

Current Concepts

The Multiple-Ligament Injured Knee: Evaluation, Treatment, and Results

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Abstract: The multiple-ligament injured knee is a complex problem in orthopaedic surgery. Most dislocated knees involve tears of the anterior and posterior cruciate ligaments (ACL/PCL) and at least 1 collateral ligament complex. Careful assessment of the extremity vascular status is essential because of the possibility of arterial and/or venous compromise. These complex injuries require a systematic approach to evaluation and treatment. Physical examination and imaging studies enable the surgeon to make a correct diagnosis and to formulate a treatment plan. Arthroscopically assisted combined ACL/PCL reconstruction is a reproducible procedure. Knee stability is improved postoperatively when evaluated using knee ligament rating scales, arthrometer testing, and stress radiographic analysis. Acute medial collateral ligament (MCL) tears, when combined with ACL/PCL tears, may in certain cases be treated with bracing. Posterolateral corner injuries combined with ACL/PCL tears are best treated with primary repair as indicated, combined with reconstruction using a post of strong autograft (split biceps tendon, biceps tendon, semitendinosus) or allograft (Achilles tendon, bone–patellar tendon–bone) tissue. Surgical timing depends on the ligaments injured, the vascular status of the extremity, reduction stability, and the overall health of the patient. We prefer to use allograft tissue for reconstruction in these cases because of the strength of these large grafts and the absence of donor site morbidity. **Key Words:** Dislocated knee—Combined ACL/PCL injury—Allograft—Arthroscopic reconstruction.

The dislocated knee is a severe injury resulting from violent trauma. It results in disruption of at least 3 of the 4 major ligaments of the knee and leads to significant functional instability. Vascular and nerve damage, as well as associated fractures, may contribute to the challenge of caring for this injury. Historical treatment was primarily limited to immobilization. However, with the advent of better surgical instrumentation and technique, the management of combined anterior and posterior cruciate ligament (ACL/PCL) tears associated with medial or lateral

collateral ligament (MCL/LCL) disruption has become primarily surgical. This article presents the basic knee anatomy, mechanisms and classifications of injury, evaluation, treatment, postoperative rehabilitation, and our experience with treating the dislocated knee.

ANATOMY

The stability of the knee is attributable to several anatomic structures. The articulation of the femorotibial joint is maintained in part by the bony anatomy of the femoral condyles and the tibial plateau. The menisci serve to increase the contact area between femur and tibia and thus increase stability of the joint. The 4 major ligaments (ACL, PCL, MCL, LCL) and the posterior medial and posterior lateral corners are the most significant ligamentous stabilizers of the knee. In addition to these static anatomic structures,

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dynamic anatomic structures, such as the musculature that crosses the knee joint, also play a role in stabilization. In any knee injury, examination must include evaluation of all these anatomic structures.

When evaluating a dislocated knee, it is imperative to evaluate the structural integrity of any remaining ligamentous structure; consequently, the functions of these structures must be well understood. The ACL primarily prevents anterior translation of the tibia relative to the femur, and accounts for about 86% of the total resistance to anterior tibial translation.¹ It is also involved in limiting internal and external rotation of the tibia relative to the femur when the knee is in extension.² The ACL will also limit varus and valgus stress in the face of either an LCL or an MCL injury.

The PCL may be considered the primary static stabilizer of the knee, given its location near the center of rotation of the knee and its relative strength.³ The PCL has been shown to provide 95% of the total restraint to posterior tibial displacement forces acting on the tibia.¹ The PCL works in concert with structures of the posterior lateral corner, and injury to both structures is required to significantly increase posterior translation.⁴

The MCL and LCL act alone to resist valgus and varus stresses, respectively, at 30° of knee flexion. Together, they act in a secondary fashion to limit anterior and posterior translation, and rotation of the tibia on the femur. The anatomy of the posterior lateral corner of the knee is complex; its major structures consists of (1) the LCL, (2) the arcuate complex, (3) the popliteal tendon, and (4) the popliteal-fibular ligament.⁵ The posterolateral corner primarily resists posterior lateral rotation of the tibia relative to the femur, but also contributes to resisting posterior tibial translation. The posteromedial corner of the knee consists primarily of the posterior oblique portion of the MCL and associated joint capsule. These structures provide resistance to valgus stress and posterior medial tibial translation. Evaluation of traumatic knee dislocation must include these anatomic structures; typically, 3 or more areas are injured in knee dislocation. Failure to recognize and treat capsular and ligamentous injury, aside from the obvious ACL/PCL injury, will result in less than optimal results.⁶⁻⁸

Neurovascular structures are also at risk of injury. The popliteal fossa is defined by the tendons of the pes anserinus and semimembranosus medially and the biceps tendon laterally. The space is closed distally by the medial and lateral heads of the gastrocnemius and proximally by the hamstrings. Within this space, the popliteal artery and vein and the tibial and peroneal

branches of the sciatic nerve are located. The popliteal artery may be most at risk to injury in knee dislocations. The popliteal artery is tethered proximally at the adductor hiatus as it exits from Hunter's canal, and distally as it passes under the soleus arch, making it vulnerable to injury in these areas. This artery is considered to be an "end artery" of the lower limb; if it is injured, the surrounding geniculate arteries are not sufficient to maintain collateral blood flow to the lower extremity. The popliteal vein is in close association with the artery, but seems to be less at risk during injury than the popliteal artery. From a surgical standpoint, the popliteal vessels are located directly posterior to the posterior horns of the medial and lateral meniscus, and dissection in this area may put these structures at risk if not adequately protected. The sciatic nerve divides into its peroneal and tibial divisions within the popliteal space. These nerves are less likely to be injured with knee dislocation, probably because they are not tethered as the popliteal artery is. The peroneal nerve is at higher risk because its course around the fibular head functionally decreases its potential excursion, and violent varus injuries may result in traction and/or avulsion injuries to this nerve. Its location must be identified during dissections to reconstruct the posterolateral corner.

CLASSIFICATION

Classification of knee dislocation is primarily based on the direction the tibia dislocates relative to the femur.^{9,10} This results in 5 different categories: anterior, posterior, lateral, medial, or rotatory. The anterior-medial and lateral, posterior-medial, and lateral dislocations are classified as "rotatory" dislocation. Other factors to be considered include whether (1) the injury is open or closed, (2) the injury was caused by "high-energy" or "low-energy" trauma, (3) the knee is completely dislocated or subluxated, and (4) there is neurovascular involvement. Furthermore, one should be acutely conscious of the fact that a complete dislocation may spontaneously reduce, and any triple-ligament knee injury constitutes a frank dislocation.^{7,11,12}

Reports vary, but anterior and/or posterior dislocation appear to be the most common direction of dislocation. Frassica et al.¹³ found a 70% incidence rate of posterior, 25% anterior, and 5% rotatory dislocations in their series. Green and Allen¹⁴ reported a 31% anterior, 25% posterior, and 3% rotatory dislocation in their series. Rotatory dislocations occur less frequently, but the posterolateral dislocation seems to be

the most common combination. This particular pattern may be irreducible as a result of the medial femoral condyle becoming "button-holed" through the antero-medial joint capsule. In addition, the MCL invaginates into the joint space, blocking reduction. This "button-holing" results in a "skin furrow" along the medial joint line as the subcutaneous tissue attachments to the joint capsule drag the skin into the joint.¹⁵ Attempts at reduction in this scenario make the skin furrow more pronounced.

The actual incidence of different directional dislocation is not as important as correctly diagnosing the direction of injury, and how it relates to potential neurovascular injury. Hyperextension injuries (or posterior dislocations), because of the tethered popliteal artery and vein, may have the highest incidence of associated vascular injury; however, any dislocation, if initial displacement is severe enough, will result in injury to the popliteal artery. The common peroneal nerve is less at risk because it has a greater excursion than the popliteal vessels, but it is still susceptible when a varus force is applied to the knee. Posterolateral dislocation is associated with a high incidence of injury to the common peroneal nerve.^{16,17}

Open knee dislocations are not uncommon; the reported incidence is between 19% and 35% of all dislocations.^{17,18} An open knee dislocation, in general, carries a worse prognosis because of the severe injury to the soft-tissue envelope. Furthermore, an open injury may require an open ligament reconstruction, or staged reconstruction, as arthroscopically assisted techniques cannot be performed in the acute setting with these open injuries.

Distinguishing between low- and high-energy injuries is important. Low-energy or low-velocity injuries, usually associated with sports injuries, have a decreased incidence of associated vascular injury. High-energy or velocity injuries, associated with motor vehicle accidents or falls from a height, tend to have an increased incidence of vascular compromise. With decreased pulses in an injured limb and the history of a high-energy injury, one should obtain vascular studies urgently.

MECHANISM OF INJURY

The mechanism of injury for the 2 most common knee dislocation patterns, anterior and posterior, are reasonably well described. Kennedy¹⁶ was able to reproduce anterior dislocation by a hyperextension force acting on the knee; at 30° of hyperextension, he found that the posterior capsule failed. When extended

further, to about 50°, the ACL, PCL, and popliteal artery fail. There is some question as to whether the ACL or the PCL fails first with hyperextension,^{16,19} but in our clinical experience,⁷ both the anterior and posterior cruciate ligaments fail with dislocation. Others have reported both ACL and PCL tears with complete knee dislocation.^{13,20,21}

A posterior-directed force applied to the proximal tibia when the knee is flexed to 90° is thought to produce a posterior dislocation, the so-called "dashboard" injury.²⁰ Medial and lateral dislocations result from varus/valgus stresses applied to the knee. A combination of varus/valgus stress with hyperextension/blow to proximal tibia will likely produce one of the rotatory dislocations.

ASSOCIATED INJURIES

Several anatomic structures are at risk in the dislocated knee. The 4 major ligaments of the knee as well as the posterior medial and lateral corners can be compromised. Vascular and nerve injuries are common. There may also be associated bony lesions: avulsion fractures of the ACL or PCL, frank tibial plateau or distal femur condylar fractures, or ipsilateral tibial or femoral shaft fractures.

There is evidence in the literature that a frank dislocation may not result in complete rupture of 3 of the 4 major ligaments^{16,17,22}; however, this seems to be the exception rather than the rule. Several investigators have found that a frank dislocation of the knee invariably results in rupture of at least 3 of the 4 major ligaments. Sisto and Warren²¹ found that all knees in their series had 3 or more ligaments compromised. In study of Frassica et al.,¹³ all 13 patients treated operatively were found to have ACL, PCL, and MCL disruptions. In the study by Fanelli et al.,⁷ 19 of 20 were found to have a third component (posterior lateral corner or MCL) in addition to complete ACL and PCL disruption. With a frank dislocation of the knee, careful ligament examination is necessary to fully diagnose the extent of the injury.

The incidence of vascular compromise in knee dislocations has been estimated to be about 32%.¹⁴ When limited to anterior or posterior dislocation, the incidence may be as high as 50%.²³ Recent studies confirm the significant incidence of arterial injury,^{13,21,24,25} reaffirming the need for careful vascular evaluation. The popliteal artery is an "end-artery" to the leg, with minimal collateral circulation through the genicular arteries. Furthermore, the popliteal vein is responsible for the majority of venous outflow from

the knee. If either structure is compromised to the point of prolonged obstruction, ischemia and eventual amputation is often the result.^{26,27}

Two mechanisms have been described for injury to the popliteal artery: one is a "stretching" mechanism, seen with hyperextension, until the vessel ruptures. This may occur secondary to the "tethered" nature of the artery at the adductor hiatus and the entrance through the gastrocnemius-soleus complex. This type of injury should be suspected with an anterior dislocation. Posterior dislocations may cause direct contusion of the vessel by the posterior plateau, resulting in intimal damage. Under no circumstance should compromised vascular status be attributed to arterial spasm; in this circumstance, there is often intimal damage and impending thrombosis formation. Cone²⁸ points out that initial examination may be normal; however, thrombus formation can occur hours to days later²⁸⁻³¹ and recent studies have found delayed thrombus formation.^{13,21} Furthermore, bicruciate ligament ruptures presenting as a 'reduced' dislocated knee may have as high an incidence of arterial injury as a frank dislocation.¹²

Popliteal vein injury occurs much less frequently, or at least historically had not been reported. Despite this, venous occlusion must also be recognized and appropriately treated. Historically, whether to repair venous injury seemed controversial. Ligating the popliteal vein, a common practice during the Vietnam conflict, led to severe edema, phlebitis, and chronic venous stasis changes. Venous repair was thought to lead to thrombophlebitis and pulmonary embolism. Currently, if obstruction to outflow is recognized, surgical repair of the popliteal vein is warranted.³²

Injury to either the peroneal nerve or the tibial nerve has been documented,^{16,17,21-25,33} with an incidence rate of about 20% to 30%. The nervous structures about the knee are not as tightly anchored as the popliteal vessels; this probably accounts for the lower incidence of injury compared with neighboring vascular structures. The mechanism of injury is usually one of stretch. The peroneal nerve seems to be more frequently involved than the tibial nerve, probably because of its anatomic location. With any varus loading of the knee, the peroneal nerve is placed under tension. Shields et al. reported that posterior dislocation caused the majority of the nerve injuries.¹⁷

Given the fact that knee dislocation is usually caused by violent trauma, associated fractures are common; the incidence rate may be as high as 60%.²² Tibial plateau fractures and ligament avulsion fractures from the proximal tibia or distal femur are com-

mon.^{13,18,21,22,33,34} Recognition of these injuries is also important because additional bony involvement has implications on definitive treatment. Associated distal femur fractures and proximal tibial fractures treated with intramedullary nailing make bone tunnel placement for ACL and PCL reconstruction difficult. With violent trauma, any fracture or avulsion conceivable may occur with a dislocated knee, but there is suggestion that medial and lateral dislocations are associated with some increased frequency of minor bony lesions.³⁵

Fracture-dislocations represent a separate entity in the spectrum of pure knee dislocation to tibial plateau fractures. Pure knee dislocation requires only soft tissue reconstruction to gain stability; tibial plateau fractures require purely bony stabilization. Fracture-dislocations of the knee often involve both bony and ligamentous repair or reconstruction, adding an element of complexity to their treatment.^{10,36} Long-term outcome of fracture-dislocation injuries to the knee joint falls somewhere between tibial plateau fractures and pure dislocations, with tibial plateau fractures doing the best and dislocations the worst.³⁶

INITIAL EVALUATION AND MANAGEMENT

General Considerations

Obvious deformity may be present on initial examination. However, in a polytrauma patient who is intubated and sedated, the injury may escape initial evaluation. Abrasions or contusions about the knee, gross crepitus, or laxity may allude to injury in an otherwise normal appearing knee. This importance of immediate recognition of knee dislocation or fracture dislocation lay not with the treatment of instability, but the recognition of potential vascular injury and possible vascular compromise.¹² Neurovascular status must be assessed on both lower extremities. Neurologic examination may be difficult in the polytrauma patient, and is not as important initially as is serial neurologic examination. Vascular examination is more pressing because ischemia lasting more than 8 hours usually results in amputation.¹⁴ In the reduced knee, a white, cool limb that is obvious on physical examination and denotes arterial damage, requires an immediate arteriogram. However, normal pulses, Doppler signals, and capillary refill do not rule out an arterial injury.²⁸ Thrombosis may occur hours to days later, necessitating serial examination. If there is any

question of perfusion of the limb, an arteriogram is warranted.

Imaging Studies

Before any manipulation, anteroposterior and lateral radiographs of the affected extremity are completed. This is important to confirm the direction of dislocation and any associated fractures, and aids in planning the reduction maneuver. In the presence of cyanosis, pallor, weak capillary refill, and decreased peripheral temperature following reduction, arteriography must be considered. Venography may be required if the clinical picture indicates adequate limb perfusion but obstruction of outflow. After the acute treatment of the dislocated knee, magnetic resonance imaging may be performed subacutely to confirm and aid in planning the reconstruction of compromised ligamentous structures.

Reduction

An unreduced dislocated knee constitutes an orthopaedic emergency, and reduction should be undertaken as soon as possible, preferably in the emergency department. Before manipulation, adequate anteroposterior and lateral radiographic evaluation is performed. This allows for determination of the direction of the dislocation, any associated fractures, and assists in planning the reduction maneuver. In the isolated knee dislocation, intravenous morphine or conscious sedation is usually required. Slow, gradual longitudinal traction is applied to the leg from the ankle, and the proximal tibia is manipulated in the appropriate direction to effect a reduction. Once reduced, radiographic evaluation to confirm tibiofemoral congruency is performed, as well as repeated neurovascular examination. The limb is then placed in either a long leg splint or extension knee immobilizer. It is imperative to perform radiographic evaluation after placement in the splint or brace, as posterior subluxation of the tibia on femur is common. A "bump" consisting of a towel or pad behind the gastrocnemius-soleus complex may aid in maintaining reduction.

The "dimple sign" indicates a posterolateral dislocation, and closed reduction may not be successful. The medial femoral condyle penetrates the medial joint capsule, causing interposition of soft tissue in the joint, warranting open reduction.^{10,15}

Physical Examination

Physical examination features of the ACL/PCL/PLC injured knee include abnormal anterior and pos-

terior translation at both 25° and 90° of knee flexion, which is usually greater than 15 mm. At 90° of knee flexion, the tibial step-off is absent, and the posterior drawer test is 2+ or greater, indicating greater than 10 mm of pathologic posterior tibial displacement. The Lachman test and pivot-shift phenomenon are positive, indicating ACL disruption, and there may be hyperextension of the knee. We have identified and described 3 types of posterolateral instability: A, B, and C.

Posterolateral instability in the multiple-ligament injured knee includes at least 10° of increased tibial external rotation compared with the normal knee at 30° and 90° of knee flexion (positive dial test, and external rotation thigh-foot angle test), and variable degrees of varus instability depending on the injured anatomic structures. Posterolateral instability (PLI) type A has increased external rotation only, corresponding to injury to the popliteofibular ligament, and popliteus tendon only. PLI type B presents with increased external rotation, and mild varus of approximately 5 mm increased lateral joint line opening to varus stress at 30° knee flexion. This occurs with damage to the popliteofibular ligament, popliteus tendon, and attenuation of the fibular collateral ligament. PLI type C presents with increased tibial external rotation, and varus instability of 10 mm greater than the normal knee tested at 30° of knee flexion with varus stress. This occurs with injury to the popliteofibular ligament, popliteus tendon, fibular collateral ligament, and lateral capsular avulsion, in addition to cruciate ligament disruption.

The MCL is tested with valgus stress at 0° and 30° of knee flexion to assess the superficial MCL, the posterior oblique ligament, and the posterior medial capsule. Extensor mechanism stability is assessed by medial and lateral patellar glide to assess the integrity of the lateral and medial patellar retinaculum.

Vascular Injuries

A full spectrum of vascular injuries may be encountered. The overall clinical picture may vary from an uncomplicated, bicruciate ligament injury with possible intimal damage with a normal physical examination to a polytrauma patient, with a closed head injury, intra-abdominal bleeding, and dislocated knee with vascular compromise. Life-threatening injuries are addressed first. The orthopaedic surgeon needs to be aware of the total limb ischemia time. If there is any suspicion of arterial damage, a vascular consult is obtained immediately. Reduction is performed to see

if this restores blood flow to the limb. When the total ischemia time approaches 6 hours,¹⁴ there is an urgency to restore flow to the lower extremity. An intraoperative angiogram during vascular exploration and shunting may be required at the expense of a high-quality preoperative angiogram.¹⁰ Mechanism of injury should also be noted. A high-energy injury (e.g., motor vehicle accident or a fall from a height) may be more suspicious for vascular injury, and one may elect to obtain arteriograms despite a normal vascular examination.¹²

When an isolated dislocated knee with suspected arterial injury occurs (asymmetric pulses, Doppler, or ankle-brachial index), arteriography is performed as the simple presence of pulses does not rule out vascular damage.²⁸ Any suspicion warrants a vascular surgery consultation. When the limb is well perfused, and all indices are normal, one may elect to forego a formal arteriogram if there are frequent neurovascular checks to the lower extremity. Despite the historical preference to obtain an arteriogram in the presence of a knee dislocation as a screening tool, it has been shown that arteriography following significant blunt trauma to the lower extremity with a normal vascular examination has a low yield rate for detecting surgical vascular lesions.^{12,37,38} Popliteal vein injury is also possible. When the clinical picture warrants, a venogram may be useful.

Absolute Surgical Indications

A state of irreducibility and vascular injury warrants immediate surgical intervention. Four-compartment fasciotomy of the limb is considered when ischemia time is greater than 2.5 hours. The inability to maintain reduction also mandates external skeletal fixation or early ligamentous reconstruction to stabilize the knee to avoid potential recurrent vascular compromise. Open dislocations and open fracture-dislocations require immediate surgical debridement to decontaminate the wound. An external fixator may be a reasonable option in the case of an open dislocation with a large soft-tissue defect, or an open fracture dislocation. In this circumstance, access to soft tissue would be maintained for surgical debridement.

DEFINITIVE SURGICAL MANAGEMENT

Historical Management

Knee dislocations were initially managed conservatively with a cylinder cast for several months.^{39,40}

Early reports by Kennedy¹⁶ and Meyers and Harvey¹⁸ reported reasonable outcomes for nonoperatively treated knee dislocations. However, there was the suggestion that a surgically stabilized dislocated knee would fare better in the long term. A recent report by Almekinders and Logan²⁴ compared surgically stabilized knees with conservative treatment and concluded that conservative treatment was comparable to surgical treatment. Despite similar outcomes, the conservatively treated knees were grossly unstable compared with surgically stabilized knees. Their study was retrospective from 1963 to 1988 and the typical surgical treatment during this period was in most cases open direct repair of the ligaments. Sisto and Warren²¹ found similar results comparing 4 conservatively treated knees with 16 direct suture repairs of torn ligaments. Frassica et al.¹³ also evaluated early (within 5 days of injury) direct repair (with or without augmentation) of torn ligamentous structures in 13 of 17 patients. They concluded that better results were obtained with early versus later direct repair of torn ligaments. This study supports surgical treatment of the dislocated knee, and introduces the concept of benefit from a ligamentously stable knee.

Within the last decade, the technique of arthroscopically assisted ACL/PCL reconstruction has become popular. Several advancements have made these techniques possible: (1) better procurement, sterilization, and storage of allograft tissue, (2) improved arthroscopic surgical instrumentation, (3) better graft fixation methods, (4) improved surgical technique, and (5) improved understanding of the ligamentous anatomy and biomechanics of the knee. Few reports of combined ACL/PCL reconstruction are available in the literature, but surgical reconstruction appears to afford at least the same results, if not better, than direct repair of the ligaments. Shapiro and Freedman²⁵ reconstructed 7 ACL/PCL injuries with primarily allograft Achilles tendon or bone-patellar tendon-bone. They found that 3 patients had excellent results, 3 good results, and 1 fair result. Furthermore, the average KT-1000 was +3.3 mm side-to-side difference, with very little varus/valgus instability or significant posterior drawer. All 7 of their patients were able to return to school or the workplace.

Fanelli et al.⁶ reported on 20 ACL/PCL arthroscopically assisted ligament reconstructions. In their study group, there was 1 ACL/PCL tear, 10 ACL/PCL/posterior lateral corner tears, 7 ACL/PCL/MCL tears, and 2 ACL/PCL/MCL/posterior lateral corner tears. Achilles tendon allografts and bone-patellar tendon-bone autografts were used in PCL reconstructions, and

autograft and allograft bone–patellar tendon–bone was used in ACL reconstruction. An additional component, not previously mentioned with any consistency in the literature, was the addressing of the associated MCL or posterior lateral corner injury. It is imperative to address these injuries as well, or the results of ACL/PCL reconstruction alone will be less than optimal.

Postoperatively, significant improvement was found according to the Lysholm, Tegner, and Hospital for Special Surgery (HSS) knee ligament rating scales, as well as the KT-1000 arthrometer. Overall postoperatively, 75% of patients had a normal Lachman test result, 85% no longer displayed a pivot-shift, 45% restored a normal posterior drawer test, and 55% displayed grade I posterior laxity. All 20 knees were deemed functionally stable and all patients returned to desired levels of activity. The authors concluded that results of reconstruction are reproducible and that appropriate reconstruction will produce a stable knee.

Noyes and Barber-Westin⁴¹ evaluated surgically reconstructed ACL/PCL tears (all had additional MCL or LCL/PCL reconstruction) at an average of 4.8 years. Seven of these knees were acute knee dislocations and 4 were chronically unstable knees secondary to knee dislocations. At follow-up, 5 of the 7 acutely injured knees had returned to preinjury level of activity. Three of the 4 chronic knee injuries were asymptomatic with activities of daily living. Arthrometric measurements at 20° showed less than 3 mm of side-to-side difference with anterior to posterior translation in 10 of the 11 knees; at 70°, there were 9 knees that had less than 3 mm side-to-side difference in anteroposterior translation. These authors concluded that simultaneous bicruciate ligament reconstruction is warranted to restore function to the knee.

Fanelli Sports Injury Clinic Experience

Our practice is located in a tertiary-care regional trauma center. There is a 38% incidence of PCL tears in acute knee injuries, with 45% of these PCL injured knees being combined ACL/PCL tears.^{42,43} Careful assessment, evaluation, and treatment of vascular injuries is essential in these acute multiple-ligament injured knees. There is an 11% incidence of vascular injury associated with these acute multiple-ligament injured knees at our center.

Our preferred approach to combined ACL/PCL injuries is an arthroscopic ACL/PCL reconstruction using the transtibial technique, with collateral/capsular ligament surgery as indicated. Not all cases are ame-

nable to the arthroscopic approach and the operating surgeon must assess each case individually.

Surgical Timing

Surgical timing is dependent on vascular status, reduction stability, skin condition, systemic injuries, open versus closed knee injury, meniscus and articular surface injuries, other orthopaedic injuries, and the collateral/capsular ligaments involved. Certain ACL/PCL/MCL injuries can be treated with bracing of the MCL followed by arthroscopic combined ACL/PCL reconstruction in 4 to 6 weeks after healing of the MCL. Other cases may require repair or reconstruction of the medial structures and must be assessed on an individual basis.

Combined ACL/PCL/posterolateral injuries are addressed as early as safely possible. ACL/PCL/posterolateral repair-reconstruction performed between 2 and 3 weeks after injury allows sealing of capsular tissues to permit an arthroscopic approach, and still permits primary repair of injured posterolateral structures.

Open multiple-ligament knee injuries/dislocations may require staged procedures. The collateral/capsular structures are repaired after thorough irrigation and debridement, and the combined ACL/PCL reconstruction is performed at a later date after wound healing has occurred. Care must be taken in all cases of delayed reconstruction to confirm that the tibiofemoral joint is reduced by serial anteroposterior and lateral radiographs.

The surgical timing guidelines outlined above should be considered in the context of the individual patient. Many patients with multiple-ligament injuries of the knee are severely injured multiple-trauma patients with multisystem injuries. Modifiers to the ideal timing protocols outlined earlier include the vascular status of the involved extremity, reduction stability, skin condition, open or closed injury, and other orthopaedic and systemic injuries. These additional considerations may cause the knee ligament surgery to be performed earlier or later than desired. We have previously reported excellent results with delayed reconstruction in the multiple-ligament injured knee^{6,7} (Table 1).

Graft Selection

The ideal graft material is strong, provides secure fixation, is easy to pass, readily available, and has low donor-site morbidity. The available options in the United States are autograft and allograft sources. Our preferred graft for the PCL is the Achilles tendon

TABLE 1. *Surgical Timing Algorithm for Acute ACL/PCL Injuries*

ACL/PCL lateral-side injuries
Surgery within 2-3 weeks after injury
Arthroscopic ACL/PCL reconstruction plus lateral side reconstruction (type A and B PLRI)
Lateral-posterolateral augmented primary repair
Stage type C lateral-side injuries
Lateral-posterolateral augmented primary repair (within first 10 days)
Arthroscopic ACL/PCL reconstruction (4-6 weeks later)
ACL/PCL medial-side injuries
Surgical timing depends on degree of medial-side damage
Low-grade MCL injury: brace treatment 4-6 weeks followed by arthroscopic ACL-PCL reconstruction
High-grade MCL injury
MCL augmented primary repair (within first 10 days)
Arthroscopic ACL/PCL reconstruction (4-6 weeks later)

allograft because of its large cross-sectional area and strength, absence of donor-site morbidity, and easy passage with secure fixation. We prefer Achilles tendon allograft or bone-patellar tendon-bone allograft for ACL reconstruction. The preferred graft material for the posterolateral corner is a split biceps tendon transfer, or free autograft (semitendinosus) or allograft tissue when the biceps tendon is not available.⁴⁴ Cases requiring MCL and posteromedial corner surgery may have primary repair, reconstruction, or a combination of both. Our preferred method for MCL and posteromedial reconstructions is a posteromedial capsular shift with autograft or allograft supplementation as needed.

Surgical Approach

Our surgical approach is a single-stage arthroscopic combined ACL/PCL reconstruction using the trans-tibial technique with collateral/capsular ligament surgery as indicated. The posterolateral corner is repaired and then augmented with a split biceps tendon transfer, biceps tendon transfer, semitendinosus free graft, or allograft tissue. Acute medial injuries not amenable to brace treatment undergo primary repair, and posteromedial capsular shift, and/or allograft reconstruction as indicated. The operating surgeon must be prepared to convert to a dry arthroscopic procedure or an open procedure if fluid extravasation becomes a problem.

Surgical Technique

The principles of reconstruction in the multiple-ligament injured knee are to identify and treat all pathology, accurately place tunnels, create anatomic graft insertion sites, utilize strong graft material, provide secure graft fixation, and provide the appropriate postoperative rehabilitation program. The patient is positioned supine on the operating room table. The surgical leg hangs over the side of the operating table and the well leg is supported by the fully extended operating table. A lateral post is used for control of the surgical leg. A leg holder is not used. The surgery is done under tourniquet control unless previous arterial or venous repair contraindicates the use of a tourniquet. Fluid inflow is by gravity; we do not use an arthroscopic fluid pump.

Allograft tissue is prepared before bringing the patient into the operating room. Arthroscopic instruments are placed with the inflow in the superior lateral portal, the arthroscope in the inferior lateral patellar portal, and instruments in the inferior medial 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 (Fig 1).

The notchplasty is performed first and consists of ACL and PCL stump debridement, bone removal, and contouring of the medial wall of the lateral femoral condyle and the intercondylar roof. This allows visualization of the over-the-top position and prevents ACL graft impingement throughout the full range of motion. Specially curved PCL instruments are used to



FIGURE 1. A 1- to 2-cm extra capsular posterior medial safety incision allows the surgeon's finger to protect the neurovascular structures and confirm the position of instruments on the posterior aspect of the proximal tibia. (Reprinted with permission.⁸)



FIGURE 2. Specially curved PCL reconstruction instruments used to elevate the capsule from the posterior aspect of the tibial ridge during PCL reconstruction. Posterior capsular elevation is critical in transtibial PCL reconstruction because it facilitates accurate PCL tibial tunnel placement, and subsequent graft passage. (Courtesy of Arthrotek, Inc, Warsaw, IN.)

elevate the capsule from the posterior aspect of the tibia (Fig 2; Arthrotek, Warsaw, IN).

The PCL tibial and femoral tunnels are created with the help of the PCL/ACL drill guide (Fig 3, Arthrotek). The transtibial PCL tunnel courses from the anteromedial aspect of the proximal tibia 1 cm below the tibial tubercle to exit in the inferior lateral aspect of the PCL anatomic insertion site. The PCL femoral tunnel originates externally between the medial femoral epicondyle and the medial femoral condylar articular surface to emerge through the center of the stump of the anterolateral bundle of the posterior cruciate ligament. The PCL graft is positioned and anchored on the femoral or tibial side, and left free on the opposite side.

The ACL tunnels are created using 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 tibia to emerge through the center of the stump of the ACL 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 ACL anatomic insertion site. The tunnel is created to leave a 1- to 2-mm posterior cortical wall so interference fixation can be used. The ACL graft is positioned and anchored on the femoral side, with the tibial side left free (Fig 4). Attention is then turned to the posterior lateral corner.

One surgical technique for posterolateral reconstruction is the split biceps tendon transfer to the lateral femoral epicondyle. The requirements for this

procedure include an intact proximal tibiofibular joint—the posterolateral capsular attachments to the common biceps tendon should be intact, and the biceps femoris tendon insertion into the fibular head must be intact. This technique creates a new popliteofibular ligament and LCL, tightens the posterolateral capsule, and provides a post of strong autogenous tissue to reinforce the posterolateral corner.

A lateral hockey-stick incision is made. The peroneal nerve is dissected free and protected throughout the procedure. The long head and common biceps femoris tendon is isolated, and the anterior two thirds is separated from the short head muscle. The tendon is detached proximal and left attached distally to its anatomic insertion site on the fibular head. The strip of biceps tendon should be 12 to 14 cm long. The iliotibial band is incised in line with its fibers and the fibular collateral ligament and popliteus tendons are exposed. A drill hole is made 1 cm anterior to the fibular collateral ligament femoral insertion. A longi-



FIGURE 3. The Fanelli PCL/ACL drill guide system is used to precisely create both the PCL femoral and tibial tunnels, and the ACL single-incision technique and double-incision technique tunnels. The drill guide is positioned for the PCL tibial tunnel so that a guidewire enters the anteromedial aspect of the proximal tibia approximately 1 cm below the tibial tubercle, at a point midway between the posteromedial border of the tibia, and the tibial crest anteriorly. The guidewire exits in the inferior lateral aspect of the PCL tibial anatomic insertion site. The guide is positioned for the PCL femoral tunnel so the guidewire enters the medial aspect of the medial femoral condyle midway between the medial femoral condyle articular margin and the medial epicondyle, 2 cm proximal to the medial femoral condyle distal articular surface (joint line). The guidewire exits through the center of the stump of the anterolateral bundle of the PCL. The drill guide is positioned for the single-incision endoscopic ACL technique so that the guidewire enters the anteromedial surface of the proximal tibia approximately 1 cm proximal to the tibial tubercle at a point midway between the posteromedial border of the tibia and the tibial crest anteriorly. The guidewire exits through the center of the stump of the tibial ACL insertion. (Courtesy of Arthrotek, Inc, Warsaw, IN.)

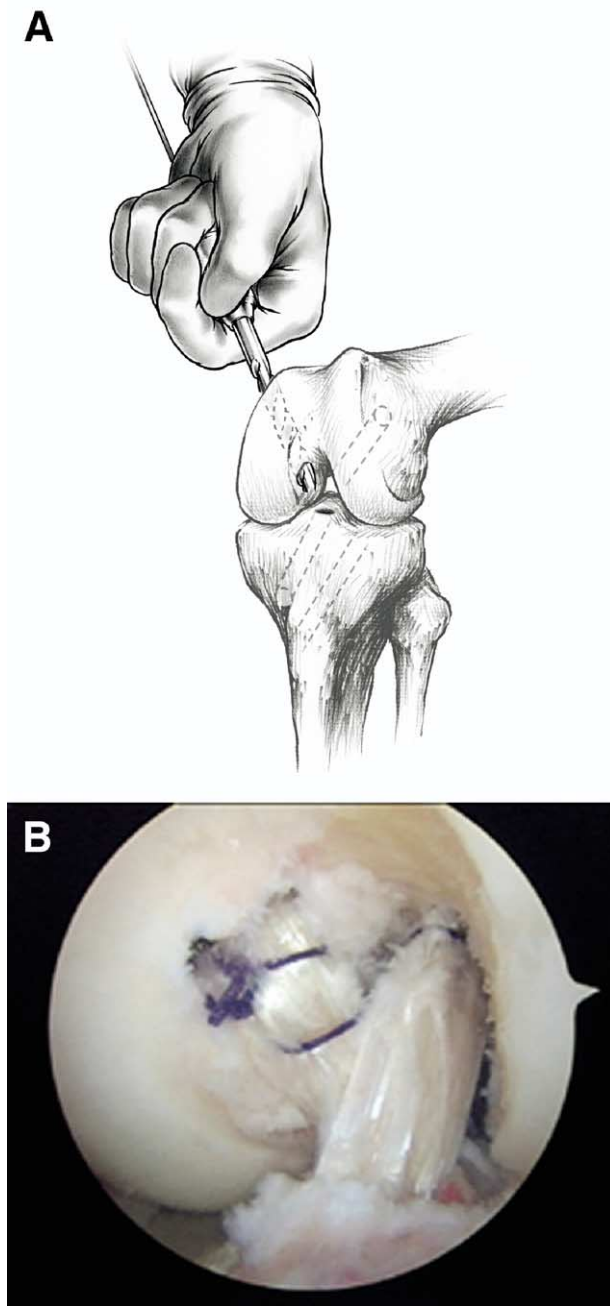


FIGURE 4. (A) Anatomic drawing of the ACL and PCL tibial and femoral tunnel positions in combined ACL/PCL reconstruction surgery. It is important to be aware of the 2 tibial tunnel directions, and to have a 1-cm bone bridge between the PCL and ACL tibial tunnels. This will reduce the possibility of fracture. (Courtesy of Arthrotek, Inc, Warsaw, IN.) (B) Combined arthroscopic ACL/PCL reconstruction using Achilles tendon allograft. The tunnels are precisely created to reproduce the anatomic insertion sites of the anterolateral bundle of the PCL and the anatomic insertion sites of the ACL. Correct and accurate tunnel placement is essential for successful combined ACL/PCL reconstructions. The Achilles tendon allograft is preferred because of its large cross-sectional area, strength, and absence of donor-site morbidity.

tudinal incision is made in the lateral capsule just posterior to the fibular collateral ligament. The split biceps tendon is passed medial to the iliotibial band and secured to the lateral femoral epicondylar region with a screw and spiked ligament washer at the aforementioned point. The residual tail of the transferred split biceps tendon is passed medial to the iliotibial band and secured to the fibular head. The posterolateral capsule that had been previously incised is then shifted and sewn into the strut of transferred biceps tendon to eliminate posterolateral capsular redundancy. In cases where the proximal tibiofibular joint has been disrupted, a 2-tailed allograft reconstruction is used to control the tibia and fibula independently.

Posterolateral reconstruction with the free graft figure-of-8 technique uses semitendinosus autograft or allograft, Achilles tendon allograft, or other soft-tissue allograft material. A curvilinear incision is made in the lateral aspect of the knee, extending from the lateral femoral epicondyle to the interval between Gerdy's tubercle and the fibular head. The fibular head is exposed and a tunnel is created in an anterior to posterior direction at the area of maximal fibular diameter. The tunnel is created by passing a guide pin followed by a cannulated drill, usually 7 mm in diameter. The peroneal nerve is protected during tunnel creation and throughout the procedure. The free tendon graft is then passed through the fibular head drill hole. An incision is then made in the iliotibial band in line with the fibers directly overlying the lateral femoral epicondyle. The graft material is passed medial to the iliotibial band and the limbs of the graft are crossed to form a figure-of-8. A drill hole is made 1 cm anterior to the fibular collateral ligament femoral insertion. A longitudinal incision is made in the lateral capsule just posterior to the fibular collateral ligament. The graft material is passed medial to the iliotibial band, and secured to the lateral femoral epicondylar region with a screw and spiked ligament washer at the above-mentioned point. The posterolateral capsule that had been previously incised is then shifted and sewn into the strut of figure-of-8 graft tissue material to eliminate posterolateral capsular redundancy. The anterior and posterior limbs of the figure-of-8 graft material are sewn to each other to reinforce and tighten the construct. The iliotibial band incision is then closed. The procedures described are intended to eliminate posterolateral and varus rotational instability (Fig 5).

Posteromedial and medial reconstructions are performed through a medial hockey-stick incision. Care is taken to maintain adequate skin bridges between

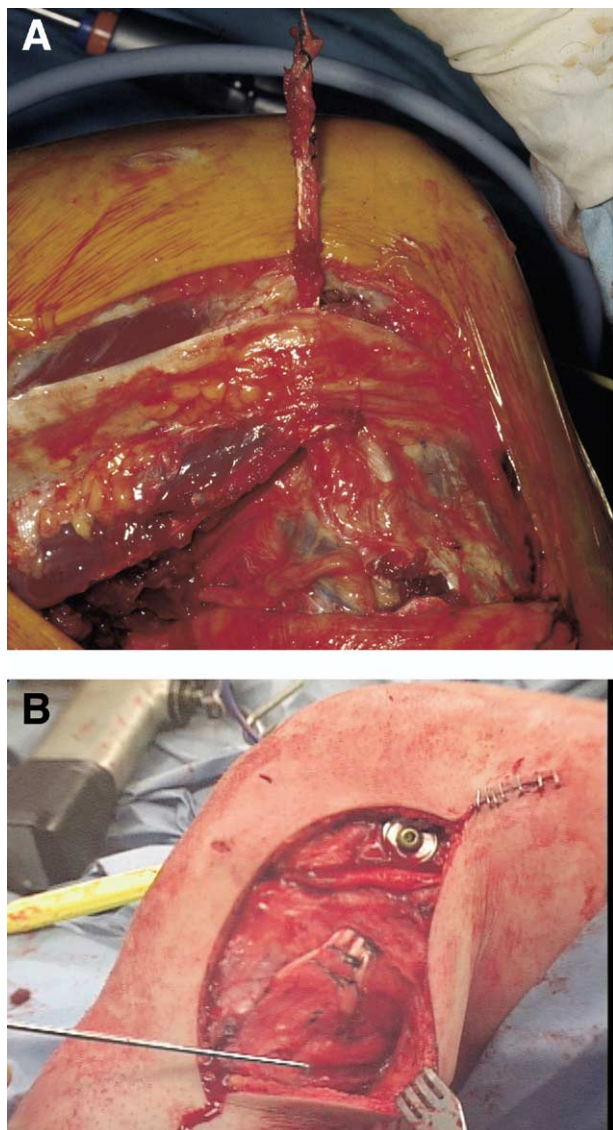


FIGURE 5. Surgical technique for posterolateral and lateral reconstruction are the (A) split biceps tendon transfer or (B) the allograft or autograft figure-of-8 reconstruction combined with posterolateral capsular shift, and primary repair of injured structures as indicated. These complex surgical procedures reproduce the function of the popliteofibular ligament and the LCL, and eliminate posterolateral capsular redundancy. The split biceps tendon transfer uses anatomic insertion sites and preserves the dynamic function of the long head and common biceps femoris tendon.

incisions. The superficial MCL is exposed and a longitudinal incision is made just posterior to the posterior border of the MCL. Care is taken not to damage the medial meniscus during the capsular incision. The interval between the posteromedial capsule and medial meniscus is developed. The posteromedial capsule is shifted anterosuperiorly. The medial meniscus

is repaired to the new capsular position and the shifted capsule is sewn into the MCL. When superficial MCL reconstruction is indicated, it is performed using allograft tissue or semitendinosus autograft. This graft material is attached at the anatomic insertion sites of the superficial MCL on the femur and tibia. The posteromedial capsular advancement is performed and sewn into the newly reconstructed MCL (Fig 6).

Graft Tensioning and Fixation

The PCL is reconstructed first followed by the ACL, followed by the posterolateral complex and medial ligament complex. Tension is placed on the PCL graft distally using the Arthrotek knee ligament tensioning device with the tension set for 20 lb (Fig 7). This restores the anatomic tibial step-off. The knee is cycled through a full range of motion 25 times to allow pretensioning and settling of the graft. The knee is placed in 70° of flexion, and fixation is achieved on the tibial side of the PCL graft with a screw and spiked ligament washer and bioabsorbable interference screw. The knee is then placed in 30° of flexion, the tibia internally rotated, slight valgus force applied to the knee, and final tensioning and fixation of the posterolateral corner is achieved. The Arthrotek knee ligament tensioning device is applied to the ACL

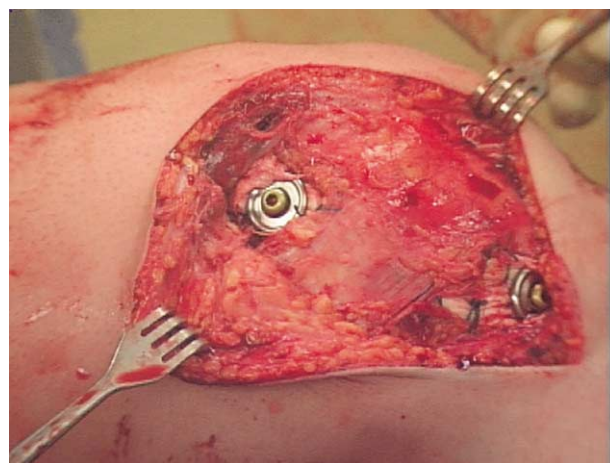


FIGURE 6. Severe medial-side injuries are successfully treated with primary repair using suture anchor technique combined with MCL reconstruction using allograft tissue combined with posteromedial capsular shift procedure. The Achilles tendon allograft's broad anatomy can anatomically reconstruct the superficial MCL. The Achilles tendon allograft is secured to the anatomic insertion sites of the superficial MCL using screws and spiked ligament washers. The posteromedial capsule can then be secured to the allograft tissue to eliminate posteromedial capsular laxity. This technique will address all components of the medial-side instability.



FIGURE 7. The mechanical graft knee ligament tensiing device is used to precisely tension PCL and ACL grafts. During PCL reconstruction, the tensiing device is attached to the tibial end of the graft and the torque wrench ratchet is set to 20 lb. This restores the anatomic tibial step-off. The knee is cycled through 25 full flexion-extension cycles, and with the knee at 0° of flexion, final PCL tibial fixation is achieved with a Lactosorb resorbable interference screw (Arthrotek), and screw and spiked ligament washer for back-up fixation. The tensiing device is applied to the ACL graft, set to 20 lb, and the graft is tensioned with the knee in 70° of flexion. Final ACL fixation is achieved with Lactosorb bioabsorbable interference screws, and spiked ligament washer back-up fixation. The mechanical tensiing device assures consistent graft tensioning and eliminates graft advancement during interference screw insertion. It also restores the anatomic tibial step-off during PCL graft tensioning, and applies a posterior drawer force during ACL graft tensioning. (Courtesy of Arthrotek, Inc, Warsaw, IN.)

graft, and set to 20 lb. The knee is placed in 70° of flexion, and final fixation is achieved of the ACL graft with a bioabsorbable interference screw and spiked ligament washer back-up fixation. Tensioning the ACL graft at 70° of knee flexion enabled us to maintain the neutral position of the knee by monitoring the tibial step-off at the time of final graft fixation. The MCL reconstruction is tensioned with the knee in 30° of flexion with the leg in a figure-of-4 position. Full range of motion is confirmed on the operating table to assure the knee is not “captured” by the reconstruction.

Technical Hints

The posteromedial safety incision protects the neurovascular structures, confirms accurate tibial tunnel placement, and allows more expeditious completion of the surgical procedure (Fig 1). The single-incision ACL reconstruction technique prevents lateral cortex crowding and eliminates multiple through-and-through drill holes in the distal femur, which reduces the stress riser effect. It is important to be aware of the

2 tibial tunnel directions, and to have a 1-cm bone bridge between the PCL and ACL tibial tunnels. This will reduce the possibility of fracture. We have found it useful to use primary and back-up fixation. Primary fixation is with resorbable interference screws, and back-up fixation is achieved with a screw and spiked ligament washer. Secure fixation is critical to the success of this surgical procedure (Fig 8).¹⁰

The order of tensioning is the PCL first, the posterior lateral corner second, the ACL third, and the MCL last. Restoration of the normal tibial step-off at 70° of flexion has provided the most reproducible method of establishing the neutral point of the tibia-femoral relationship in our experience.

Postoperative Rehabilitation

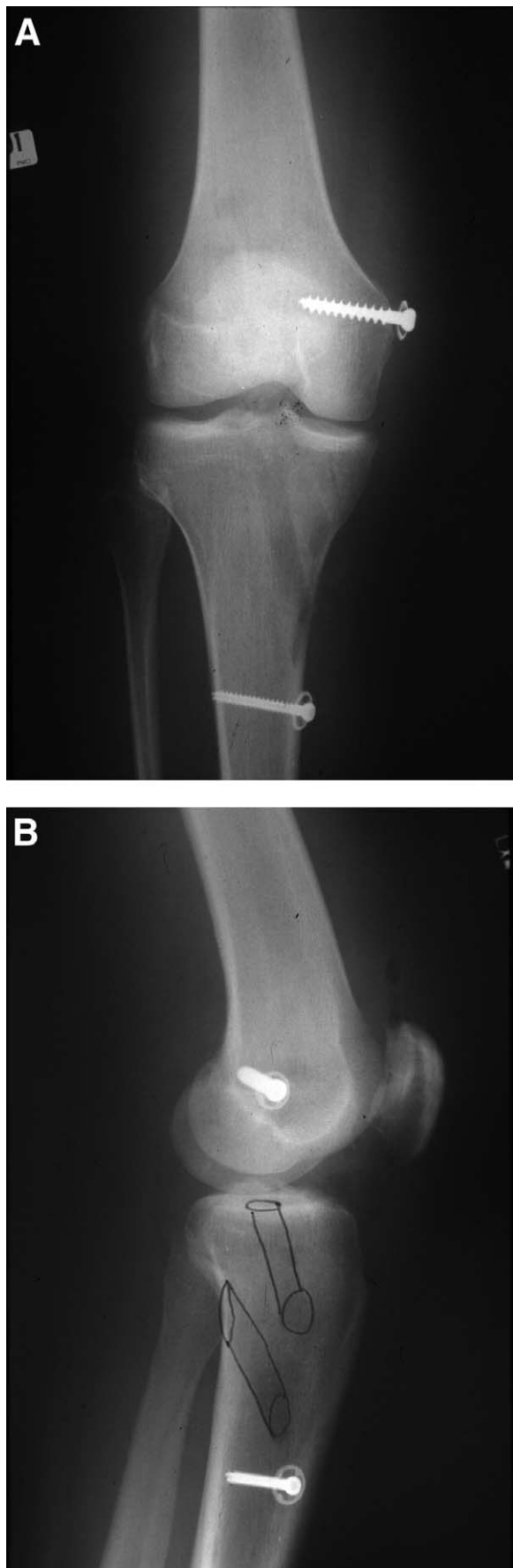
The knee is maintained in full extension for 3 weeks non-weight bearing. Progressive range of motion occurs during weeks 4 through 6. Progressive weight bearing occurs at the end of 6 weeks. Progressive closed-chain kinetic strength training and continued motion exercises are performed. The brace is discontinued after the tenth week. Return to sports and heavy labor occurs after 9 months when sufficient strength and range of motion has returned.

Complications

Potential complications in treatment of the multiple-ligament injured knee include failure to recognize and treat vascular injuries (both arterial and venous), iatrogenic neurovascular injury at the time of reconstruction, iatrogenic tibial plateau fractures at the time of reconstruction, failure to recognize and treat all components of the instability, postoperative medial femoral condyle osteonecrosis, knee motion loss, and postoperative anterior knee pain.

PUBLISHED RESULTS

Recent published reports on the results of the treatment of the multiple-injured knee provide insight into this complex problem. Wang et al.⁴⁵ reviewed the results of 25 combined arthroscopic single-bundle PCL and posterolateral complex reconstructions. The average time from injury to surgery was 10 months with an average follow-up of 40 months. Restoration of ligamentous stability was obtained in only 44% of patients, with 20% having 5 to 10 mm of residual laxity; 44% of the knees had degenerative changes at the time of surgery. Their study recommended early surgical repair of the multiple-injured knee.



Ohkoshi et al.⁴⁶ studied a 2-stage reconstruction technique with autograft tissue for knee dislocations. Their study group consisted of 9 knees undergoing a 2-stage reconstruction with autograft tissue. Stage 1 consisted of PCL reconstruction using semitendinosus and gracilis hamstring autografts from the contralateral knee 2 weeks after injury. Stage 2 consisted of ACL reconstruction with or without MCL and/or posterolateral reconstruction 3 months after injury. The ACL reconstruction was performed using ipsilateral hamstring or bone–patellar tendon–bone autograft reinforced by an artificial ligament. MCL reconstruction was performed with autogenous semitendinosus plus artificial ligament reinforcement. Posterolateral reconstruction was performed with biceps tendon transfer. All knees in their study had negative Lachman test results, 66% had a negative posterior drawer test, and 44% had a grade 1 posterior drawer. All knees were stable to varus and valgus stress. KT-1000 arthrometer side-to-side difference values were reported to be $2.3 \text{ mm} \pm 1.9 \text{ mm}$, and passive range of motion of the surgical knee being 0° to 139° .

Mariani et al.⁴⁷ have recently reported their results of 1-stage arthroscopically assisted ACL and PCL reconstruction. Their study group consisted of 15 knees. The ACL reconstructions were performed using hamstring autografts and the PCL reconstruction using bone–patellar tendon–bone autografts. KT-2000 arthrometer side-to-side difference measurements were $5.8 \pm 1.1 \text{ mm}$. Preoperative and postoperative HSS knee ligament rating scale scores were 32 and 89 points, respectively. Preoperative and postoperative Lysholm knee ligament rating scale scores were 65 and 95 points, respectively.

Richter et al.⁴⁸ compared surgical and nonsurgical treatment in patients with traumatic knee dislocations. Their study group consisted of 89 patients; 63 patients underwent surgical repair and/or reconstruction within 2 weeks of injury and 26 patients had nonsurgical treatment. The average follow-up was 8.2 years. Lysholm knee ligament rating scale scores were 78.3 for the surgical group, and 64.8 for the nonsurgical group—a statistically significant difference. Tegner knee ligament rating scale scores were 4.0 for the surgical group and 2.7 for the nonsurgical group—a

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FIGURE 8. Anteroposterior and lateral radiographs after combined ACL/PCL reconstruction. Note the position of tibial tunnel on the lateral radiograph. The tibial tunnel guidewire exits at the apex of the tibial ridge posteriorly, which places the graft at the anatomic tibial insertion site after the tibial tunnel is drilled.

statistically significant difference. These authors recommended early surgical treatment of traumatic knee dislocations.

Harner et al.⁴⁹ have reported excellent objective and functional results after surgical reconstruction of the multiple-ligament injured knee. Nearly all of their patients were able to return to normal activities of daily living; however, the ability of their patients to return to high-demand sports and strenuous manual labor was less predictable.

Fanelli Sports Injury Clinic Results

We have previously published the results of our arthroscopically assisted combined ACL/PCL and PCL/posterolateral complex reconstructions using the reconstructive technique described in this article.⁶⁻⁸ Our results of combined ACL/PCL reconstructions were presented in 2002.⁵⁰ This study presented the 2- to 10-year (24 to 120 month) results of 35 arthroscopically assisted combined ACL/PCL reconstructions evaluated preoperatively and postoperatively using the Lysholm, Tegner, and HSS knee ligament rating scales, KT-1000 arthrometer testing, stress radiography, and physical examination.

The study population included 26 male and 9 female patients with 19 acute and 16 chronic knee injuries. Ligament injuries included 19 ACL/PCL/posterolateral instabilities, 9 ACL/PCL/MCL instabilities, 6 ACL/PCL/posterolateral/MCL instabilities, and 1 ACL/PCL instability. All knees had grade III preoperative ACL/PCL laxity, and were assessed preoperatively and postoperatively with arthrometer testing, 3 different knee ligament rating scales, stress radiography, and physical examination. Arthroscopically assisted combined ACL/PCL reconstructions were performed using the single-incision endoscopic ACL technique, and the single femoral tunnel–single bundle transtibial tunnel PCL technique. PCLs were reconstructed with allograft Achilles tendon (26), autograft BTB (7), and autograft semitendinosus/gracilis (2). ACLs were reconstructed with autograft BTB (16), allograft BTB (12), Achilles tendon allograft (6), and autograft semitendinosus/gracilis (1). MCL injuries were treated with bracing or open reconstruction. Posterolateral instability was treated with biceps femoris tendon transfer, with or without primary repair, and posterolateral capsular shift procedures as indicated.

Postoperative physical examination results revealed normal posterior drawer/tibial step-off in 16 of 35 knees (46%) and normal Lachman and pivot-shift tests in 33 of 35 knees (94%). Posterolateral stability was

restored to normal in 6 of 25 knees (24%), and tighter than the normal knee in 19 of 25 knees (76%) evaluated with the external rotation thigh-foot angle test: 30° varus stress testing was normal in 22 of 25 knees (88%), and showed grade 1 laxity in 3 of 25 knees (12%); 30° valgus stress testing was normal in 7 of 7 surgically treated MCL tears (100%), and normal in 7 of 8 of brace-treated knees (87.5%). Postoperative KT-1000 arthrometer testing mean side-to-side difference measurements were 2.7 mm (PCL screen), 2.6 mm (corrected posterior), and 1.0 mm (corrected anterior) measurements, a statistically significant improvement from preoperative status ($P = .001$). Postoperative stress radiographic side-to-side difference measurements measured at 90° of knee flexion and 32 lb of posteriorly directed proximal force were 0 to 3 mm in 11 of 21 knees (52.3%), 4 to 5 mm in 5 of 21 knees (23.8%), and 6 to 10 mm in 4 of 21 knees (19%). Postoperative Lysholm, Tegner, and HSS knee ligament rating scale mean values were 91.2, 5.3, and 86.8, respectively, which shows a statistically significant improvement from preoperative status ($P = .001$).

The conclusions drawn from the study were that combined ACL/PCL instabilities could be successfully treated with arthroscopic reconstruction and the appropriate collateral ligament surgery. Statistically significant improvement was noted from the preoperative condition at 2- to 10-year follow-up using objective parameters of knee ligament rating scales, arthrometer testing, stress radiography, and physical examination. Postoperatively, these knees are not normal, but they are functionally stable. Continuing technical improvements will most likely improve future results.

Another group of multiple-ligament reconstructions that warrant attention are our 2- to 10-year results of combined PCL-posterolateral reconstruction.⁵¹ This study presented the 2- to 10-year (24 to 120 month) results of 41 chronic arthroscopically assisted combined PCL/posterolateral reconstructions evaluated preoperatively and postoperatively using Lysholm, Tegner, and HSS knee ligament rating scales, KT-1000 arthrometer testing, stress radiography, and physical examination.

This study population included 31 male and 10 female patients with 24 left and 17 right chronic PCL/posterolateral knee injuries and functional instability. The knees were assessed preoperatively and postoperatively with arthrometer testing, 3 different knee ligament rating scales, stress radiography, and physical examination. PCL reconstructions were per-

formed using the arthroscopically assisted single femoral tunnel–single bundle transtibial tunnel PCL reconstruction technique using fresh-frozen Achilles tendon allografts in all 41 cases. In all 41 cases, posterolateral instability reconstruction was performed with combined biceps femoris tendon tenodesis and posterolateral capsular shift procedures. The paired *t* test and power analysis were the statistical tests used; 95% confidence intervals were used throughout the analysis.

Postoperative physical examination revealed normal posterior drawer/tibial step-off in 29 of 41 knees (70%). Posterolateral stability was restored to normal in 11 of 41 knees (27%), and tighter than the normal knee in 29 of 41 knees (71%) evaluated with the external rotation thigh-foot angle test: 30° varus stress testing was normal in 40 of 41 knees (97%), and grade 1 laxity was shown in 1 of 41 knees (3%). Postoperative KT-1000 arthrometer testing mean side-to-side difference measurements were 1.80 mm (PCL screen), 2.11 mm (corrected posterior), and 0.63 mm (corrected anterior) measurements. This is a statistically significant improvement from preoperative status for the PCL screen and the corrected posterior measurements ($P = .001$). The postoperative stress radiographic mean side-to-side difference measurement measured at 90° of knee flexion and 32 lb of posterior directed force applied to the proximal tibia using the Telos device was 2.26 mm. This is a statistically significant improvement from preoperative measurements ($P = .001$). Postoperative Lysholm, Tegner, and HSS knee ligament rating scale mean values were 91.7, 4.92, and 88.7, respectively, showing a statistically significant improvement from preoperative status ($P = .001$).

Conclusions drawn from this study were that chronic combined PCL/posterolateral instabilities could be successfully treated with arthroscopic PCL reconstruction using fresh-frozen Achilles tendon allograft combined with posterolateral corner reconstruction using biceps tendon transfer combined with posterolateral capsular shift procedure. Statistically significant improvement is noted ($P = .001$) from the preoperative condition at 2- to 10-year follow-up using objective parameters of knee ligament rating scales, arthrometer testing, stress radiography, and physical examination.

CONCLUSIONS AND SUMMARY

Multiple-ligament injuries of the knee are complex injuries requiring a systematic approach to evaluation

and treatment. Gentle reduction and documentation and treatment of vascular injuries are primary concerns in the acute dislocated/multiple-ligament injured knee. Arthroscopically assisted combined ACL/PCL reconstruction with appropriate collateral ligament surgery is a reproducible procedure. Knee stability is improved postoperatively when evaluated with knee ligament rating scales, arthrometer testing, and stress radiographic analysis. Acute MCL tears when combined with ACL/PCL tears may in certain cases be treated with bracing. Posterolateral corner injuries combined with ACL/PCL tears are best treated with primary repair as indicated, combined with reconstruction using a post of strong autograft (split biceps tendon, biceps tendon, semitendinosus) or allograft tissue. Surgical timing depends on the ligaments injured, the vascular status of the extremity, reduction stability, and the overall health of the patient. We prefer the use of allograft tissue for reconstruction in these cases because of the strength of these large grafts, and the absence of donor-site morbidity.

REFERENCES

1. Butler DL, Noyes FR, Grood ES. Ligamentous restraints to anterior-posterior drawer in the human knee. A biomechanical study. *J Bone Joint Surg Am* 1980;62:259-270.
2. Wilson SA, Vigorita VJ, Scott WN. Anatomy. In: Scott WN, ed. *The knee*. St. Louis: Mosby, 1994.
3. Van Dommelen BA, Fowler PJ. Anatomy of the posterior cruciate ligament. A review. *Am J Sports Med* 1989;17:24-29.
4. Gollehon DL, Torzilli PA, Warren RF. The role of the posterior lateral corner and cruciate ligaments in the stability of the human knee. A biomechanical study. *J Bone Joint Surg Am* 1987;69:233-242.
5. Seebacher JR, Inglis AE, Marshall JL, et al. The structure of the posterolateral aspect of the knee. *J Bone Joint Surg Am* 1982;64:536-541.
6. Fanelli GC, Gianotti BF, Edson CJ. Arthroscopically assisted combined anterior and posterior cruciate ligament reconstruction. *Arthroscopy* 1996;12:5-14.
7. Fanelli GC, Gianotti BF, Edson CJ. Arthroscopically assisted combined posterior cruciate ligament/posterior lateral complex reconstruction. *Arthroscopy* 1996;12:521-530.
8. Fanelli GC, Gianotti BF, Edson CJ. The posterior cruciate ligament: Arthroscopic evaluation and treatment. *Arthroscopy* 1994;10:673-688.
9. Ghalambor N, Vangsness CT. Traumatic dislocation of the knee: A review of the literature. *Bull Hosp Joint Dis* 1995;54:19-24.
10. Good L, Johnson RJ. The dislocated knee. *J Am Acad Orthop Surg* 1995;3:284-292.
11. Shelbourne KD, Porter DA, Clingman JA, et al: Low-velocity knee dislocation. *Orthop Rev* 1991;20:995-1004.
12. Wascher DC, Dvirnak PC, Decoster TA. Knee dislocation: Initial assessment and implications for treatment. *J Orthop Trauma* 1997;11:525-529.
13. Frassica FJ, Sim FH, Staeheli JW, et al. Dislocation of the knee. *Clin Orthop* 1991;263:200-205.
14. Green A and Allen BL. Vascular injuries associated with

- dislocation of the knee. *J Bone Joint Surg Am* 1977;59:236-239.
15. Wand JS. A physical sign denoting irreducibility of a dislocated knee. *J Bone Joint Surg Br* 1989;71:862.
 16. Kennedy JC. Complete dislocation of the knee joint. *J Bone Joint Surg Am* 1963;45:889-904.
 17. Shields L, Mital M, Cave EF. Complete dislocation of the knee: Experience at the Massachusetts General Hospital. *J Trauma* 1969;9:192-215.
 18. Meyers MH, Harvey JP Jr. Traumatic dislocation of the knee joint: a study of eighteen cases. *J Bone Joint Surg Am* 1971;53:16-29.
 19. Girgis FG, Marshall JL, Monajem A. The cruciate ligaments of the knee joint. *Clin Orthop* 1975;106:216-231.
 20. Roman PD, Hopson CN, Zenni EJ Jr. Traumatic dislocation of the knee: A report of 30 cases and literature review. *Orthop Rev* 1987;16:917-924.
 21. Sisto DJ, Warren RF. Complete knee dislocation: A follow-up study of operative treatment. *Clin Orthop* 1985;198:94-101.
 22. Meyers MH, Moore TM, Harvey JP Jr. Traumatic dislocation of the knee joint. *J Bone Joint Surg Am* 1975;57:430-433.
 23. Welling RE, Kakkasseril J, Cranley JJ. Complete dislocations of the knee with popliteal vascular injury. *J Trauma* 1981;21:450-453.
 24. Almekinders LC, Logan TC. Results following treatment of traumatic dislocation of the knee joint. *Clin Orthop* 1991;284:203-207.
 25. Shapiro MS, Freedman EL. Allograft reconstruction of the anterior and posterior cruciate ligaments after traumatic knee dislocation. *Am J Sports Med* 1995;23:580-587.
 26. Ashworth EM, Dalsing MC, Glover JL, et al. Lower extremity vascular trauma: A comprehensive, aggressive approach. *J Trauma* 1988;28:329.
 27. Rich NM, Hobson RW, Wright CB. Repair of lower extremity venous trauma: A more aggressive approach required. *J Trauma* 1974;14:639.
 28. Cone JC. Vascular injury associated with fracture-dislocations of the lower extremity. *Clin Orthop* 1989;243:30-35.
 29. Grimley RP, Ashton F, Slaney G, et al. Popliteal arterial injuries associated with civil knee trauma. *Injury* 1981;13:1-6.
 30. O'Donnell TF Jr, Brewster DC, Darling RC, et al. Arterial injuries associated with fractures and/or dislocations of the knee. *J Trauma* 1977;17:775-784.
 31. Savage R. Popliteal artery injury associated with knee dislocation: Improved outlook? *Am J Surg* 1980;46:627-632.
 32. Rich NM, Hobson RW, Collins GJ, et al. The effect of acute popliteal venous interruption. *Ann Surg* 1976;183:365-368.
 33. Wright DG, Covey DC, Born CT, et al. Open dislocation of the knee. *J Orthop Trauma* 1995;9:135-140.
 34. Malizos KN, Xenakis T, Mavrodontidis AN, et al. Knee dislocations and their management. *Acta Orthop Scand* 1997;68:80-83 (suppl 275).
 35. McCoy GF, Hannon DG, Barr RJ, et al. Vascular injury associated with low-velocity dislocations of the knee. *J Bone Joint Surg Br* 1987;69:285-287.
 36. Moore TM. Fracture-dislocation of the knee. *Clin Orthop* 1981;156:450-453.
 37. Applebaum R, Yellin AE, Weaver FA, et al. Role of routine arteriography in blunt lower-extremity trauma. *Am J Surg* 1990;160:221-225.
 38. Trieman GS, Yellin AE, Weaver FA, et al. Evaluation of the patient with a knee dislocation: The case for selective arteriography. *Arch Surg* 1992;127:1056-1063.
 39. Myles JW. Seven cases of traumatic dislocation of the knee. *Proc R Soc Med* 1967;60:279.
 40. Taylor AR, Arden GP, Rainey MA. Traumatic dislocations of the knee: A report of forty three cases with special reference to conservative treatment. *J Bone Joint Surg Br* 1972;54:94.
 41. Noyes FR, Barber-Westin SD. Reconstruction of the anterior and posterior cruciate ligaments after knee dislocation. *Am J Sports Med* 1997;25:769.
 42. Fanelli GC. PCL injuries in trauma patients. *Arthroscopy* 1993;9:291-294.
 43. Fanelli GC, Edson CJ. PCL injuries in trauma patients. Part II. *Arthroscopy* 1995;11:526-529.
 44. Fanelli GC, Feldmann DD. The use of allograft tissue in knee ligament reconstruction. In: Parisien JS, ed. *Current techniques in arthroscopy*. Ed 3. New York: Thieme, 1998.
 45. Wang CJ, Chen HS, Huang TW, Yuan LJ. Outcome of surgical reconstruction for PCL and PLC instabilities of the knee. *Injury* 2002;33:815-821.
 46. Ohkoshi Y, Nagasaki S, Shibata N, Yamamoto K, Hashimoto T, Yamane S. Two-stage reconstruction with autografts for knee dislocations. *Clin Orthop* 2002;398:169-175.
 47. Mariani PP, Margheritini F, Camillieri G. One-stage arthroscopically assisted anterior and posterior cruciate ligament reconstruction. *Arthroscopy* 2001;17:700-707.
 48. Richter M, Bosch U, Wiperman B, Hofmann A, Krettek C. Comparison of surgical repair or reconstruction of the cruciate ligaments versus nonsurgical treatment in patients with traumatic knee dislocations. *Am J Sports Med* 2002;30:718-727.
 49. Harner C, Waltrip R, Bennett C, Francis K, Cole B, Irrgang J. Surgical management of knee dislocations. *J Bone Joint Surg Am* 2004;86:262-273.
 50. Fanelli GC, Edson CJ. Arthroscopically assisted combined ACL/PCL reconstruction: 2-10 year follow-up. *Arthroscopy* 2002;18:703-714.
 51. Fanelli GC, Edson CJ. Combined posterior cruciate ligament-posterolateral reconstruction with Achilles tendon allograft and biceps femoris tendon tenodesis: 2-10 year follow-up. *Arthroscopy* 2004;20:339-345.