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Summary
The multiple ligament injured knee is a complex problem in orthopaedic surgery. These injuries may or may not present as acute knee dislocations, and careful assessment of the extremity vascular and neurologic status is essential because of the possibility of arterial and/or venous compromise, and nerve injury. 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 formulate a treatment plan. Knee stability is improved postoperatively when evaluated with knee ligament rating scales, arthrometer testing, and stress radiographic analysis. Surgical timing depends upon the injured ligaments, vascular status of the extremity, reduction stability, and the overall health of the patient. The use of allograft tissue is preferred because of the strength of these large grafts, and the absence of donor site morbidity.

Introduction
The multiple ligament injured knee is a complex problem in orthopaedic surgery. These injuries may or may not present as acute knee dislocations, and 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 formulate a treatment plan. The combined anterior and posterior cruciate ligament (ACL/PCL) injured (dislocated) knee is a severe injury that can result from high or low energy trauma. Both cruciates are torn plus one or both collateral ligament complexes. The frequency of popliteal artery injuries occurs with the same frequency in bicruciate knee ligament injuries, and frank tibio-femoral dislocations. Nerve injuries, associated fractures, other structural injuries, functional instability, and post traumatic arthrosis may all occur with this injury complex (1,2).

Classification
Combined ACL/PCL injuries may or may not present as acute knee dislocations. Classification of knee dislocations is primarily based on the direction the tibia dislocates relative to the femur (3,4). This results in five different categories: anterior, posterior, lateral, medial, or rotatory. The anterior-medial and lateral, posterior-medial and lateral dislocations are classified as rotatory dislocations. Other factors to be considered include whether 1) the injury is opened or closed, 2) the injury is due to high energy or low energy trauma, 3) the knee is completely dislocated or subluxed, and 4) there is neurovascular involvement. Furthermore, one should be acutely aware of the fact that a complete knee dislocation may spontaneously reduce, and any triple ligament knee injury constitutes a frank dislocation (5,6,7).

Open knee dislocations are not uncommon. Reported incidence is between 19% and 35% of all dislocations (8,9). An open knee dislocation carries a worse prognosis secondary to severe injury to the soft tissue envelop. 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/high velocity injuries secondary to motor vehicle accidents or falls from heights, tend to have increased incidence of vascular compromise. Decreased pulses in an injured limb, and the history of a high energy injury indicate the need to obtain vascular studies urgently.

Mechanism of Injury
The mechanism of injury for the two most common knee dislocation patterns, anterior and posterior, are reasonably well described. Kennedy (10) was able to reproduce anterior dislocation by a hyperextension force acting on the knee. At 30 degrees of hyperextension, Kennedy found that the posterior capsule failed. When
extended further, to about 50 degrees, the ACL, PCL and popliteal artery fail. There is some question whether the ACL or the PCL fails first with hyperextension (10, 11), however, in our (12) clinical experience, both the anterior and posterior cruciate ligaments fail with dislocation. Others (13, 14, 15) series demonstrated both ACL and PCL tears with complete knee dislocation.

A posterior directed force applied to the proximal tibia when the knee is flexed to 90 degrees is thought to produce a posterior dislocation, the so-called “dashboard” injury (14). 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.

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. Cone (16) points out that initial examination may be normal; however, thrombus formation can occur hours to days later (16, 17, 18, 19) and recent series have demonstrated delayed thrombus formation (13, 15). Furthermore, bicruciate ligament ruptures presenting as a ‘reduced’ dislocated knee may have as high an incidence of arterial injury as a frank dislocation (7).

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 (20).

**Initial Evaluation and Surgical Indications**

Initial evaluation of the acute bicruciate ligament injured knee includes evaluation of the deformity, location of abrasions or contusions, the neurovascular status of the extremity, and the presence of absence of a dimple sign. The presence of normal pulses, normal Doppler, and normal capillary refill in the presence of a reduced bicruciate (dislocated) knee does not guarantee the absence of vascular injury. Serial physical examinations, ankle brachial indices, and arteriogram all must be utilized as necessary to document intact arterial circulation to the injured lower extremity (7,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35).

Physical examination of the ACL-PCL injured knee will demonstrate abnormal anterior posterior tibiofemoral laxity at 30 and 90 degrees of knee flexion. The pivot shifting phenomenon will be present. The tibial step off will be negative, the posterior drawer will be positive, and there will be abnormal varus and/or valgus laxity at full extension and 30 degrees of knee flexion.

Imaging studies used in the evaluation of the acute and chronic PCL based multiple ligament injured knee include plain radiographs, magnetic resonance imaging, arteriograms, and venograms. Emergent surgical indications include irreducible dislocation, vascular injury, compartment syndrome, inability to maintain reduction, and open dislocations. The surgical indication in the chronic multiple ligament injured knee is functional instability. Assessment of ligament stability, meniscus and articular surface integrity, and gait are essential. In addition to ligament reconstruction, osteotomy, meniscus transplantation, and osteochondral allograft transplantation may be necessary.

**Imaging Studies**

Plain radiographs should include standing anterior-posterior of both knees if possible, lateral, 30° anterior-posterior axial of both patella, and an intercondylar notch views. These radiographic views will help document reduction of the tibiofemoral and patellofemoral joints, assess bony alignment, evaluate for insertion site bony avulsions of the cruciates, collateral ligament complexes, and the extensor mechanisms.

Magnetic resonance imaging has a high diagnostic accuracy in acute posterior cruciate ligament injuries, and is helpful in assessing tear location of the cruciate and collateral ligaments, and formulating a treatment plan (36, 37). Bone scans may be helpful in evaluating subacute and chronic cases. Increased activity in the patellofemoral joint and medial compartment may signify the onset of early degenerative arthrosis providing an indication for surgical stabilization (38, 39).
The presence of cyanosis, pallor, weak capillary refill and decreased peripheral temperature following reduction, arteriography must be considered. Venography is considered when the clinical picture indicates adequate limb perfusion but obstruction of outflow.

**Diagnostic Arthroscopy**

The three zone method of posterior cruciate ligament evaluation enhances the information gained from imaging studies, and examination to the injured knee under anesthesia (40). Zone 1 of the PCL is the femoral insertion to the middle on third of the ligament. Zone 2 is the middle one third of the PCL. And zone 3 is the tibial insertion site area. Utilization of a 30° arthroscope, the anterolateral patellar portal, and the posteromedial portal, systematic evaluation of the posterior cruciate ligament and the posterolateral structures can be performed. Direct and indirect findings are assessed, and surgical treatment decisions can be made. We have found arthroscopic evaluation of the posterior cruciate ligament most helpful in assessing the interstitial damage of the PCL and ACL in bony insertion site avulsions. Severe interstitial disruption of the ligaments zone two region has indicated reconstruction as the procedure of choice rather than primary repair.

**Treatment**

The current consensus indicates that surgical treatment yields better results than non-surgical treatment of the multiple ligament injured knee (41, 42, 43, 44, 45, 46). Technical advancements in the procurement, processing, and use of allograft tissue, arthroscopic surgical instruments, graft fixation methods, improved surgical techniques, and an improved understanding of the ligament structures and the biomechanics of the knee, have led to more predictable and successful results in the treatment of these complex knee injuries. Various studies have published excellent results with return to pre-injury level of function documenting with physical examination, arthrometer measurements, knee ligament rating scales, and stress radiography (2, 47, 48, 49, 50, 51, 52, 53, 54).

**Surgical Timing**

Surgical timing in the acute bicruciate multiple ligament injured knee is dependent upon the vascular status of the involved extremity, the collateral ligament injury severity, the degree of instability, and the post reduction stability. Delayed or staged reconstruction of two to three weeks post injury has demonstrated a lower incidence of arthrofibrosis in our experience (51, 52).

Surgical timing in acute ACL-PCL-lateral side injuries is dependent upon the lateral side classification (38). Arthroscopic combined ACL-PCL reconstruction with lateral side repair and reconstruction with allograft tissue is performed within two to three weeks post injury in knees with types A and B lateral posterolateral instability. Type C lateral posterolateral instability combined with ACL-PCL tears is often treated with staged reconstruction. The lateral posterolateral repair and reconstruction with allograft tissue is performed within the first week after injury, followed by arthroscopic combined ACL-PCL reconstruction three to six weeks later.

Surgical timing in acute ACL-PCL-medial side injuries is also dependent on the medial side classification. Some medial side injuries will heal with four to six weeks of brace treatment, provided that the tibiofemoral joint is reduced in all planes. Other medial side injuries require surgical intervention. Types A and B medial side injuries are repaired-reconstructed as a single stage procedure with combined arthroscopic ACL-PCL reconstruction. Type C medial side injuries combined with ACL-PCL tears are often treated with staged reconstruction. The medial posteromedial repair-reconstruction augmented with allograft tissue is performed within the first two weeks after injury, followed by arthroscopic combined ACL-PCL reconstruction three to six weeks later (1, 2, 51, 52, 55, 56, 57, 58).

Surgical timing may be affected by modifiers beyond the surgeon’s control, and may cause the surgical treatment to be performed either earlier or later than desired. The surgical timing modifiers include the injured extremity vascular status, open wounds, reduction stability, skin conditions, multiple system injuries, other orthopaedic injuries, and meniscus and articular surface injuries (1, 2).

Chronic bicruciate multiple ligament knee injuries often present to the orthopaedic surgeon with functional instability, and possibly, some degree of post traumatic arthrosis. Considerations for treatment require the determination of all structural injuries. These may include ligaments injured; meniscus injuries, bony malalignment, articular surface injuries, and gait abnormalities. Surgical procedures under consideration may include proximal tibial or distal femoral osteotomy, ligament reconstruction, meniscus transplant, and osteochondral grafting.

**Graft Selection**

Our preferred graft for the posterior cruciate ligament is the Achilles tendon allograft for single bundle PCL reconstructions, and an Achilles tendon and tibialis anterior allografts for double bundle PCL reconstructions. We
prefer Achilles tendon allograft or other allograft for the ACL reconstruction. The preferred graft material for the posterolateral corner is allograft tissue combined with a primary repair, and or posterolateral capsular shift procedure. Our preferred method for medial side injuries is a primary repair of all injured structures combined with posteromedial capsular advancement and allograft tissue supplementation as needed (57).

**Combined PCL ACL Reconstruction Surgical Technique**

The principles of reconstruction in the multiple ligament injured knee are to identify and treat all pathology, accurate tunnel placement, anatomic graft insertion sites, utilize strong graft material, mechanical graft tensioning, secure graft fixation, and a deliberate postoperative rehabilitation program (57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71).

The patient is placed on the operating room table in the supine position, and after satisfactory induction of anesthesia, the operative and nonoperative lower extremities are carefully examined (57,66). Pre and postoperative antibiotics are given to the patient. A tourniquet is applied to the upper thigh of the operative extremity, and that extremity is prepped and draped in a sterile fashion. When allograft tissue is used, it is prepared prior to bringing the patient into the operating room. Autograft tissue is harvested prior to beginning the arthroscopic portion of the procedure.

The arthroscopic instruments are inserted with the inflow through the superolateral patellar portal. Instrumentation and visualization are positioned through inferomedial and inferolateral patellar portals, and can be interchanged as necessary. Additional portals are established as necessary. Exploration of the joint consists of evaluation of the patellofemoral joint, the medial and lateral compartments, medial and lateral menisci, and the intercondylar notch. The residual stumps of both the anterior and posterior cruciate ligaments are debrided. The notchplasty for the ACL portion of the procedure is performed at this time.

An extra capsular extraarticular posteromedial safety incision is made by creating an incision approximately 1.5 to 2cm long starting at the posteromedial border of the tibia approximately one inch below the level of the joint line and extending distally. Dissection is carried down to the crural fascia, which is incised longitudinally. An interval is developed between the medial head of the gastrocnemius muscle and the nerves and vessels posterior to the surgeon’s finger, and the capsule of the knee joint anterior to the surgeon’s finger. The posteromedial safety incision enables the surgeon to protect the neurovascular structures, confirm the accuracy of the PCL tibial tunnel, and to facilitate the flow of the surgical procedure.

The curved over-the-top PCL instruments (Biomet Sports Medicine, Warsaw, Indiana) are used to sequentially lyse adhesions in the posterior aspect of the knee, and elevate the capsule from the posterior tibial ridge. This will allow accurate placement of the PCL/ACL drill guide, and correct placement of the tibial tunnel.

The arm of the PCL/ACL guide (Biomet Sports Medicine, Warsaw, Indiana) is inserted through the inferior medial patellar portal. The tip of the guide is positioned at the inferior lateral aspect of the PCL anatomic insertion site. This is below the tibial ridge posterior and in the lateral aspect of the PCL anatomic insertion site. The bullet portion of the guide contacts the anteromedial surface of the proximal tibia at a point midway between the posteromedial border of the tibia, and the tibial crest anterior approximately 1cm 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. The tip of the guide, in the posterior aspect of the tibia is confirmed with the surgeon’s finger through the extra capsular extraarticular posteromedial safety incision. Intraoperative AP and lateral X-ray may also be used. When the PCL/ACL guide is positioned in the desired area, a blunt spade-tipped guide wire is drilled from anterior to posterior. The surgeon’s finger confirms the position of the guide wire through the posterior medial safety incision.

The standard cannulated reamer is used to create the tibial tunnel. The surgeon’s finger through the extra capsular extra-articular posteromedial incision is monitoring the position of the guide wire. When the drill is engaged in bone, the guide wire is reversed, blunt end pointing posterior, for additional patient safety. The drill is advanced until it comes to the posterior cortex of the tibia. The chuck is disengaged from the drill, and completion of the tibial tunnel is performed by hand.

The PCL single bundle or double bundle femoral tunnels can be made from inside out using the double bundle aimers (Biomet Sports Medicine, Warsaw, Indiana). The double bundle aimer is inserted through a low anterior lateral patellar arthroscopic portal and creates the PCL anterior lateral bundle femoral tunnel. The double bundle aimer is positioned directly on the footprint of the femoral anterior lateral bundle PCL insertion site. The appropriately sized guide wire is drilled through the aimer, through the bone, and out a small skin incision. Care is taken to insure there is no compromise of the articular surface. The double bundle aimer is removed, and an
acorn reamer is used to endoscopically drill from inside out the anterior lateral PCL femoral tunnel. When the surgeon chooses to perform a double bundle double femoral tunnel PCL reconstruction, the same process is repeated for the posterior medial bundle of the PCL. Care must be taken to ensure that there will be an adequate bone bridge (approximately 5 mm) between the two femoral tunnels prior to drilling. This is accomplished using the calibrated probe, and direct arthroscopic visualization.

A Magellan suture retriever (Biomet Sports Medicine, Warsaw, Indiana) is introduced through the tibial tunnel into the joint, and retrieved through the femoral tunnel. The traction sutures of the graft material are attached to the loop of the Magellan suture retriever, and the graft is pulled into position. The graft material is secured on the femoral side using the Biomet BioCore screw for primary aperture opening fixation, and a Biomet polyethylene ligament fixation button for back up fixation.

Tension is placed on the PCL graft distally using the graft-tensioning boot (Biomet Sports Medicine, Warsaw, Indiana). Tension is gradually applied with the knee in zero degrees of flexion (full extension) reducing the tibia on the femur. This restores the anatomic tibial step off. The knee is cycled through a full range of motion multiple times to allow pre-tensioning and settling of the graft. The process is repeated until there is no further change in the torque setting on the graft tensioner. The knee is placed in 70-90 degrees of flexion, and fixations is achieved on the tibial side of the PCL graft with a Biomet BioCore interference screw, and back up fixation with a bicortical screw and spiked ligament washer.

With the knee in approximately 90 degrees of flexion, the ACL tunnels are created using the PCL/ACL drill guide (Biomet Sports Medicine, Warsaw, Indiana) using the single incision endoscopic surgical technique. The arm of the drill guide enters the knee joint through the inferior medial patellar portal. The bullet of the drill guide contacts the anterior medial proximal tibia externally at a point 1 cm proximal to the tibial tubercle midway between the posterior medial border of the tibia, and the tibial crest anterior. The guide wire is drilled through the guide to emerge through the center of the stump of the ACL tibial footprint. A standard cannulated reamer is used to create the tibial tunnel.

With the knee in approximately 90 degrees of flexion, an over the top femoral aimer is introduced through the tibial tunnel, and used to position a guide wire on the medial wall of the lateral femoral condyle to create a femoral tunnel approximating the anatomic insertion site of the anterior cruciate ligament. The ACL graft is positioned, and fixation achieved on the femoral side using a Biomet BioCore interference screw, and back up fixation with a polyethylene ligament fixation button.

The ACL graft is tensioned on the tibial side using the Biomet graft-tensioning boot. Traction is placed on the ACL graft sutures with the knee in zero degrees of flexion, and tension is gradually applied reducing the tibia on the femur. The knee is then cycled through multiple full flexion and extension cycles to allow settling of the graft. The process is repeated until there is no further change in the torque setting on the graft tensioner, and the Lachman and pivot shift tests are negative. The knee is placed in 30 degrees of flexion, and fixation is achieved on the tibial side of the ACL graft with a Biomet BioCore interference screw, and back up fixation with a Biomet polyethylene ligament fixation button.

**Lateral Posterolateral Reconstruction**

Our most commonly utilized surgical technique for posterolateral reconstruction is the free graft figure of eight technique utilizing semitendinosus autograft or allograft, Achilles tendon allograft, or other soft tissue allograft material. This procedure requires an intact proximal tibiofibular joint, and the absence of a hyperextension external rotation recurvatum deformity. This technique combined with capsular repair and/or posterolateral capsular shift procedures, mimics the function of the popliteofibular ligament and lateral collateral ligament, tightens the posterolateral capsule, and provides a post of strong tissue to reinforce the posterolateral corner. When there is a disrupted proximal tibiofibular joint, or hyperextension external rotation recurvatum deformity, a two-tailed (fibular head, proximal tibia) posterior lateral reconstruction is required.

Posterolateral reconstruction with the free graft figure of eight technique utilizes semitendinosus or tibialis anterior allograft. A curvilinear incision is made in the lateral aspect of the knee extending from the interval between Gerdy’s tubercle and the fibular head to the lateral epicondyle and then proximal following the course of the iliotibial band. The peroneal nerve neurolysis is performed, and the Peroneal nerve is protected throughout the procedure. The fibular head is exposed and a tunnel is created in an anterior to posterior direction at the area of maximal fibular head diameter. The tunnel is created by passing a guide pin followed by a cannulated drill 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

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with the fibers directly overlying the lateral femoral epicondyle. The graft material is passed medial to the iliotibial band for the fibular collateral ligament limb and medial to the common biceps tendon and iliotibial band for the popliteus tendon popliteofibular ligament limb. The limbs of the graft are crossed to form a figure of eight. 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 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 eight graft tissue material to eliminate posterolateral capsular redundancy. The anterior and posterior limbs of the figure of eight graft material are sewn to each other to reinforce and tighten the construct. The final graft tensioning position is approximately 30 to 40 degrees of knee flexion with a slight valgus force applied and slight internal tibial rotation. The iliotibial band incision is closed. The procedures described are designed to eliminate posterolateral and varus rotational instability.

When there is a disrupted proximal tibiofibular joint, or hyperextension external rotation recurvatum deformity, a two-tailed (fibular head, proximal tibia) posterior lateral reconstruction is utilized. A seven millimeter drill hole is made over a guide wire approximately two centimeters below the lateral tibial plateau. A tibialis anterior allograft is passed through this tibial drill hole and follows the course of the popliteus tendon to its anatomic insertion site on the lateral femoral epicondylar region. The tibialis anterior graft is secured with a suture anchor, and multiple number two braided non absorbable sutures at the popliteus anatomic femoral insertion site. The knee is cycled and the graft tensioned, and secured in the tibial tunnel with a BioCore interference screw and polyethylene ligament fixation button (Biomet Sports Medicine, Warsaw, Indiana). The fibular head based reconstruction is then carried out as described above.

**Medial Posteromedial Reconstruction**

Posteromedial and medial reconstructions are performed through a medial hockey stick incision. Care is taken to maintain adequate skin bridges between incisions. The Sartorius fascia is incised and retracted exposing the superficial medial collateral ligament and the posterior medial capsule. A longitudinal incision is made just posterior to the posterior border of the superficial 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 medial collateral ligament. Number two permanent braided sutures are used. When superficial medial collateral ligament reconstruction is indicated, this is performed using allograft tissue. This graft material is attached at the anatomic insertion sites of the superficial medial collateral ligament on the femur and tibia using a screw and spiked ligament washer, or suture anchors. The posteromedial capsular advancement is performed, and sewn into the newly reconstructed MCL. The final graft tensioning position is approximately 30 to 40 degrees of knee flexion.

**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 knee ligament-tensioning device (Biomet Sports Medicine, Warsaw, Indiana). This reduces the tibia on the femur in full extension, and restores the anatomic tibial step off. The knee is cycled through a full range of motion multiple times to allow pretensioning and settling of the graft. The knee is placed in 70-90 degrees of flexion, and fixation is achieved on the tibial side of the PCL graft with Biomet BioCore bioabsorbable interference screw, and screw and spiked ligament washer. The Biomet knee ligament-tensioning device is applied to the ACL graft, and tension gradually applied at full extension reducing the tibia on the femur. The knee is cycled through a full range of motion multiple times to allow pre-tensioning and settling of the graft. The knee is placed in 30 degrees of flexion, and final fixation is achieved of the ACL graft with a Biomet Bio Core bioabsorbable interference screw, and Biomet polyethylene ligament fixation button. The knee is placed in 30° of flexion, the tibia slightly internally rotated, slight valgus force applied to the knee, and final tensioning and fixation of the posterolateral corner is achieved. The MCL reconstruction is tensioned with the knee in 30° of flexion with the leg in a figure four position. Full range of motion is confirmed on the operating table to assure the knee is not “captured” by the reconstruction.
Additional Technical Ideas

The posteromedial safety incision protects the neurovascular structures, confirms accurate tibial tunnel placement, and allows the surgical procedure to be done at an accelerated pace. It is important to be aware of the two 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 Biomet BioCore interference screws, and back-up fixation is performed with a screw and spiked ligament washer, and Biomet ligament fixation buttons. Secure fixation is critical to the success of this surgical procedure. Mechanical tensioning of the cruciates at zero degrees of knee flexion (full extension), and restoration of the normal tibial step-off at 70-90 degrees of flexion has provided the most reproducible method of establishing the neutral point of the tibia-femoral relationship in our experience. Full range of motion is confirmed on the operating table to assure the knee is not “captured” by the reconstruction.

Post Operative Rehabilitation

The knee is maintained in full extension for five weeks non-weight bearing. Progressive range of motion occurs during weeks 5 through 10. Progressive weight bearing occurs at the beginning of postoperative week six progressing at a rate of twenty percent body weight per week during postoperative weeks six through ten. Progressive closed kinetic chain strength training, proprioceptive training, and continued motion exercises are initiated very slowly beginning at postoperative week eleven. The long leg range of motion brace is discontinued after the tenth week and the patient wears a PCL functional brace for all activities. Return to sports and heavy labor occurs after the ninth post-operative month when sufficient strength, range of motion, and proprioceptive skills has returned (68, 69, 70, 71).

Review of Literature

Fanelli and Edson presented the 2-10 year results of 35 arthroscopically assisted combined ACL/PCL reconstructions evaluated pre and postoperatively using Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scales, KT 1000 arthrometer testing, stress radiography, and physical examination (52). 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 were assessed pre and postoperatively with arthrometer testing, 3 different knee ligament rating scales, stress radiography, and physical examination. Arthroscopically assisted combined ACL/PCL reconstructions were performed. 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 16/35 (46%) of knees. Normal Luckman and pivot shift tests in 33/35 (94%) of knees. Posterolateral stability was restored to normal in 6/25 (24%) of knees, and tighter than the normal knee in 19/25 (76%) of knees. 30° varus stress testing was normal in 22/25 (88%) of knees, and grade 1 laxity in 3/25 (12%) of knees. 30° valgus stress testing was normal in 7/7 (100%) of surgically treated MCL tears, and normal in 7/8 (87.5%) of brace treated knees. Postoperative KT 1000 arthrometer testing mean side-to-side difference measurements were 2.7mm (PCL screen), 2.6mm (corrected posterior), and 1.0mm (corrected anterior) measurements, a statistically significant improvement from preoperative status (p = 0.001). Postoperative stress radiographic side-to-side difference measurements measured at 90° of knee flexion, and 32 pounds of posteriorly-directed proximal force were 0-3mm in 11/21 (52.3%), 4-5mm in 5/21 (23.8%), and 6-10mm in 4/21 (19%) of knees. Postoperative Lysholm, Tegner, and HSS knee ligament rating scale mean values were 91.2, 5.3, and 86.8 respectively demonstrating a statistically significant improvement from preoperative status (p = 0.001). The authors concluded that combined ACL/PCL instabilities could be successfully treated with arthroscopic reconstruction and the appropriate collateral ligament surgery (52).

In 2008 Ibrahim et al reported on 20 patients retrospectively reviewed with dislocated knees treated with primary arthroscopic reconstruction with autologous grafting of the ACL, PCL and collateral ligaments (72). Average time of follow up was 43 months. Mean Lysholm score was 91, mean score on the survey of daily activities was 90, and the sports activities score on the Knee Outcome Surgery averaged 86 points. IKDC rating was normal in 0, nearly normal in 9, abnormal in 9 and severely abnormal in 2. Mean loss of extension was 0-2 degrees and mean

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loss of flexion was 10-15 degrees. Tegner activity score decreased in all patients. Postoperative stiffness was the most common complication.

Duran et al. retrospectively reviewed 24 arthroscopically assisted ACL and PCL reconstruction with repair of collateral ligaments after knee dislocation at an average of 25 months (73). 45.8% recovered to normal sports level. The side-to-side difference was less than 5 mm in all 24 pts. Lysholm scores in these patients improved from 41.8 pre-operatively to 87 post-operatively, and ROM improved from 87.5 to 125 (105).

In 2007 Bin et al. published results of a 2 stage management of 15 multiple ligament knee reconstructions after knee dislocation with mean follow up of 88.9 months (74). Collateral ligaments were repaired or reconstructed within 2 weeks. Once full ROM was obtained ACL and PCL were evaluated. ACL was reconstructed if grade 1+ instability or greater was present on exam and PCL was reconstructed if 1+ laxity was present. By this protocol 3/15 knees required ACL reconstruction and 7/15 had PCL reconstruction. Thirty-three percent did not require reconstruction. Mean Lysholm and Tegner scores were 87.6 and 3.9, respectively. Final overall IKDC rating was normal in 3 knees, nearly normal in 8, and abnormal in 4. All patients recovered full ROM. They theorize that a 2 stage surgical approach shortens operative time and lowers the incidence of arthrofibrosis. They conclude that the 2 stage approach results in good outcomes for acute knee dislocation in terms of ROM and stability.

In 2010 Levy et al. compared posterolateral corner repair vs reconstruction in 28 patients with multiple ligament knee injuries with greater than 24 month follow-up (75). One group underwent repair of medial and lateral sided injuries with delayed reconstruction of the central pivot while the second group had single stage multi-ligament knee reconstruction. Clinical and functional outcomes evaluated included failure of repair/reconstruction, IKDC and Lysholm subjective scores, range of motion and laxity. Within this study three patients in the reconstruction group and one patient in the repair group had ACL/PCL/PMC injuries. They found a 40% failure rate in the PLC repair group while only 6% of the PLC reconstructions failed. This was a statistically significant finding. Patients that had lateral sided failure required revision PLC reconstruction. Following revision reconstruction no significant difference in IKDC or Lysholm scores were found between the two groups. They concluded that in the setting of multi-ligament knee injuries PLC reconstruction is a more reliable option than PLC repair alone.

In 2005 Stannard et al. reported on a prospective cohort series in which they evaluated the results of PLC repair versus reconstruction in the setting of multi-ligament knee injuries (76). Fifty-seven knees were evaluated with mean follow up of 33 months. They found a statistically significant higher rate of failure in the repair group (37%) compared to the reconstruction group (9%). Two patients in this series had ALC/PCL/PLC/PMC injuries and both initially had failure of their reconstruction. Both had successful results with revision reconstruction. The authors concluded that results of PLC repair were significantly inferior when compared with PLC reconstruction in the setting of multi-ligament knee injuries.

In 2003 Liow et al. reported the results of repair/reconstruction of 22 knee dislocations with a mean follow up of 32 months (77). The effect timing of treatment had on outcome was evaluated. Patients were evaluated using Lysholm, Tegner and IKDC scores as well as range of motion and stability. Seven patients had ACL/PCL/lateral side injuries, five patients had ALC/PCL/MCL injuries the remaining ten patients had other variations of injury patterns. In their study 36% of patients under went acute treatment, within 2 weeks of injury, while 64% had late reconstruction. Mean Lysholm score was 79. Mean Lysholm for patients undergoing acute treatment was 87 compared to 75 in the late reconstruction group. Tegner activity rating was 5 in the acute group and 4.4 in the delayed group. No difference was found in IKDC between the two groups. Patients undergoing acute reconstruction had better ACL stability than those treated in a delayed fashion. No difference was found between the two groups in regard to PCL stability. The authors concluded that outcomes were better for knees reconstruction within two weeks of injury although differences were small.

Noyes and Barber-Westin published results of 11 patients with multiple ligament knee reconstructions after knee dislocation with mean follow up of 4.8 years (78). The group was comprised of five ACL/PCL/MCL injuries, five ACL/PCL/PLC injuries and one ACL/PCL/MCL/PLC. Seven of the patients were treated in the acute setting while 4
were treated for chronic instability after knee dislocation. At final follow-up 10 of 11 knees had less than 3mm of side-to-side difference with anterior to posterior translation at 20° of flexion with arthrometric testing. At final follow up five of seven patients treated in the acute setting were able to return to pre-injury activity levels while 75% of patients treated for chronic instability were asymptomatic with activates of daily living. The authors concluded that simultaneous bicruciate ligament reconstruction with medial and lateral procedures are warranted to restore knee function.

In 2006 Tzurbkis et al reported mid-term results of surgical treatment of multi-ligament injured knees (79). Patients underwent ACL and PCL reconstruction while the medial and lateral sides underwent repair if the ligaments were avulsed and reconstruction if the collateral tears were mid-substance. Forty-four patients were followed for a mean of 51 months and evaluated with Lysholm, Tegner, IKDC forms as well as KT 1000 measurements. Patient population was as follows: 12 ACL/MCL, 11 ACL or PCL with PLC, and 25 with ACL/PCL with collateral ligament injury. Average Lysholm score was 87 and average Tegner score was 5.09 while the mean range of motion was 129.9 degrees. The mean side-to-side difference was <3 mm for 65% of patients. The authors concluded that surgical treatment provided satisfactory stability, range of motion and subjective improvement in quality of life but pre-injury levels were not fully obtained at final follow-up.

Author’s Results

Our results of multiple ligament injured knee treatment without mechanical graft tensioning are as follows (52). This study presented the 2-10 year (24-120 month) results of 35 arthroscopically assisted combined ACL/PCL reconstructions evaluated pre and postoperatively using Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scales, KT 1000 arthrometer testing, stress radiography, and physical examination. This study population included 26 males, 9 females, 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 pre 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. PCL’s were reconstructed with allograft Achilles tendon (26 knees), autograft BTB (7 knees), and autograft semitendinosus/gracilis (2 knees). ACL’s were reconstructed with autograft BTB (16 knees), allograft BTB (12 knees), Achilles tendon allograft (6 knees), and autograft semitendinosus/gracilis (1 knee). 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. No Biomet graft tensioning boot was used in this series of patients.

Postoperative physical examination results revealed normal posterior drawer/tibial step off in 16/35 (46%) of knees. Normal Lackman and pivot shift tests in 33/35 (94%) of knees. Posterolateral stability was restored to normal in 6/25 (24%) of knees, and tighter than the normal knee in 19/25 (76%) of knees evaluated with the external rotation thigh foot angle test. 30° varus stress testing was normal in 22/25 (88%) of knees, and grade 1 laxity in 3/25 (12%) of knees. 30° valgus stress testing was normal in 7/7 (100%) of surgically treated MCL tears, and normal in 7/8 (87.5%) of brace treated knees. Postoperative KT 1000 arthrometer testing mean side-to-side difference measurements were 2.7mm (PCL screen), 2.6mm (corrected posterior), and 1.0mm (corrected anterior) measurements, a statistically significant improvement from preoperative status (p = 0.001).

Postoperative stress radiographic side-to-side difference measurements measured at 90° of knee flexion, and 32 pounds of posteriorly-directed proximal force were 0-3mm in 11/21 (52.3%), 4-5mm in 5/21 (23.8%), and 6-10mm in 4/21 (19%) of knees. Postoperative Lysholm, Tegner, and HSS knee ligament rating scale mean values were 91.2, 5.3, and 86.8 respectively demonstrating a statistically significant improvement from preoperative status (p = 0.001). No Biomet graft tensioning boot was used in this series of patients.

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 2-10 year follow-up using objective parameters of knee ligament rating scales, arthrometer testing, stress radiography, and physical examination.

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AAOS 2016 Annual Meeting Symposium
Our results of multiple ligament injured knee treatment with mechanical graft tensioning are as follows (2). This data presents the 2-year follow up of 15 arthroscopic assisted ACL/PCL reconstructions using the Biomet graft tensioning boot. This study group consists of 11 chronic and 4 acute injuries. These injury patterns included 6 ACL PCL PLC injuries, 4 ACL PCL MCL injuries, and 5 ACL PCL PLC MCL injuries. The Arthrotek tensioning boot was used during the procedures as in the surgical technique described above. All knees had grade III preoperative ACL/PCL laxity, and were assessed pre and postoperatively using Lysholm, Tegner, and Hospital for Special Surgery knee ligament rating scales, KT 1000 arthrometer testing, 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. PCL’s were reconstructed with allograft Achilles tendon in all 15 knees. ACL’s were reconstructed with Achilles tendon allograft in all 15 knees. MCL injuries were treated surgically using primary repair, posteromedial capsular shift, and allograft augmentation as indicated. Posterolateral instability was treated with allograft semitendinosus free graft, with or without primary repair, and posterolateral capsular shift procedures as indicated. The Biomet graft tensioning boot was used in this series of patients.

Post-reconstruction physical examination results revealed normal posterior drawer/tibial step off in 13/15 (86.6%) of knees. Normal Lackman test in 13/15 (86.6%) knees, and normal pivot shift tests in 14/15 (93.3%) knees. Posterolateral stability was restored to normal in all knees with posterolateral instability when evaluated with the external rotation thigh foot angle test (9 knees equal to the normal knee, and 2 knees tighter than the normal knee). Thirty degree varus stress testing was restored to normal in all 11 knees with posterolateral lateral instability. Thirty and zero degree valgus stress testing was restored to normal in all 9 knees with medial side laxity. Postoperative KT-1000 arthrometer testing mean side-to-side difference measurements were 1.6 mm (range –3 to 7 mm) for the PCL screen, 1.6 mm (range –4.5 to 9 mm) for the corrected posterior, and 0.5 mm (range –2.5 to 6 mm) for the corrected anterior measurements, a significant improvement from preoperative status. Postoperative stress radiographic side-to-side difference measurements measured at 90° of knee flexion, and 32 pounds of posteriorly-directed proximal force using the Telos stress radiography device were 0-3mm in 10/15 knees (66.7%), 4mm in 4/15 knees (26.7%), and 7 mm in 1/15 knees (6.67%). Postoperative Lysholm, Tegner, and HSS knee ligament rating scale mean values were 86.7 (range 95-95), 4.5 (range 2-7), and 85.3 (range 65-93) respectively, demonstrating a significant improvement from preoperative status. The study group demonstrates the efficacy and success of using a mechanical graft-tensioning device.

Our comparison of single bundle and double bundle posterior cruciate ligament reconstruction in the PCL based multiple ligament injured knee revealed the following (65). Ninety consecutive arthroscopic transtibial PCL reconstructions were performed by a single surgeon (GCF). Forty five single bundle and 45 double bundle reconstructions were performed using fresh frozen Achilles tendon allograft for the anterolateral bundle, and tibialis anterior allograft for the posteromedial bundle. Postoperative comparative results were assessed using Telos stress radiography, KT 1000, Lysholm, Tegner, and HSS knee ligament rating scales. Postoperative period ranged from 15 months to 72 months.

Three groups of data were analyzed: Single and double bundle all; single bundle PCL-collateral and PCL double bundle-collateral; and single bundle PCL-ACL-collateral and double bundle PCL-ACL-collateral.

Mean postoperative side to side difference values for Telos, KT PCL screen, KT corrected posterior, and KT corrected anterior measurements for the overall single bundle group in millimeters were 2.56, 1.91, 2.11, and 0.23, respectively. Mean postoperative side to side difference values for Telos, KT PCL screen, KT corrected posterior, and KT corrected anterior measurements for the overall double bundle group in millimeters were 2.36, 2.46, 2.94, and 0.15, respectively. Mean postoperative values for Tegner, Lysholm, and Hospital for Special Surgery (HSS) knee ligament rating scales for the single bundle group was 5.0, 90.3, and 86.2, respectively. Mean postoperative values for Tegner, Lysholm, and Hospital for Special Surgery (HSS) knee ligament rating scales for the double bundle group was 4.6, 87.6, and 83.3, respectively.

Mean postoperative side to side difference values for Telos, KT PCL screen, KT corrected posterior, and KT corrected anterior measurements for the PCL-collateral single bundle group in millimeters were 2.59, 1.63, 2.03, and 0.25, respectively. Mean postoperative side to side difference values for Telos, KT PCL screen, KT corrected posterior, and KT corrected anterior measurements for the PCL-collateral double bundle group in millimeters were 1.85, 2.03, 2.83, and -0.17, respectively. Mean postoperative values for Tegner, Lysholm, and Hospital for Special Surgery (HSS) knee ligament rating scales for the single bundle PCL-collateral group was 5.4, 90.9, and 87.7,
respectively. Mean postoperative values for Tegner, Lysholm, and Hospital for Special Surgery (HSS) knee ligament rating scales for the double bundle PCL-collateral group was 4.9, 89.0, and 86.5, respectively. Mean postoperative side to side difference values for Telos, KT PCL screen, KT corrected posterior, and KT corrected anterior measurements for the PCL-ACL-collateral single bundle group in millimeters were 2.53, 2.19, 2.19, and 0.22, respectively. Mean postoperative side to side difference values for Telos, KT PCL screen, KT corrected posterior, and KT corrected anterior measurements for the PCL-ACL-collateral double bundle group in millimeters were 3.16, 2.86, 3.09, and 0.41, respectively. Mean postoperative values for Tegner, Lysholm, and Hospital for Special Surgery (HSS) knee ligament rating scales for the PCL-ACL-collateral single bundle group was 4.7, 89.6, and 84.6, respectively. Mean postoperative values for Tegner, Lysholm, and Hospital for Special Surgery (HSS) knee ligament rating scales for the PCL-ACL-collateral double bundle group was 4.3, 86.0, and 79.4, respectively. There was no statistically significant difference between the single bundle and the double bundle PCL reconstruction in any of the groups compared (p > 0.05).

In addition, return to pre-injury level of activity was evaluated between the single and double bundle PCL reconstruction groups. The bicruciate single bundle reconstruction group return to pre-injury level of activity was 73.3%, and the bicruciate double bundle reconstruction group return to pre-injury level of activity was 84.0%. There was no statistically significant difference (p = 0.572).

We have concluded that both single bundle and double bundle arthroscopic transibial tunnel PCL reconstructions provide excellent results in these complex multiple ligament injured knee instability patterns. Our results did not indicate that one PCL reconstruction surgical procedure was clearly superior to the other.

Summary

The multiple ligament injured knee is a severe injury that may also involve neurovascular injuries and fractures. Surgical treatment offers good functional results documented in the literature by physical examination, arthrometer testing, stress radiography, and knee ligament rating scales. Pre and postoperative antibiotics are routinely used. Mechanical tensioning devices are helpful with cruciate ligament tensioning. Some low grade medial collateral ligament complex injuries may be amenable to brace treatment, while high grade medial side injuries require augmented repair and/or reconstruction. Lateral posterolateral injuries are most successfully treated with surgical augmented repair and/or reconstruction. Surgical timing in acute multiple ligament injured knee cases depends upon the ligaments injured, injured extremity vascular status, skin condition of the extremity, degree of instability, and the patients overall health. Allograft tissue is preferred for these complex surgical procedures. Delayed reconstruction of 2 to 3 weeks may decrease the incidence of arthrofibrosis, and it is important to address all components of the instability. Both single and double bundle posterior cruciate ligament reconstructions provide excellent surgical results and clinical outcomes in these severely injured knees.

References

47. Shapiro MS and Freedman EL: Allograft reconstruction of the anterior and posterior cruciate ligaments after traumatic knee dislocation. AJSM, 23(5):580-587, 1995

Recommended Reading