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Management of Complex Knee Ligament Injuries

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An Instructional Course Lecture, American Academy of Orthopaedic Surgeons

Initial Evaluation of Acute and Chronic Multiligament Knee Injuries

Initial evaluation of a knee with multiple ligament injuries begins with a thorough and complete neurovascular examination, an assessment of the soft tissue, and determination of the instability pattern. Failure to recognize a vascular injury can lead to catastrophic limb dysfunction and ultimately to amputation. Injury to the tibial and/or peroneal nerves can also have devastating consequences and is encountered in almost 25% of dislocated knees[1]. The modified Schenck classification[2], in which not only ligamentous structures but also neurovascular injury and the presence of periarticular fracture are taken into account, is widely used to describe these injuries.

Vascular Assessment

There are several algorithms for the assessment of vascular injury of the lower limb. Vascular assessment may include physical examination alone, use of the ankle-brachial index, arterial ultrasound, and conventional and/or computed tomography angiography. A palpable pulse may be present distal to a complete popliteal arterial occlusion, as a result of the presence of collateral flow (Fig. 1). When a patient presents with "hard signs" of ischemia, which include a cool, pulseless, obviously dysvascular limb, immediate vascular surgery consultation is warranted. When the level of the lesion (for example, the popliteal artery in the setting of a dislocated knee) is known, the vascular surgeon may opt for immediate surgical exploration or proceed with angiography. Typically, a saphenous vein bypass graft obtained from the contralateral side is used to reestablish arterial flow, and concomitant prophylactic four-compartment fasciotomies are done. When a patient presents with "soft signs" of ischemia, including palpable but asymmetric pulses and asymmetric warmth and/or color of the limb, further assessment is needed.

The ankle-brachial index is determined by obtaining the systolic blood pressure of the affected limb at the level of the ankle and comparing it with the systolic blood pressure of the ipsilateral arm at the level of the brachial artery (Fig. 2): ankle-brachial index = Doppler systolic arterial pressure in injured limb (ankle)/Doppler systolic arterial pressure in uninjured limb (brachial).

Mills et al.[3] showed that when the ankle-brachial index is ≥0.9 there is no risk of a major arterial injury but, because delayed thrombus is a risk, serial pulse examination should be done every four to six hours for a period of twenty-four hours. When the ankle-brachial index is <0.9, either arterial ultrasound or computed tomography angiography[4] should be done. Duplex arterial ultrasound has excellent sensitivity and specificity; however, it is technician-dependent and not all centers have access to an ultrasound technician around the clock. The advantage of computed tomography angiography over conventional angiography is that there is less than one-fourth the dose of radiation, access is obtained through the antecubital fossa as opposed to the groin, and computed tomography angiography is 100% sensitive and specific[5]. Conventional angiography has a 5% to 7% false-positive rate.

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Fig. 1

Conventional arteriogram demonstrating collateral flow to the distal part of the lower extremity despite complete popliteal artery occlusion.

Neurologic Assessment

Niall et al.[1] reported the risk of peroneal nerve injury with dislocation of the knee to be approximately 25%. In their series, <50% of the patients had nerve recovery. Prompt placement of an ankle-foot orthosis in the early postinjury period is important to prevent equinus deformity from Achilles tendon contracture.

Treatment of a peroneal nerve palsy can include sural nerve grafting, direct repair, neurolysis, and tibial tendon transfer, but the success of treatment can vary widely. The direct transfer of tibial nerve motor branches to the peroneal nerve has promise, but the long-term results of this procedure are unknown.

Diagnostic Imaging

A substantial number of dislocated knees spontaneously reduce, and radiographic findings may be subtle, but standard anteroposterior and lateral radiographs of the knee are necessary following this injury. Joint asymmetry, mild tibiofemoral subluxation, avulsion fractures, and rim fractures are clues to the extent of the injury. In the nonacute setting, bilateral comparison stress radiography (varus, valgus, and posterior) can help to determine the extent of ligamentous instability. LaPrade et al.[6] reported that demonstration of a side-to-side difference of 2.7 mm on comparison of varus stress anteroposterior radiographs indicates a fibular collateral ligament injury, whereas a side-to-side difference of >4.0 mm indicates a fibular collateral ligament and posterolateral corner injury. In the acute setting, fluoroscopic stress examination with the patient under anesthesia helps to confirm clinical and/or magnetic resonance imaging findings.

Magnetic resonance imaging is the diagnostic imaging modality of choice after radiographs have been obtained. Magnetic resonance imaging identifies the ligament injury and its specific location and extent, both of which are critical for surgical planning.

Indications for Emergency Surgical Treatment

The indications for emergency surgical treatment include an open knee dislocation, an irreducible knee dislocation, and a compartment syndrome. Open knee dislocations require aggressive irrigation and debridement and placement of antibiotic bead pouches and/or a wound vacuum-assisted closure device (VAC; Kinetic Concepts, San Antonio, Texas), and may warrant plastic surgery for soft-tissue coverage. The irreducible knee dislocation is typically a posterolateral dislocation in which the medial femoral condyle buttonholes through the medial aspect of the capsule and/or the medial collateral ligament, causing a classic puckering of the medial skin. Prompt reduction is imperative to avoid skin necrosis and typically requires an open arthrotomy. In emergency cases such as these, definitive ligament repair or reconstruction is usually performed in a staged fashion, once all debridement and/or wound considerations have been addressed and the soft tissues have healed satisfactorily to allow additional surgery. Indications for the immediate placement of joint-spanning external fixation include vascular injury requiring repair, an open knee dislocation, and the inability to maintain tibiofemoral joint reduction by other means[7,8].

Fig. 2

Measurement of the ankle-brachial index.

Combined Posterior Cruciate and Anterior Cruciate Ligament Reconstruction

The principles of reconstruction in a knee with multiple ligament injuries include identification and treatment of all torn ligaments with accurate tunnel placement, anatomic graft insertion sites, utilization of strong graft material, secure graft fixation, and an extensive postoperative rehabilitation program[8-24].

An Achilles tendon allograft is our preferred graft for single-bundle posterior cruciate ligament reconstructions, and we prefer Achilles tendon and tibialis anterior allografts for double-bundle posterior cruciate ligament reconstructions. We prefer either a tibialis anterior or a patellar tendon allograft for anterior cruciate ligament reconstructions. The allograft tissue is prepared, and arthroscopic instruments are placed with the inflow in the superolateral portal, the arthroscope in the inferolateral patellar portal, and instruments in the inferomedial patellar portal. An accessory extracapsular extra-articular posteromedial safety incision is used to protect the neurovascular structures and to confirm the accuracy of tibial tunnel placement.

Notch preparation is performed first and consists of anterior cruciate and posterior cruciate ligament stump debridement, bone removal, and contouring of the medial and lateral walls and roof of the intercondylar notch. Specially designed 90° curets and rasps placed through the notch to the posterior aspect of the tibia are used to elevate the capsule and clearly identify the tibial footprint of the posterior cruciate ligament.

The arm of the PCL ACL guide is inserted through the inferomedial patellar portal to begin creation of the tibial tunnel for the posterior cruciate ligament graft. The tip of the guide is positioned at the inferolateral aspect of the anatomic insertion site of the posterior cruciate ligament. The bullet portion of the guide contacts the anteromedial surface of the proximal part of the tibia at a point midway between the posteromedial border of the tibia and the anterior aspect of the tibial crest approximately 1 cm below the tibial tubercle. This will provide an angle of graft orientation such that the graft will turn two very smooth 45° angles on the posterior aspect of the tibia and will not have an acute 90°-angle turn, which may cause pressure necrosis of the graft. The tip of the guide in the posterior aspect of the tibia is confirmed with the surgeon's finger through the extracapsular extra-articular posteromedial safety incision. Intraoperative anteroposterior and lateral radiographs may also be used. The surgeon's finger confirms the position of the guidewire through the posteromedial safety incision, providing a double safety check. The appropriately sized standard cannulated reamer is used to create the tibial tunnel. The surgeon's finger through the extracapsular extra-articular posteromedial incision monitors the position of the guidewire. The drill is advanced until it comes to the posterior cortex of the tibia. The chuck is disengaged from the drill, and the tibial tunnel is completed by hand, which provides an additional margin of safety for completion of the tibial tunnel.

The femoral tunnels for single-bundle or double-bundle reconstruction of the posterior cruciate ligament can be made from inside out. Inserting the appropriately sized double-bundle aimer through a low anterolateral patellar arthroscopic portal creates the femoral tunnel for the anterolateral bundle of the posterior cruciate ligament graft. The double-bundle aimer is positioned directly on the femoral footprint of the insertion site of the anterolateral bundle of the posterior cruciate ligament graft. The appropriately sized guidewire is drilled through the aimer, through the bone, and out a small skin incision. The double-bundle aimer is removed, and an acorn reamer is used to drill endoscopically from inside out the femoral tunnel for the anterolateral bundle of the posterior cruciate ligament graft. When the surgeon chooses to perform a double-bundle double-femoral-tunnel reconstruction of the posterior cruciate ligament, the same process is repeated for the posteromedial bundle of the posterior cruciate ligament graft. There should be at least 5 mm of bone between the two drill holes.

The tunnels for anterior cruciate ligament reconstruction are created with use of the single-incision technique. The tibial tunnel begins externally at a point 1 cm proximal to the tibial tubercle on the anteromedial surface of the proximal part of the tibia to emerge through the center of the stump of the anterior cruciate ligament tibial footprint. The femoral tunnel is positioned next to the over-the-top position on the medial wall of the lateral femoral condyle near the anatomic insertion site of the anterior cruciate ligament. The anterior cruciate ligament graft is positioned and is anchored on the femoral side; this is followed by tensioning and tibial fixation of the anterior cruciate ligament graft[25] (Figs. 3, 4, and 5).

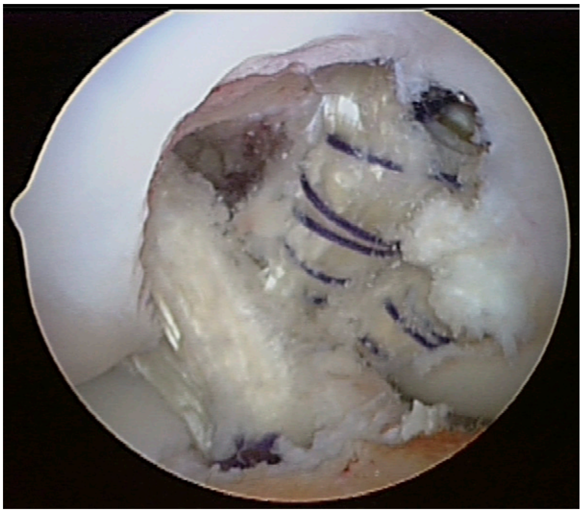

Fig. 3

Double-bundle posterior cruciate ligament reconstruction with use of an Achilles tendon allograft (anterolateral bundle) and a tibialis anterior allograft (posteromedial bundle) as well as anterior cruciate ligament reconstruction with use of an Achilles tendon allograft.

Lateral-Sided Reconstruction

The lateral side of the knee is commonly injured as part of a multiligament knee dislocation complex. The modified Schenck[2,26] classification of knee dislocations includes KD IIIL (injuries involving the anterior and posterior cruciate ligaments as well as the lateral complex). KD IV is less common and more severe, as this injury involves both the medial and lateral sides as well as both cruciate ligaments. The mechanism of this injury includes a strong varus and external rotation force that is high-energy[26]. The lateral side of the knee is complex anatomically and therefore difficult to replicate with reconstructive techniques.

The lateral side consists of static and dynamic stabilizers. The static stabilizers include the fibular collateral ligament and the popliteofibular ligament as well as the posterolateral aspect of the capsule. The popliteus muscle and tendon act as both a static and a dynamic stabilizer to control posterolateral rotation of the knee. The fibular collateral ligament acts as a primary restraint to varus stress and a secondary restraint to posterolateral rotation of the tibia on the femur. The popliteofibular ligament acts as a primary restraint to external rotation of the tibia on the femur at 30° of flexion, as does the popliteus muscle and tendon. The posterolateral aspect of the capsule acts in a secondary supportive role to resist external rotation, hyperextension, and varus moments[27-29].

The challenge of anatomic reconstructions is to recreate the posterolateral anatomy as closely as possible, usually with a combination of femoral, tibial, and fibular drill holes and allograft tissue. An alternative is to simplify the repair by performing a fibular and femoral-based reconstruction alone[14,21,30-32] (Figs. 6-A and 6-B). There are few studies comparing types of reconstructions in the literature, but, with other knee reconstructions, the more anatomic restorations tend to produce the best results. A reconstruction described by LaPrade et al.[33] is often mentioned as the closest reproduction of normal anatomy and will be described later in this paper.

The timing of surgery has been one of the most controversial aspects of knee dislocation management. Recent studies have indicated that earlier reconstruction may be better[34], but the evidence is not strong. The benefits of early surgery must be balanced against the risks of arthrofibrosis and the risks of infection where open wounds persist from either external

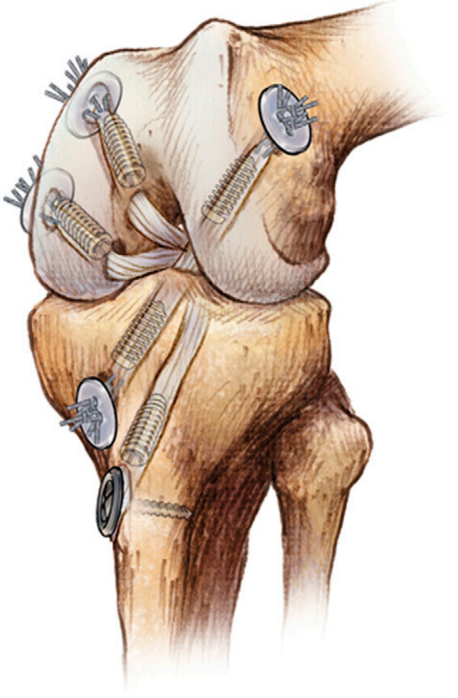

Fig. 4

Drawing depicting fixation, tunnel, and graft positioning in a combined reconstruction of the posterior and anterior cruciate ligaments. Note the primary aperture-opening fixation combined with cortical suspensory back-up fixation. (Reprinted, with permission, from: Fanelli GC. Rationale and surgical technique for PCL and multiple knee ligament reconstruction. Warsaw, IN: Biomet Sports Medicine; 2008.)

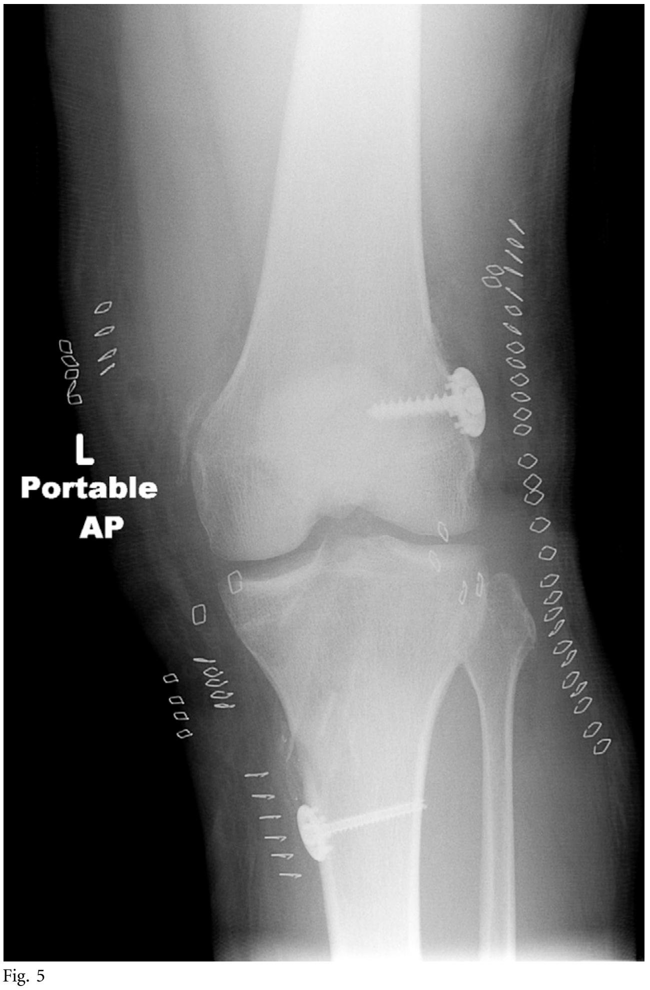

Fig. 5

Postoperative radiograph made after reconstruction of the anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner.

fixation pin sites or wounds from soft-tissue injury (Fig. 7). The decision when to operate needs to be individualized.

Another controversial issue is whether to repair or reconstruct the posterolateral corner. Recent work by both Stannard et al.[34] and Levy et al.[35] indicates that reconstruction is probably better than repair. When surgery is performed within the first three weeks after the injury, a combination of repair and reconstruction can be done and should provide the best chance of producing a stable posterolateral corner. Stannard et al. recently reported a trial of repair versus reconstruction of the posterolateral corner in fifty-seven knees[34]. Forty-four (77%) of the patients had sustained multiple ligament injuries of the knee, and the minimum duration of follow-up was twenty-four months. The repair failure rate was 37%, compared with a reconstruction failure rate of 9%. Reconstruction was found to have a significant advantage over repair in terms of stability on clinical examination.

In the study by Levy et al.[35], patients with multiligament knee injuries treated by a single surgeon were identified in a prospective database. Between February 2004 and May 2005, patients underwent repair of medial and lateral-sided injuries, followed by delayed cruciate ligament reconstructions. Between May 2005 and February 2007, patients underwent single-stage multiligament knee reconstruction. Forty-five knees (forty-two patients) with a minimum of two years of follow-up were identified. Four of ten repairs of the fibular collateral ligament and posterolateral corner and one of eighteen reconstructions of the fibular collateral ligament and posterolateral corner failed ($p = 0.04$). Although neither of these studies[34,35] was randomized, the findings of the two were quite similar, with both showing the rate of failure of repairs of the fibular collateral ligament and posterolateral corner to be significantly higher than the rate of failure of reconstructions of those structures.

Numerous surgical techniques to treat posterolateral corner injury have been described, with varying clinical outcomes[14,36-38]. Stannard et al. used a modified two-tailed technique that reconstructs the popliteofibular ligament and fibular collateral ligament through transtibial and transfibular bone tunnels and around a single screw on the lateral femoral condyle[36]. Twenty-two knees were followed for a minimum of two years, and the mean range of motion at the time of follow-up was 133°. The mean Lysholm knee score was 90 points for the entire group, 92 points for the knees with multiligament injuries, and 88 points for those with an isolated posterolateral corner reconstruction. There were two failures (13%) in the group with multiligament knee injuries, compared with no failures in the group with an isolated posterolateral corner reconstruction.

Strobel et al. evaluated the clinical outcomes after single-stage anterior cruciate ligament, posterior cruciate ligament, and posterolateral corner reconstruction in seventeen patients with chronic knee injuries and a minimum duration of follow-up of twenty-four months[37]. The posterolateral corner was reconstructed with a graft passed through the proximal part of the fibula, with both graft limbs inserting at an isometric point on the femur. At the final evaluation, performed with the International Knee Documentation Committee (IKDC) score, the result was graded as nearly normal for five of the seventeen patients, as abnormal for ten, and as grossly abnormal for two. The mean postoperative subjective IKDC score was 71.8 ± 19.3 points.

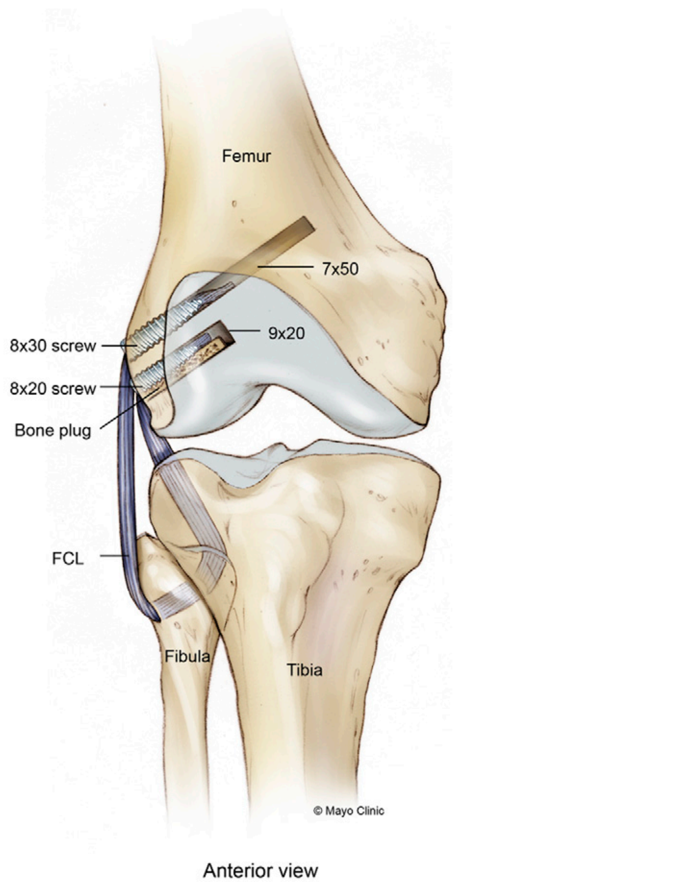

Fig. 6-A

Fig. 6-A and 6-B Pictorial representations of fibular and femoral-based reconstructions of the fibular collateral ligament (FCL) and posterolateral corner. PFL = popliteofibular ligament. (Copyrighted and used with permission of Mayo Foundation for Medical Education and Research, all rights reserved.)

The LaPrade technique[33] has been popularized as a stable and anatomically complete reconstruction utilizing a two-tailed graft (usually an Achilles tendon allograft) and reconstructing the fibular collateral ligament, the popliteofibular ligament, and the popliteus tendon. This technique requires four tunnels: two in the femur (for the insertion of the fibular collateral ligament and the popliteus tendon), one in the fibula, and one in the proximal part of the tibia. The Achilles tendon can be split into two separate grafts and bone blocks. Both bone blocks are inset into the femoral tunnels and secured with interference screws, replicating the insertions of the fibular collateral ligament and popliteus tendon, respectively. The fibular collateral ligament graft then runs from anterior to posterior through the tunnel in the fibula and subsequently into the tibia. The popliteus portion then runs from the femur into the tibial tunnel to join the other graft. A large bioabsorbable screw is then placed from anterior to posterior with the two graft limbs under tension at 30° of flexion and slight internal rotation. Excessive internal rotation force can constrain the knee excessively. Although the procedure is technically challenging, the results of this reconstruction appear to be good.

When the posterolateral corner is torn, there are usually other knee ligament injuries. Therefore, when the posterolateral corner is being repaired the lateral collateral ligament and the popliteofibular ligament complexes should be repaired as well. Allograft tissue is recommended for posterolateral corner reconstruction so that autogenous grafts can be used to repair the other ligaments and donor site morbidity is kept to a minimum. Numerous surgical techniques are available, but varus and posterolateral rotatory stability is best restored by the technique with which the surgeon is most familiar.

Reconstruction of the Medial Collateral Ligament and Posteromedial Corner

Combined injuries of the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament/posteromedial corner are classified as Type III according to the modified Schenck anatomic classification scheme. The anatomic structures on the medial side are arranged in three distinct layers: Layer 1 is the sartorius and sartorius fascia; Layer 2 is the superficial medial collateral ligament, posterior oblique ligament, and semimembranosus; and Layer 3 is the deep medial collateral ligament (the meniscofemoral and meniscotibial ligaments) and the posteromedial aspect of the capsule. The gracilis and semitendinosus tendons are found between Layers 1 and 2. These layers are not always separate since Layers 1 and 2 blend anteriorly, whereas Layers 2 and 3 blend posteriorly.

LaPrade et al.[39] described the clinically relevant medial knee anatomy. There are three osseous prominences on the medial aspect of the distal part of the femur: the medial epicondyle, the adductor tubercle, and the gastrocnemius tubercle. The femoral origin of the superficial medial collateral ligament is approximately 3 mm proximal and 5 mm posterior to the epicondyle, while the tibial insertion is approximately 6 cm distal to the joint line. The deep medial collateral ligament inserts along the tibial plateau margin, just distal to the articular cartilage. The femoral origin of the posterior oblique ligament is approximately 8 mm distal and 6 mm posterior to the adductor tubercle. These anatomic sites correspond to the radiographic landmarks described by Wijdicks et al.[40]. The combination of recognition of osseous prominences and radiographic identification helps to guide the surgeon to the proper ligament origin and insertion sites during repair or reconstruction. In a study of cadaver knees, Stannard et al.[41] found

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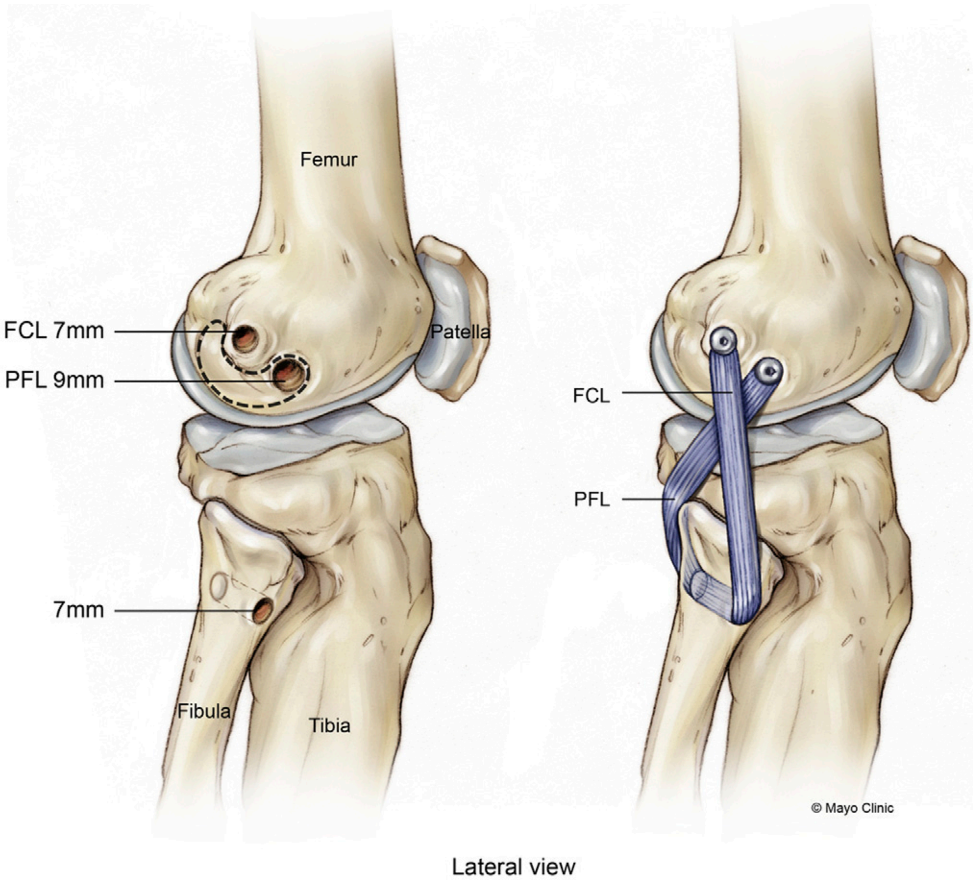

Fig. 6-B

that use of radiographic landmarks, rather than palpating the osseous prominences, led to better reproduction of the isometry of the superficial medial collateral ligament.

More than 10 mm of medial joint opening with the knee in full extension is the hallmark finding in a knee with a combined injury involving the medial side and both cruciate ligaments. Stress examination, with the patient under anesthesia, with the use of fluoroscopy or radiography to compare joint space opening of the injured knee with that of the contralateral knee helps the surgeon to understand the extent of pathologic ligament laxity. Magnetic resonance imaging is a sensitive tool for identifying injured structures.

Once the soft tissues are satisfactory, acute surgery (performed one to three weeks after the injury) is indicated when there is extensive medial disruption, a displaced meniscal tear, or a so-called Stener lesion of the knee in which the distal medial collateral ligament is flipped over the pes anserinus tendons. Delayed surgical intervention (at more than three weeks after the injury) may be necessary to allow the swelling to resolve and knee motion to return. When the only medial damage is a femoral medial collateral ligament avulsion, healing may occur and only the cruciate ligaments need to be repaired. When the anterior cruciate ligament, posterior cruciate ligament, and medial side need to be repaired, a single-stage procedure with anterior and posterior cruciate ligament reconstructions along with repair or reconstruction of the medial collateral ligament and posteromedial corner, as indicated, is best.

In the acute setting, a femoral or tibial-sided avulsion of the medial collateral ligament with good ligament substance can be repaired to the anatomic origin with a suture post and ligament washer. Figure 8 shows an example of a tibial-sided disruption of the medial collateral ligament. The intact ligament with excellent tissue substance allows a secure repair without the need for augmentation or reconstruction. The deep meniscotibial ligament can be reattached with suture anchors. The repair should be tensioned with the knee at 30° of flexion, a varus stress, and slight tibial external rotation. Injuries of the posterior oblique ligament and the posteromedial aspect of the capsule are also repaired anatomically with suture anchors and tensioning near full extension. It is important to avoid overtensioning in flexion, as this may prevent full knee extension.

Numerous reconstruction techniques for treatment in the chronic setting have been described[23,42-44]. Our preferred technique is to use an Achilles tendon allograft with the bone plug fixed in a femoral socket with an interference screw and the tendon secured to the tibia with a suture post/ligament washer construct. Figure 9 shows the Achilles tendon allograft after fixation

Fig. 7
Clinical photograph of a knee dislocation requiring spanning external fixation with substantial soft-tissue injury.

of the femoral attachment. The posterior oblique ligament and posteromedial aspect of the capsule are repaired if necessary.

A detailed search of the literature from 1978 through 2008 identified all studies with outcome data on repair or reconstruction of the medial collateral ligament in the setting of combined ligament injuries[8]. Only eight studies met the inclusion criteria: five were on medial collateral ligament repair, and three were on medial collateral ligament reconstruction. No prospective studies directly compared medial collateral ligament repair or reconstruction with nonoperative treatment or compared medial collateral ligament reconstruction with repair. The collective results suggest that either repair or reconstruction in the knee with multiple ligament injuries yields satisfactory outcomes. Owens et al.[45] reported on eleven knees with injuries to the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament, with the medial collateral ligament repaired only if it was avulsed, and all were stable to valgus stress at the time of final follow-up. One of us (G.C.F.) and colleagues[22] reported on nine knees with injuries to the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament, and all were stable to valgus stress, including seven that were treated surgically. In a study by Hayashi et al.[46] in which seven reconstructions of the anterior cruciate ligament, posterior cruciate ligament, and medial collateral ligament were performed with use of a semitendinosus autograft, the average Lysholm score was 95.1 points. Stannard et al.[41] reported on seventy-three dislocated knees with posteromedial corner

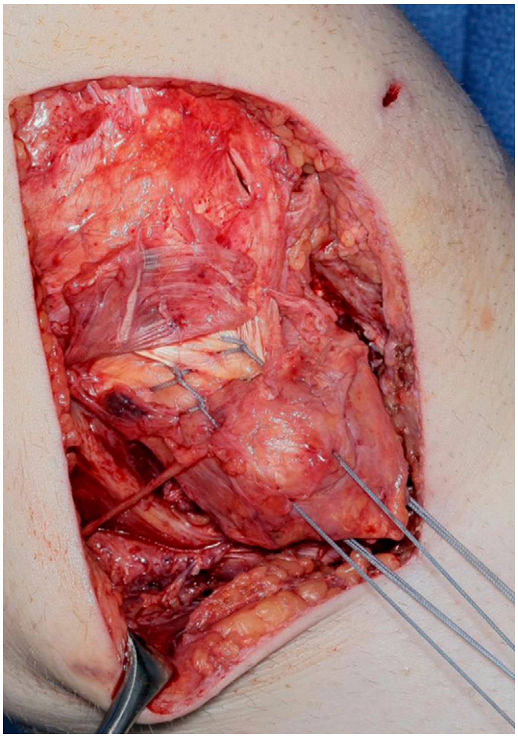

Fig. 8
A tibial-sided disruption of the medial collateral ligament with excellent tissue substance that is amenable to direct repair.

Fig. 9
A reconstruction of the medial collateral ligament with an Achilles tendon allograft after fixation of the bone block in the femoral socket.

injuries. Forty-eight underwent autograft or allograft reconstruction of the medial collateral ligament, and twenty-four had a medial collateral ligament repair. On the basis of a 20% failure rate in the repair group compared with a 4% failure rate in the reconstruction group, Stannard concluded that medial collateral ligament repair is inferior to reconstruction in a knee with multiple ligament injuries.

It is important to make an accurate, anatomic diagnosis with the use of physical examination, imaging studies, and bilateral comparison stress radiographs. The surgeon needs to determine the safe and appropriate timing of surgery and then proceed with reconstruction of the anterior and posterior cruciate ligaments along with repair or reconstruction of the medial collateral ligament, posterior oblique ligament, and posteromedial aspect of the capsule.

Postoperative Rehabilitation

The knee should be kept in full extension for a minimum of three weeks, and the patient should remain non-weight-bearing for six weeks[47]. Progressive range-of-motion exercises start three weeks after the operation. The brace should be unlocked at the end of the third week, and use of the crutches is discontinued once the patient can bear full weight. Progressive closed-kinetic-chain strength training and continued motion exercises are performed. Use of the brace should be discontinued after the tenth week. The patient can return to sports and strenuous labor after the ninth postoperative month as long as sufficient strength, proprioceptive skills, and motion have returned[11,48]. A loss of 10° to 15° of terminal flexion might be expected after these complex knee ligament reconstructions.

Fracture-Dislocations

Fracture-dislocations of the knee are severe injuries that have frequently been associated with poor outcomes[49-54]. The most common fracture around the knee associated with a multiligament knee injury is a tibial plateau fracture. It is difficult to treat patients who have instability of both the bone (a fracture) and ligaments of the knee. Reconstructing ligaments is a challenge when one is trying to anchor a reconstruction in fractured bone. The risk of failure of early reconstruction of the posterolateral corner with use of the modified two-tailed technique is higher in patients with a tibial plateau fracture than it is in patients who do not have a fracture[34,36].

Knee fracture-dislocations occur more frequently than generally thought and are particularly challenging to diagnose. It is difficult to determine the stability of the knee in a patient with a tibial plateau fracture. These patients also frequently have multiple injuries that divert the attention of treating teams away from the knee injury. As identified with magnetic resonance imaging, the prevalence of concomitant ligament injuries with tibial plateau fractures has been reported to be as low as 33% and as high as 90%[55-58]. While many of these injuries do not represent fracture-dislocations, in Stannard's series of 103 consecutive tibial plateau fractures, more than half of the patients had multiple ligament injuries and 26% had a fracture-dislocation[55]. Magnetic resonance imaging is an important adjunct to an examination under anesthesia for the successful diagnosis of fracture-dislocations of the knee.

There are very few published studies dedicated to the topic of fracture-dislocation of the knee. The published results show a high prevalence of poor outcomes, with pain, instability, and arthrofibrosis being the most common complications[49-54]. Conservative treatment is associated with poor results, and most authors have recommended surgical treatment for patients with fracture-dislocation. Delamarter et al. reported that 40% of their patients with a fracture-dislocation had a poor outcome after nonoperative treatment compared with a 16% rate of poor results in those who had had an operation[59]. Stannard et al. developed a staged treatment protocol for fracture-dislocations, in which the treatment of the fracture is separated from that for the dislocation, and it has yielded good functional outcomes in most patients[60]. Outcome scores after use of this staged protocol have been encouraging in patients with these complex injuries.

The initial phase of treatment for a patient with a fracture-dislocation of the knee is on the day of injury. The mechanism of injury, radiographic findings, and examination of the skin lead to a suspicion of a fracture-dislocation. The fracture is gently reduced with traction, and a careful vascular examination is performed. If the knee remains reduced, the extremity should be immobilized with a splint or knee-immobilizer and magnetic resonance imaging should be performed. In most cases, the skin and soft-tissue injury are so severe that surgical treatment should be delayed for at least three to seven days. Once the condition of the soft tissues around the knee is satisfactory, the second phase of treatment can begin.

Phase two is surgical stabilization of the fracture and any avulsions of major ligaments. Locked plates are frequently necessary to stabilize the complex fractures associated with fracture-dislocations. Preoperative planning is critical, both for successful treatment of the fracture and to ensure that the implants do not block future tunnels that will be necessary for reconstruction of the injured ligament. A knee-immobilizer should be applied after stabilization of the fracture, and one must be certain that the knee stays reduced.

Phase three is the early reconstructive phase of the protocol. If the condition of the patient and the soft tissues allow it, we advance to this phase during week three or four following the injury. Allograft ligament reconstruction is the mainstay of this phase. There are no definitive data in the literature regarding the timing or staging of ligament reconstructions in patients following knee dislocations. On the basis of the findings in the series evaluated by Stannard et al.[34,36], reconstruction of the anterior cruciate ligament and posterolateral corner should be delayed for approximately four months to allow early healing of the tibial plateau before tunnels are drilled through the tibia. Those authors reported a failure rate of >30% when posterolateral corner reconstructions had been performed during phase three compared with a failure rate of 8% when the same posterolateral corner reconstruction technique had been performed in patients without a tibial plateau fracture[34,36]. A hinged external fixator is placed at the end of the surgery in phase three, providing a stable environment for early ligament healing. Gentle motion is initiated on postoperative day one if the condition of the soft tissue allows it.

Phase four is the late reconstructive phase. The patient should have at least 80° of knee flexion before starting phase four. The hinged external fixator is removed, and the anterior cruciate ligament and posterolateral corner are reconstructed if the knee remains unstable. Again, allograft tissue is normally used for the reconstructions. Early motion after surgery is used to minimize arthrofibrosis.

In series evaluated by Stannard et al.[60], good functional outcomes were achieved in patients in whom a fracture-dislocation had been treated with this staged protocol. In a series of fifty patients with a total of fifty-four fracture-dislocations, the final Lysholm knee score averaged 86 points (range, 50 to 100 points). According to the final objective IKDC scores, there were thirty-two normal or nearly normal knees and seventeen abnormal knees. However, while good function was achieved, patients required an average of four surgical procedures to complete their treatment.

Complications

Complications are frequent after knee dislocations and fracture-dislocations. Complications include a wide variety of conditions including wound-healing, vascular, and neurologic problems. The most common complications remain pain, arthrofibrosis, and ligament instability despite reconstruction. Pain is a difficult complication to quantify objectively, but many patients have problems with chronic pain following these injuries. The prevalence of chronic pain has ranged from 25% to 68%[61]. Arthrofibrosis remains a substantial source of pain and disability following knee dislocations. The prevalence has ranged from 5% to 71% in the published literature, with a mean of 29% of patients having arthrofibrosis requiring surgical treatment[61]. The prevalence of persistent instability was 100% after nonoperative treatment, and it ranged from 18% to 100% after surgical treatment, with a mean of 42% of patients having instability in at least one plane[61].

Results of Treatment of Knee Dislocations

Outcomes after knee dislocation are difficult to quantify in large part because the injuries are heterogeneous[62]. A knee dislocation can range from a three-ligament noncontact injury that reduced spontaneously to one sustained in a high-speed motor-vehicle accident and is associated with severe neurologic and vascular injuries. Nevertheless, the data on the outcomes of these injuries are summarized below.

Levy et al.[8] performed a systematic review of 413 articles on this topic. They evaluated studies that compared surgical treatment with nonoperative treatment[63-66], studies that compared repair with reconstruction[34,67], and studies that compared early and late surgical treatment[21,68-71].

Of the four studies that compared operative and nonoperative treatment[63-66], one was a meta-analysis of investigations published prior to 2000[63]. In three studies in which the Lysholm score was used to record postoperative outcomes, surgical treatment resulted in higher mean scores[63-65], with one of the differences being significant[64]. The surgical group also had higher IKDC scores[64,66]. Return to work and to sports activities were also better overall in the surgically treated group.

Two studies that compared surgical repair with reconstruction were identified[34,67]. Direct repair of cruciate ligaments resulted in inferior motion, a higher rate of positive posterior sag signs, and a lower rate of return to the preinjury activity level[67]. The rate of failure after repair of the posterolateral corner was also found to be higher than that after reconstruction[34].

In general, three weeks was the most consistent time point up to which surgery was described as "early." Overall, the patients who had had early surgery had improved outcomes for several parameters[21,68-71]. However, there is potential for substantial bias with respect to the timing of surgery because the reason for early or late surgery may be related to prognosis (such as other injuries or the status of the soft tissues around the knee).

An excellent prospective cohort study with a minimum of two years of follow-up after reconstruction for treatment of knee dislocations was carried out by Engebretsen et al.[72]. Inclusion criteria were injury to both the anterior and the posterior cruciate ligament as well as an injury to the medial and/or lateral side. Patients were treated with surgical reconstruction within two weeks after the injury, when that was not contraindicated by other injuries. The authors used both autograft and allograft tissue, with a trend toward using autograft later in the study enrollment period. Of 121 patients who were initially eligible, eighty-five patients had sufficient follow-up. Approximately half of the patients in this cohort sustained what was considered high-energy knee dislocations. The median Lysholm score for the patients who were followed was 83 points, and the median Tegner score was 5 points. The authors found that injuries resulting from high-energy trauma and those involving all four major ligaments resulted in worse outcomes than did those resulting from low-energy trauma and those involving three ligaments.

Despite some excellent case series as well as comparative studies and the prospective cohort study by Engebretsen et al.[72], we are not aware of any randomized controlled trials to assist us with outcome assessment after knee dislocation. These injuries are complex and not easily amenable to randomized trials for many reasons[62]. Additional research is needed to identify prognostic factors and treatment algorithms to improve outcomes after these rare and devastating injuries.

Overview

Recent advances in surgical techniques, including anatomic reconstructions, for management of knees with multiple ligament injuries have led to improved patient outcomes. Current recommendations include measurement of the ankle-brachial index in each patient, early surgical management (earlier than three weeks postinjury), the use of autograft or allograft tissue, reconstruction as opposed to repair alone of the fibular collateral ligament and posterolateral corner structures, reconstruction of the anterior and posterior cruciate ligaments, and repair and/or reconstruction of the medial collateral ligament and posteromedial corner, depending on the injury pattern and quality of tissue. Future research including the establishment of multicenter working groups and the collection of prospective data may hold the key to identifying optimal treatment protocols for these complex injuries.

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