Technical Aspects of Addressing Multiligament Knee Instability

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ABSTRACT

Multiligament Knee Injuries (MLKIs) are rare but devastating injuries that require both acute and chronic management. These injuries necessitate operative management with individual patient factors dictating management in an acute (<6 weeks) versus chronic (>6 weeks) timeframe. Anterior cruciate ligament, posterior cruciate ligament and posterolateral corner reconstruction remains the gold standard for operative management while most medial collateral ligament injuries can be managed non-operatively. Graft fixation sequence is essential in re-tensioning the soft tissues to allow for a functional and balanced knee post-operatively- the PCL is first fixed in flexion, followed by the ACL in extension, and then lastly, the PLC and MCL are addressed as needed. This review paper highlights technical considerations demonstrated in two cases performed by the senior author (Claude T Moorman III). Among many essential aspects of surgery in two cases performed by the senior author (Claude T Moorman III). Among many essential aspects of surgery

Keywords: Graft fixation sequence, Graft selection, Multiligament knee injury, Technical considerations.

INTRODUCTION

Multiligament knee injuries (MLKIs) by definition include at least two of the four major ligamentous stabilizers of the knee: The anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), posterolateral corner (PLC), and the posteromedial corner (PMC). This rare injury (<0.02% of all knee injuries) can be devastating. They typically occur secondary to a knee dislocation due to a high-energy trauma (54%) (i.e., a motor vehicle collision) or a low-energy mechanism (46%) like a sporting event. These patients will typically present acutely, and a complete work-up is a necessity in order to avoid disastrous events, such as compartment syndrome, vascular or neurologic compromise.

A thorough history can aid the physician in understanding not only the mechanism of the sustained injury but also whether signs point to a prior dislocation that spontaneously reduced. If the patient presents with a dislocated knee, immediate reduction through open or closed techniques is required. Of note, a medial dimple sign points toward an irreducible posterolateral dislocation with the medial femoral condyle penetrating the medial joint capsule. Failure to promptly reduce a knee dislocation can lead to skin necrosis and vascular compromise. After reduction, the neurovascular status along with compartment pressures should be closely evaluated. Many authors advocate for performing immediate ankle-brachial index (ABI) measurements. If the result is less than 0.9 (100% specificity and sensitivity for arterial injury), then more invasive evaluation with a computed tomography (CT) arteriogram (CTA) or magnetic resonance angiography is warranted. Due to constraints of warm ischemia time as well as the ease of pan-scan CT scans in the setting of major traumas, our home institution has utilized CTA as its imaging modality of choice if ABIs are abnormal. Computed tomography arteriogram has demonstrated equally accurate results to formal angiogram but require less time and radiation. Emergency surgery is reserved for irreducible knee dislocations, compartment syndrome, or vascular compromise when limb viability is threatened. In all three of these circumstances, a spanning external fixator is used to maintain adequate reduction temporarily, to allow access to the soft tissues, and to protect any vascular repairs that have been performed. In the setting of compartment syndrome or revascularization after a prolonged period of arterial compromise, a four-compartment fasciotomy is indicated.

This review paper will highlight surgical considerations after the orthopaedic trauma team has performed the initial evaluation and management from the emergency department. These surgical highlights will be represented in two cases performed by the senior author (Claude T Moorman III). Among many essential aspects of surgery when approaching this complex pathology, we will attempt to focus on three key surgical elements when approaching MLKIs: timing of surgery/staging of surgery, graft selection, and order of graft fixation and tensioning.
TIMING AND STAGING OF SURGERY FOR MULTILIGAMENT KNEE INSTABILITY

After immediately addressing any sources of potential tissue hypoxia, if present, and temporarily stabilizing the knee, some controversy exists about timing of reconstruction. In the experience of our senior author, he has waited 6 weeks after vascular repair to allow re-epithelialization of the graft before placing a tourniquet, per the recommendation of vascular surgeons; he has done so on greater than 100 cases without complication. Each case should be evaluated independently, and individual factors should be taken into account including concomitant ipsilateral fractures, medical comorbidities, and the patient’s overall state of health. Historically, surgery is considered acute if performed within 6 weeks, and surgery is considered chronic after that point in time. Theoretically, the benefit of acute surgery is the clear identification of tissue planes during surgery before scar tissue forms, and the proposed risk of acute reconstruction is arthrofibrosis leading to joint stiffness. Subhia et al found no significant difference in terms of Lysholm score, International Knee Documentation Committee grade, range of motion, or functional outcome between surgeries that occurred before and after 3 weeks. A study by Karataglis et al concluded that although chronic reconstruction rarely results in a “normal” knee, citing pain on exertion as a considerable problem, it offers significant improvement and satisfactory stability. Tzurbakis et al compared acute vs chronic reconstruction and found improved scores in multiple systems among acute repairs; however, the difference was not statistically significant. In a systematic review of 24 retrospective studies including 396 knees, Mook et al found that acute treatment was associated with significant residual anterior knee instability and flexion deficits, and patients were more likely to need additional treatment for joint stiffness compared with chronic treatment. They found that staged reconstruction resulted in the highest percentage of excellent and good subjective outcomes.

In the experience of our senior author, acute treatment offers the advantage of clear tissue planes during surgery. He feels that the arthrofibrosis that occurs following surgery may be protective and beneficial in the healing process, with the decreased range of motion being amenable to rehabilitation. For these reasons, he recommends acute treatment in the absence of complicating factors. He emphasizes the importance of having an experienced operating team and thorough preoperative planning. Our senior author rarely stages this procedure, although he stresses the importance of being cognizant of tourniquet time, even addressing the lateral collateral ligament (LCL) with tourniquet down if warranted.12

GRAFT SELECTION

Although there have been few studies reporting good outcomes with primary ligament repair, reconstruction remains the standard of care when surgically treating multiligament injuries. Specifically, ACL/PCL/PLC injuries require reconstruction, while most medial collateral ligament (MCL) injuries are amenable to repair with the exception of those that are mid-substance or chronic. A prospective level II study by Stannard et al reported a 37% failure rate in repair compared with a 9% failure in reconstruction of PCL tears in MLKIs at a 2-year follow-up. A key principle in reconstruction is choosing a durable graft that will incorporate at the graft–bone interface. When managing isolated ligamentous injuries, autografts are popular due to faster revascularization and maturity. However, with multiple ligament reconstructions, allografts allow many graft size options, decreased donor site morbidity, and shorter tourniquet times. There have been multiple studies showing excellent results with allograft reconstruction.

The first published article describing ACL/PCL reconstruction in an MLKI was by Dr EW Hey Groves in 1917. He describes using a iliotibial (IT) band autograft reconstruction of the ACL and semitendinosus autograft for the PCL. Since this time, research has evolved to find better techniques using a variety of grafts for reconstruction. When deciding on graft selection, it is important to first identify which ligaments/structures need reconstruction. As mentioned earlier, involved structures amenable to reconstruction include the PCL, ACL, PLC/LCL, and PMC/MCL. For PCL reconstruction, successful outcomes have been reported with Achilles tendon allograft for single bundle and adding tibialis anterior allograft for double bundle reconstruction. A cohort study by Kim et al reported no difference in stability and outcomes in double vs single bundle PCL reconstruction in combination with PLC reconstruction. Although there are a number of studies looking at optimal graft options for isolated ACL tears, in the setting of multiligament injuries, ACL reconstruction with bone–tendon–bone (BTB) allograft and Achilles tendon allograft have shown promising long-term outcomes.

Many advancements have been made in PLC reconstruction since the first attempt by Dr Leo Mayer in 1930, which involved stripping the IT band and biceps femoris tendon. Posterolateral corner reconstruction is known to be the most challenging step in multiligament knee injury management due to the complexity of its anatomy. Attention in the literature is more focused on
technique as opposed to graft selection; as a result, there is a lack of evidence comparing graft options. The most important factor consists of restoring the popliteofibular ligament and stabilizing the LCL.21 Using Achilles tendon allograft for the PLC in the setting of multiligament reconstruction, despite few reports, shows promising clinical outcomes when sources of autograft are limited.22 Depending on the technique used, a split biceps tendon transfer and semitendinosus autograft are often the grafts of choice.20,21 The senior author has seen best results for PLC reconstruction using hamstring autograft, but will resort to Achilles tendon allograft if reconstruction of both the MCL and LCL are required. Lateral collateral ligament repair vs reconstruction remains controversial; however, many techniques describe a primary repair, if possible, and allograft augmentation with capsular shift procedure.21,23 Isolated LCL injuries can often be treated nonoperatively; however, in the setting of LCL/popliteofibular ligament injury, Stannard et al13 demonstrate better results with reconstruction over repair.

For PMC/MCL injuries, a retrospective study by Stannard et al reveals 21% (5/24) failure rate with MCL repair as opposed to a 4% (2/48) failure rate with reconstruction in multiligament injuries. Reconstructing the PMC involves augmenting the MCL along with recreating dynamic stability from the semimembranosus tendon and posterior oblique ligament.21 Reconstruction techniques and graft selection for the PMC, like other structures, are based on expert opinion/surgeon preference. Graft choice includes, but are not limited to, Achilles tendon allograft,24 semitendinosus autograft,25 and tibialis anterior allograft.26 Overall graft selection for multiligament reconstructions should follow basic principles. The graft material should be strong, easy to pass through bone tunnels, readily available, and able to incorporate at bone–graft interface.23 All allografts should sterilized, tested, and screened in accordance to the American Associated of Tissue Banks guidelines.15

**GRAFT FIXATION SEQUENCE**

Graft fixation sequence has been well described by multiple sources.27-30 Originally described by Marks et al, the graft fixation sequence is as follows: Prepare both PCL and ACL tunnels first, pass and fix the PCL in flexion, fix the ACL in extension, and finally, address remaining lateral and medial ligamentous laxity. The senior author’s preference is the following: Repair MCL unless tear is mid-substance or chronic, reconstructions of the MCL are completed with a modified Bosworth technique with semitendinosus autograft, and PLC injuries are reconstructed using a fibular-based Figure 8 graft with hamstring autograft knowing there is little role for true PLC injuries.

**Posterior Cruciate Ligament**

After a thorough diagnostic arthroscopy, a posteromedial portal can be used as both a working and viewing portal site to adequately prepare the tibial PCL footprint (Fig. 1). In our case, with the use of fluoroscopy and an adequate notchplasty, viewing of the PCL footprint can be seen through the anterolateral portal. The view of the PCL footprint is maximized using and interchanging 30 and 70° scopes as needed. Of note, the popliteal artery and tibial nerve run approximately 1.5 cm behind the capsule at the level of the joint, and great care should be taken to not extend beyond the capsule.30 The two primary surgical techniques for PCL reconstruction are the tibial inlay technique and the transtibial technique. The advantage of the tibial inlay is preventing graft lengthening and thinning, while a “killer curve” has been described in transtibial tunnel fixation of the PCL that in cadaveric studies leads to graft attenuation.31 However, clinical studies have demonstrated equivocal results.32 The senior author performs the PCL reconstruction with the transtibial technique using an Achilles allograft with calcaneal bone plug. In our case (Fig. 1), the PCL tibial tunnel is drilled under fluoroscopic guidance, carefully placing it 7 mm off the back wall as measured along the PCL facet. Next, the PCL femoral tunnel is drilled with a PCL guide at the junction of the roof and wall of the medial femoral condyle 1 cm posterior to the articular surface utilizing prior remnant PCL landmarks. This is drilled in an outside-in manner and docked into the lateral femoral condyle (Fig. 1). In order to minimize the acute angle of the “killer curve,” the lead author utilizes an Arthrex Gore Smoother graft passer. The bone plug from the Achilles allograft is fixed in the femoral tunnel with a biologic interference screw passed retrograde (Milagro biocomposite screw® in our case) and the soft tissue portion of the graft, utilizing FiberLoop® in a whip stitch pattern, is fixed into the tibia with a post and washer (low-profile Arthrex 12 mm washer® and 6.5 mm cancellous screw) and supplemented by another retrograde biocomposite interference screw. An important technical point in PCL fixation is performing an anterior drawer on the tibia during fixation of the PCL while the leg is 70 to 90° of flexion (Fig. 1).

**Anterior Cruciate Ligament**

Anterior cruciate ligament fixation (Fig. 2) is typically performed with BTB autograft or allograft based on surgeon preference and experience. Despite vastly different trajectories, it is essential to ensure that there is a large enough bone bridge between the two tibial tunnels of the ACL and PCL on the anteromedial tibia. Debridement from diagnostic arthroscopy should ensure...
adequate visualization of the tibial ACL footprint placing the center of the guide just medial to the anterior horn of the lateral meniscus. Multiple guides allow for anatomic placement of the femoral ACL tunnel ensuring adequate bone stock of the back wall and placing it in a 10:30 or 2:30 placement for right and left knees respectively. The senior author utilizes a flexible reamer system to next prepare the femoral ACL tunnel with a 7 mm offset to prevent blowout of the back wall. The ACL is tensioned in complete extension and in our case, fixed with biologic interference fixation (Milagro biocomposite screw®).

Medial Collateral Ligament

Medial collateral ligament fixation (Fig. 3) is based on preoperative exam and degree of laxity. Multiple procedures have compared different fixation methods to obtain valgus stability of the knee. Four well-known techniques were compared in a cadaveric study by Feeley et al: Bosworth, modified Bosworth, anatomical single bundle, and anatomical double bundle. They demonstrated that double bundle configurations (modified Bosworth and anatomic double bundle) best approximate the native MCL stability with regard to external rotation and decreased valgus laxity.33 In the setting of concomitant ACL utilizing a BTB autograft, the incision from the BTB can be extended proximally and mobilized to facilitate fixation of the MCL. In the case example, semitendinosus autograft was used in a modified Bosworth fixation using Arthrex low-profile washers and screws. The senior author elects to reconstruct MCL in the setting of MLKI in Grade II+ MCL tears, midsubstance tears, a Stener lesion of the MCL, persistent laxity after ACL/PCL fixation, and
anteromedial rotatory instability. Important technical points of the procedure are ensuring identification of the origin and insertion of the MCL. This technique has been described by multiple sources – proximally, the MCL is situated between the medial epicondyle and the adductor tubercle. On a lateral radiograph, the insertion is in line with the posterior cortex 3 to 5 mm proximal and posterior to the medial epicondyle. Distally, the graft itself or a temporary suture can be held on the tibia just posterior to the pes anserine to determine the isometric point ranging the knee from 0 to 90°. The knee should be placed in 20 to 30° of flexion with varus stressing to tension the graft appropriately.24

Lateral Collateral Ligament/Posterolateral Corner

One of the leading causes of ACL graft reconstruction failure is an unrecognized and untreated PLC injury of the knee.34 The anatomy of the posterior lateral corner of the knee consists of the LCL, the arcuate complex, the popliteal tendon, and the popliteal-fibular ligament (Fig. 4).35 In a recent systematic review by LaPrade et al, it was found that staged reconstruction of the PLC and cruciates places a higher demand on the PLC repair, leading to a 38% overall failure rate, whereas a single staged cruciate and PLC reconstruction decreased the failure rate to 9%. Furthermore, in both acute and chronic injuries, no exact repair technique could be recommended over another.36,37 Surgical techniques include variations of fibular slings, capsular shifts, and anatomic-based techniques with a variation including a fibular tunnel and a tibial tunnel. The senior author has experienced good anecdotal results with a fibular-based reconstruction of the PLC. He utilizes a single femoral tunnel to act as the footprint for both the popliteus and fibular collateral ligament. This is achieved with the use of an 18 mm washer, as the average distance between these two points coincides with this measurement. The surgical technique (Fig. 4) begins with a separate lateral incision proximal to the lateral epicondyle extending distal to the joint midway between Gerdy’s tubercle and the fibular head. By splitting the anterior one-third of the IT band, the first window allows access to the lateral epicondyle and exposure for the femoral tunnel placement. Next, the head of the fibula is carefully accessed in two planes: one is between insertion of the long and short head of the biceps femoris and the other is posterior to the biceps femoris. Using appropriate retractors to protect the common peroneal nerve, a fibular tunnel is drilled with a guide-pin followed by a size No. 6 reamer in an anterior to posterior direction. A low-profile Arthrex cancellous screw with an 18 mm washer is placed in the femoral tunnel and the semitendinosus autograft, with ends of the tendon fixed in a whipstitch pattern looped through the fibular tunnel, around the post, and tied to itself. The graft is tensioned with the leg in 30° of flexion, internal rotation, and valgus-directed force.
CONCLUSION

An MLKI is often due to a knee dislocation, which requires prompt reduction, neurovascular monitoring, and occasionally vascular repair if needed. Reconstruction has shown a lower risk of failure compared with that of repair alone for ACL/PCL/PLC injuries, while most MCL injuries are amenable to repair. Surgical reconstruction in less than 6 weeks allows for fresh tissue planes that facilitate dissection and is recommended by the senior author. This complex surgery requires extensive presurgical planning for use of autograft and allograft, and both should be available on the day of surgery. Lastly, technical considerations in regard to sequence of bone tunnel preparation as well as fixation and tensioning sequence must be thought of carefully prior to the case in order to maximize the surgical benefit.

REFERENCES


