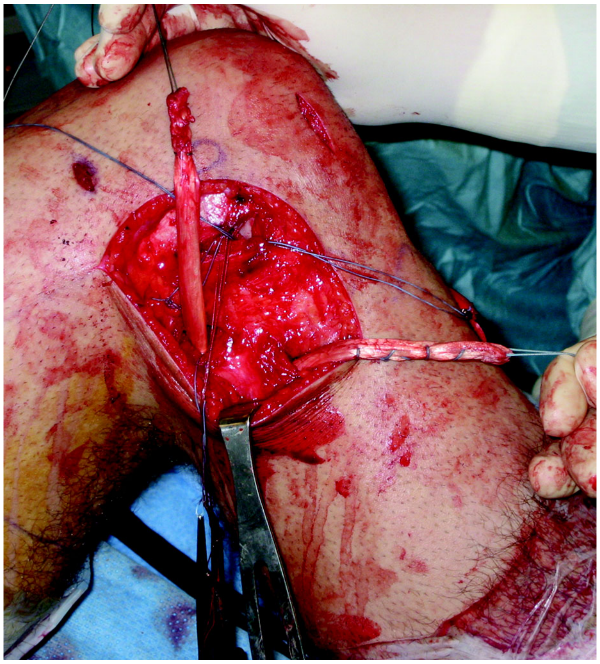

FIG. 19-E

Passing of graft through the fibular head.

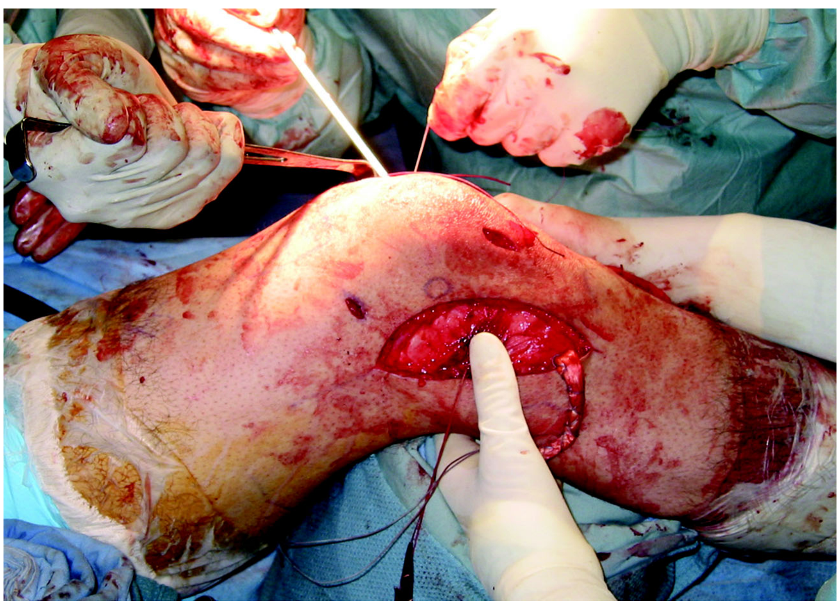

FIG. 19-F

Fixing the graft on the femoral side.

CRITICAL CONCEPTS | continued

- The presence of a knee dislocation does not change the management of a compartment syndrome. Prompt diagnosis and fasciotomies are necessary for a successful outcome.
- During emergent surgery on a dislocated knee, it is acceptable to perform simple primary r1epair of injured soft-tissue structures as they are encountered during the surgical exposure.
- Additional incisions should be avoided in the emergent setting, and definitive ligament reconstruction should be delayed several days to allow for recovery of soft-tissue swelling. In cases of vascular injury, additional time is required to ensure that the vascular repair is adequate and the limb remains viable.

CONTRAINDICATIONS:
Currently, contraindications to surgical repair of knee dislocations are rare but include the following:

- advanced age or sedentary lifestyle
- an active infection
- intra-articular or periarticular fractures
- osteoarthritis
- debilitating medical or posttraumatic comorbidities.

continued

the whip-stitch is confirmed if the whole posterolateral corner becomes taut when tension is applied to the suture. A 6-mm femoral drill tunnel is then placed at the lateral epicondyle to a depth of 25 to 30 mm, and the tunnel is expanded to 7 mm in diameter with the serial dilators. The posterior border of the fibula at the insertion of the popliteofibular ligament is exposed by incising horizontally just distal to the biceps insertion proximal to the peroneal nerve. The anterior border of the fibula is also exposed, and a 3/32-in (0.24-cm) guide wire loaded on a chuck is

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CRITICAL CONCEPTS | continued

PITFALLS:
Our skin incisions for the procedure are well planned to avoid potential pitfalls with exposure, infection, or wound compromise. Consequently, we prefer a minimally invasive approach. This includes the use of allograft tissue for the graft reconstruction and the use of arthroscopic measures when possible. We reserve the open technique for portions of the procedure that are not amenable to arthroscopic techniques. For medial and/or lateral repair or reconstructions, we do not recommend a midline incision as this provides limited access to the collateral ligaments and may be complicated by skin sloughing over the patella. In the rare instance that both medial and lateral incisions are required, then at least 10 cm between incisions is recommended.

When performing arthroscopy for multiple-ligament surgery, it is important to maintain a low intra-articular fluid pressure (gravity only) to prevent extravasation of fluid. If the fluid does extravasate into the leg and thigh, a compartment syndrome may result. Therefore, the leg and thigh are intermittently palpated throughout the procedure to ensure that the compartments are soft. If there is any question about the vascularity or leg compartment pressures, then the arthroscopic irrigation is stopped and the procedure is completed in a dry arthroscopic field or with an open technique. If necessary, compartment pressures are measured and fasciotomies are performed.

continued

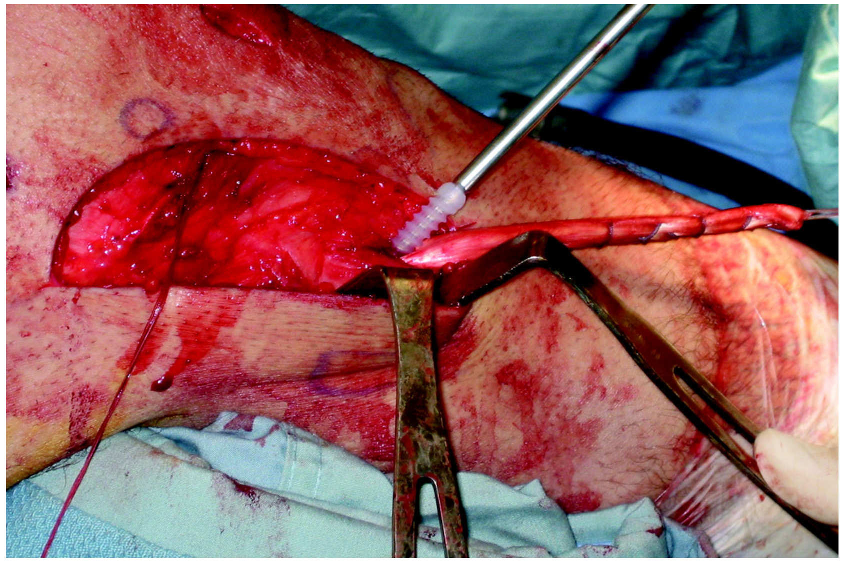


FIG. 19-G

Fixing the graft on the fibular side.

FIG. 19-H

Reinforcing the graft by suturing it onto itself.

then passed by hand from anterior to posterior across the fibular head in an attempt to match the oblique slope of the fibular head. The popliteofibular ligament tunnel rests more medial and closer to the proximal tibiofibular joint than does the previously drilled lateral collateral ligament tunnel. The fibular

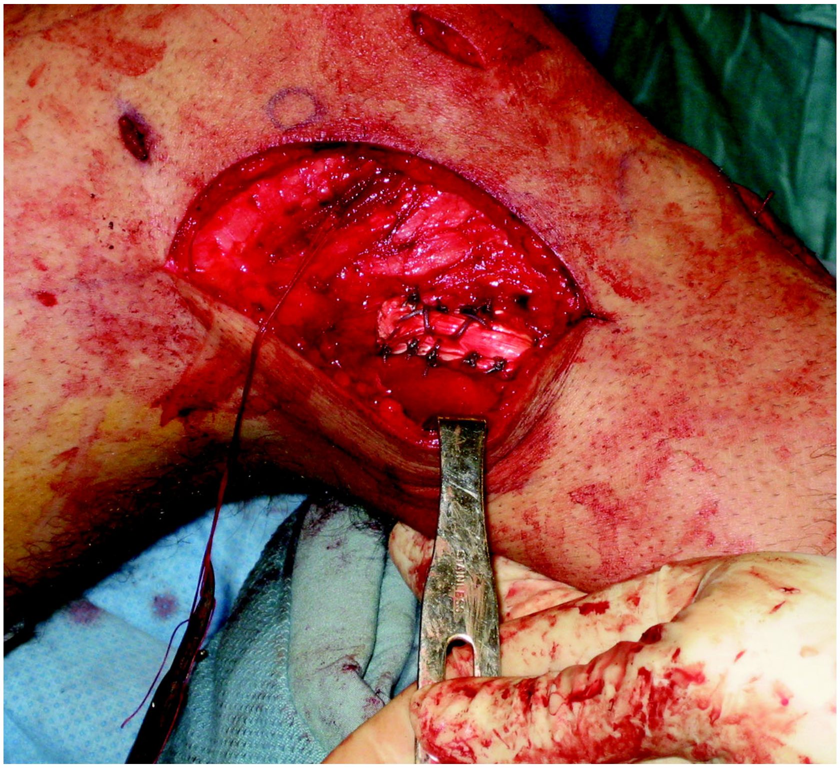


FIG. 19-I

Final lateral-side reconstruction.

head tunnel for the popliteofibular ligament graft is then drilled obliquely over the guide wire by hand with a 6-mm drill and is dilated to a diameter of 7 mm. The graft is passed from posterior to anterior through the tunnel with a Hewson suture passer, but it is not fixed to the fibula until it is properly tensioned. The graft is then passed underneath and medial to the lateral collateral ligament and into the previously drilled femoral tunnel at the popliteus tendon insertion by means of a Beath pin. The graft and the native popliteus tendon that was dissected subperiosteally are pulled into the tunnel. Approximately 25 mm of the allograft and approximately 10 mm of the popliteus tendon end up in the femoral tunnel. The graft and the popliteus tendon are tied over a 4.5-mm AO screw and a washer or a button on the anteromedial aspect of the distal part of the femur. The reconstructed tendon is fixed to the fibula with either a bioabsorbable interference screw or over a button as the final step. Figures 19-A through 19-I demonstrate the intraoperative steps of a lateral-side reconstruction.

Medial-Side Injury

If the cruciate ligaments are injured in combination with a medial-side injury, then a standard medial curvilinear incision is made. The femoral tunnel for the posterior cruciate ligament, tibial tunnels for the anterior and posterior cruciate ligaments, medial meniscal repairs, or medial capsular tears can be addressed through this incision. Peripheral meniscal tears can be repaired by standard meniscal repair techniques, and any capsular disruptions can be repaired with suture anchors. During the approach, the infrapatellar branch of the saphenous nerve should be identified ap-

CRITICAL CONCEPTS | continued

Popliteal neurovascular injury is possible during the creation of the tibial tunnel for the posterior cruciate ligament. Consequently, we use a posteromedial portal to visualize and palpate the posterior cortex. In addition, we use fluoroscopy during placement of the guide wire and drilling of the tunnel, and we protect the guide wire and drill-tip from posterior penetration with a curet.

During the lateral reconstruction, it is imperative to visualize and protect the peroneal nerve, especially when drilling the fibula. With a medial approach, the saphenous nerve should be identified and protected throughout the procedure.

Laxity of the grafts will occur if they are not tensioned and secured appropriately. The posterior cruciate ligament graft must be secured first to restore the step-off of the tibial plateau. Next, the anterior cruciate ligament should be tensioned to ensure reduction of the tibiofemoral joint. Last, the medial or lateral reconstruction is completed.

continued

proximately 1 cm proximal to the joint line and protected throughout the procedure.

We believe that the medial collateral ligament should only be repaired or reconstructed for grade-3 injuries, i.e., those that open up in full extension to valgus stress testing. In the acute setting (less than three weeks after the injury), the medial collateral ligament can be repaired at the time of cruciate ligament reconstruction. Medial collateral ligament avulsions off the tibial or femoral surface are reattached to bone by means of suture anchors, while intrasubstance tears are primarily repaired with number-2 braided nonabsorbable sutures with use of a modified Kessler stitch configuration. In the chronic setting, a reconstruction may be required to augment the repair.

The posterior oblique ligament, which is confluent with the posterior edge of the superficial medial collateral ligament, is reinforced by the semimembranosus and is critical to medial knee stability. The plane between the posterior edge of the medial collateral ligament and the posterior oblique ligament is incised longitudinally, and the two flaps are elevated. The medial meniscal attachments to the posterior oblique ligament must be released to the posteromedial corner of the knee. The peripheral border of the medial meniscus is rasped to prepare the bed for the eventual repair to the posterior oblique ligament. The medial meniscus is repaired to the anteriorly advanced posterior oblique ligament with full-thickness outside-in number-0 Cottony Dacron sutures (Deknatel, Fall River, Massachusetts) placed through the meniscus. The posterior oblique ligament is then advanced anteriorly and imbricated to the medial collateral ligament in a pants-over-vest fashion with use of number-2 Cottony Dacron sutures (Fig. 20). If needed, the reconstruction can be augmented with a soft-tissue graft at the anatomic origin and insertion of the medial collateral ligament. The graft is inserted directly into bone on both the femoral and the tibial surfaces with suture anchors and reinforced to the native medial collateral ligament in a side-to-side fashion.

Graft Tensioning and Distal Fixation

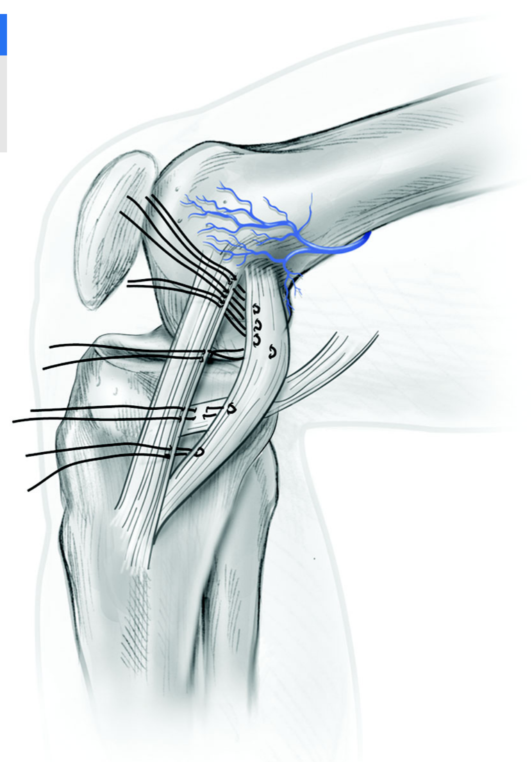
After all grafts are successfully passed and fixed to the femur, the final graft tensioning and distal fixation can be accomplished. In a stepwise fashion, we prefer to tension and fix the posterior cruciate ligament, anterior cruciate ligament, and lateral structures and then the medial structures.

Posterior Cruciate Ligament

The knee is brought to 90° of flexion, and a bolster is placed under the tibia to support its weight against gravity. The medial step-off is reduced with an anterior drawer so that the anterior edge of the medial tibial plateau rests approximately 10 mm anterior to the medial femoral condyle. The graft is fixed to the

FIG. 20

Posterior oblique ligament imbrication procedure.



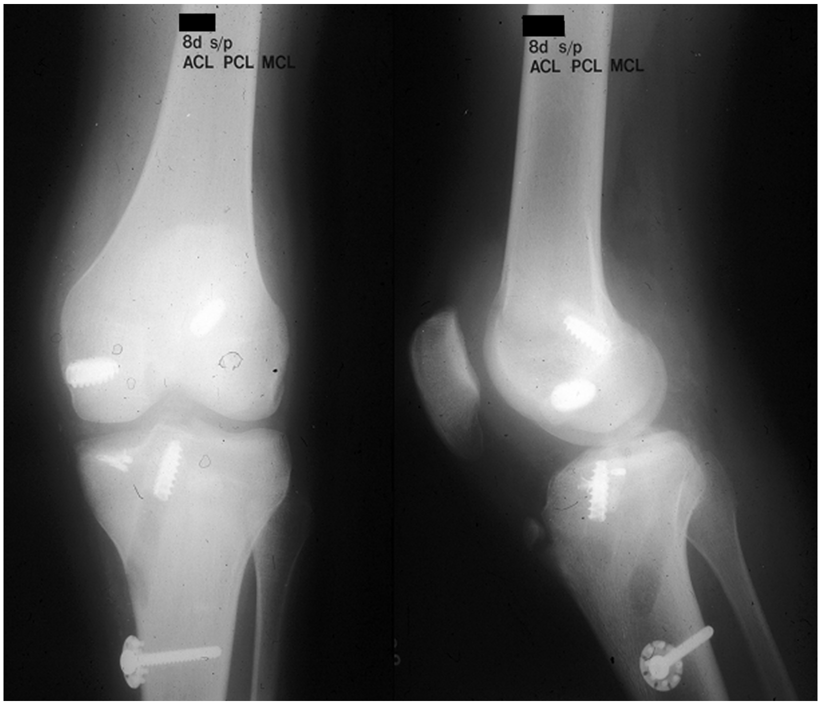


FIG. 21

Postoperative radiographs showing reconstruction of the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament.

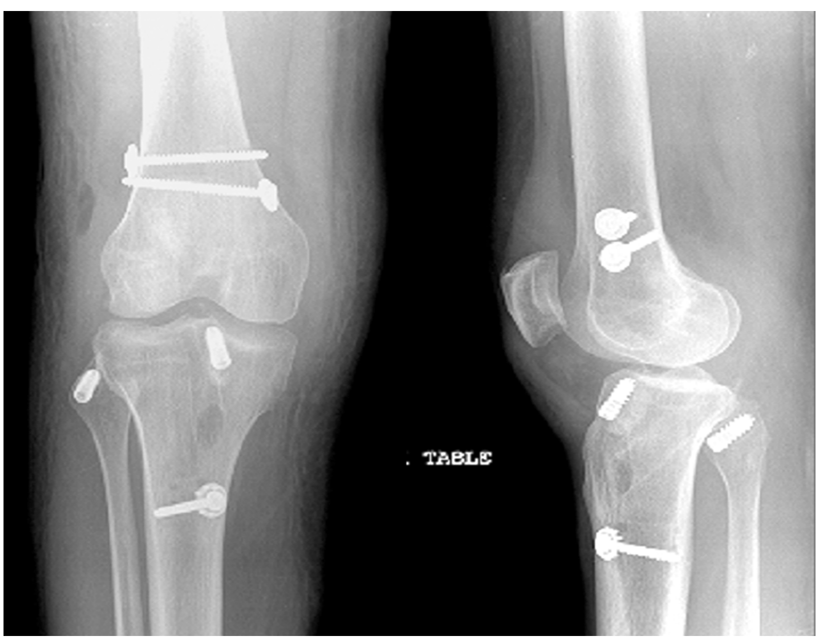


FIG. 22

Postoperative radiographs showing reconstruction of the anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner.

tibia with a 10 × 30-mm bioabsorbable interference screw and/or a 4.5-mm AO screw with a soft-tissue washer.

Anterior Cruciate Ligament

The anterior cruciate ligament graft is tensioned and fixed with the knee in full extension. We prefer a 7 × 20-mm metal interference screw for the bone-patellar tendon-bone allograft fixation in the tibia.

Posterolateral Corner

The posterolateral corner of the knee is reduced with an internal rotation force applied to the tibia relative to the fixed femur, and the lateral collateral ligament and the popliteofibular ligament are tensioned at 30° of knee flexion. The lateral collateral ligament is fixed with a 7 × 20-mm metal interference screw into the fibular head. The popliteofibular ligament is fixed with a bioabsorbable interference screw in the fibula, and the remaining graft is reapproximated to itself and/or over the insertion of the biceps in a figure-of-eight pattern with a number-2 braided absorbable suture. Alternatively, the popliteofibular ligament graft is fixed to the fibula with sutures tied over a button.

Medial Collateral Ligament

The medial collateral ligament is fixed at 30° of knee flexion while the posterior oblique ligament is fixed near full extension. This method prevents overconstraining of the knee during the repair or reconstruction.

After adequate tensioning and fixation, the knee is taken through a range of motion and examined, with the patient under anesthesia, to ensure proper fixation. An intraoperative radiograph is made to confirm that all of the hardware is intact and that the knee is adequately reduced (Figs. 21 and 22).

Closure

The wounds are well irrigated with antibiotic solution throughout the procedure. The deep layer is reapproximated with a 0 Vicryl suture (polyglactin; Ethicon, Somerville, New Jersey), while the subcutaneous tissue is closed with a 2-0 Vicryl suture. The skin is reapproximated with staples. Before the patient is taken out of the operating suite, the dorsalis pedis pulse is palpated or localized with a Doppler and the calf is palpated to ensure that a compartment syndrome did not occur. A standard sterile surgical dressing, consisting of Adaptic (Johnson and Johnson, Raynham, Massachusetts), sterile gauze, Webril

CRITICAL CONCEPTS | continued

AUTHOR UPDATE:

We believe strongly that anatomic reconstruction of all injured ligamentous structures is critical for a good outcome. Isolated reconstruction of the central pivot of the cruciate ligaments or the isolated reconstruction of the collateral ligaments neglects the complex biomechanical interaction between the knee ligaments during knee function. Consequently, we have recognized the specific injury patterns that affect the following components of the posterior cruciate ligament: the anterolateral bundle, the posteromedial bundle, and the meniscofemoral ligaments. When possible, we are selective about preserving the intact components (i.e., the posteromedial bundle and the meniscofemoral ligaments) while reconstructing the injured portion of the ligament (the anterolateral bundle) (Figs. 23-A and 23-B). If all components of the posterior cruciate ligament are torn or the injury is chronic, then a double-bundle posterior cruciate ligament reconstruction with use of an Achilles tendon allograft for the anterolateral bundle and a semitendinosus autograft for the posteromedial bundle is performed.

Since the original publication of this paper, we no longer use a tourniquet because of the potential length of the procedure and the resulting tourniquet risks. Meticulous dissection and hemostasis is paramount.

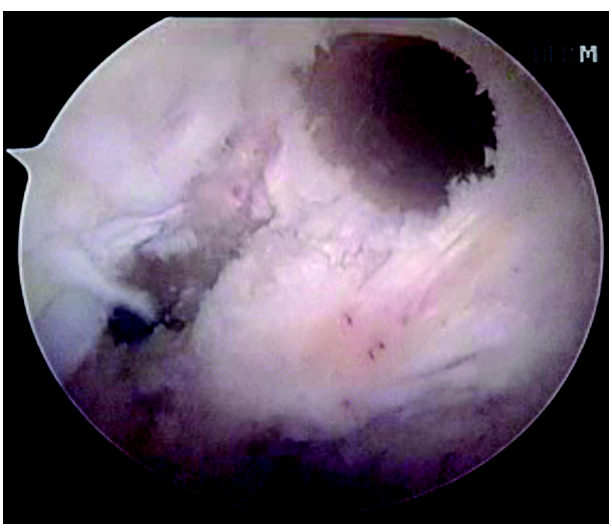


FIG. 23-A

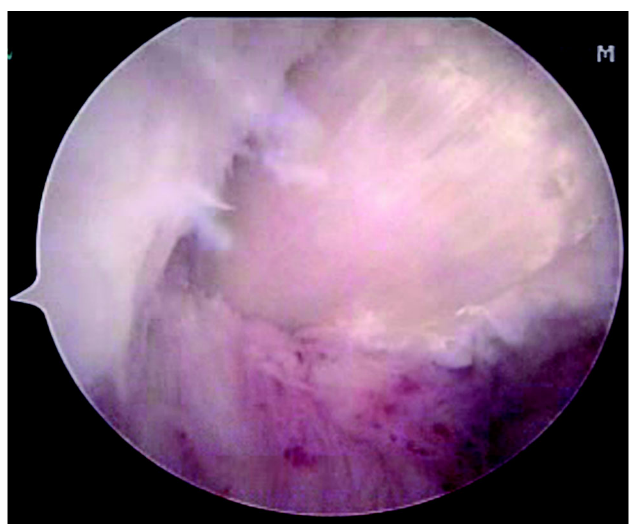


FIG. 23-B

Fig. 23-A Arthroscopic image depicting preservation of an intact bundle of the posterior cruciate ligament (posteromedial bundle).
Fig. 23-B Arthroscopic image of posterior cruciate ligament augmentation (anterolateral bundle) after graft passage.

(Kendall Health Care Products, Mansfield, Massachusetts), and a bias stockinette dressing, is applied. A brace with the knee locked in full extension is applied, and a pillow is placed under the calf. The patient is taken to the postanesthetic recovery room and is admitted for observation overnight. Prophylaxis against deep venous thrombosis is given to patients who are at high risk.

Postoperative Rehabilitation

In the early postoperative period, the main goals are to protect the healing structures, maximize quadriceps firing, and restore full passive extension. We keep the limb locked in full extension in the brace for the first four weeks. Exercises immediately following surgery include passive knee extension to neutral and isometric quadriceps sets with the knee in full extension.

At two weeks postoperatively, the physical therapist begins passive flexion limited to 90° and should prevent posterior tibial subluxation by applying an anteriorly directed force to the proximal aspect of the tibia. For the first six weeks, active flexion is avoided to prevent posterior tibial translation that results from hamstring contraction. At six weeks, passive and active-assisted range of motion and stretching exercises are begun to increase knee flexion. The brace is discontinued after six weeks. Gentle manipulation, with the patient under general anesthesia, is sometimes required for patients who fail to regain 90° of flexion at twelve weeks.

Quadriceps strengthening is progressed to limited-arc open-chain knee-extension exercises only from 60° to 75° of knee flexion as tolerated after four weeks. These exercises are limited to prevent excessive stress on the reconstructed grafts. Open-chain hamstring exercises are avoided for twelve weeks to prevent posterior tibial translation and excessive stress on the posterior cruciate ligament graft. Weight-bearing with use of crutches is progressed from partial to full weight-bearing as tolerated over the first four weeks unless a lateral repair or reconstruction was performed. In that case, we maintain partial weight-bearing until the patient has regained good quadriceps control, at which time, the brace may be unlocked for controlled gait training. Running is permitted at six months if 80% of the quadriceps strength has been achieved. Patients may return to sedentary work in two to three weeks, heavy labor in six to nine months, and sports in nine to twelve months.

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