CHAPTER 1

SURGICAL TECHNIQUES FOR KNEE JOINT REPAIR

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Introduction

As the number of people participating in organized sports has increased in recent years, so has the incidence of sports related injuries. This increased participation in organized athletics has been found in school children, all the way up to “weekend warrior” athletes. It has been estimated that 30 million children in the United States participate in organized sports.\(^1\)

In 2009, Darrow et al. specifically looked at high school athletes and found the incidence of sports-related injuries approached 40% of all non-fatal, unintentional injuries among high school youth treated in emergency departments.\(^2\) Of all the injuries reported in their cohort, it was found that the most commonly injured body site was the knee, which accounted for 29% of total cases. Other injury types included in this study were accidents involving the head (6.8%), shoulder (10.9%), wrist (4.3%), finger/hand (7.9%), and ankle (12.3%). It was found that of the reported injuries that required surgical intervention, more than half (53.9%) involved the knee.

Knee injuries in sports related accidents account for millions of visits to emergency departments each year. The most common knee injuries sustained by athletes include anterior or posterior cruciate ligament ruptures, medial or lateral meniscal injuries, cartilage injuries, and collateral ligament injuries. These injuries have a myriad of different treatment

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strategies with the goal of returning the patient to their prior level of function and sport. This chapter will focus on the surgical management of these pathologies. We will specifically discuss epidemiology, anatomy, mechanism of injury, diagnostic work up, surgical options, and surgical outcomes.

**Anterior Cruciate Ligament Injury**

**Anatomy**

The anterior cruciate ligament (ACL) originates from the medial wall of the lateral femoral condyle and courses anteriorly and medially to insert into the tibial articular surface. It is composed of two functional bundles, the anteromedial and posterolateral bundles, named based on their tibial insertion sites. The specific locations of these attachments plays an important role in the biomechanics of the ACL. Due to the large attachment sites, the ACL allows different portions of the ligament to tighten at various degrees of knee flexion. The femoral attachment site is located on the posteromedial surface of the intercondylar notch on the lateral femoral condyle. The attachment is circular, spanning an area of approximately 113 mm$^2$. The tibial attachment is located approximately 15 mm from the anterior border of the tibial articular surface, covering an area of about 136 mm$^2$. The mid-substance cross-sectional area is approximately 40 mm$^2$ (Figure 1).

**Biomechanics**

The function of the ACL is to provide primary anteroposterior stability and secondary rotatory and coronal stability to the knee joint. There is age related loss of strength of the ACL, with older ACLs failing with lower loads than younger ACLs. The ACL withstands a wide range of forces ranging from 100 N during passive range of motion exercises to about 1700 N during cutting, and pivoting maneuvers. The maximal tensile load is 2160 N.

**Epidemiology**

The ACL is the most commonly injured ligament in the knee. It is most commonly injured during sports related activity with only a minority of
ACL injuries occurring in high-energy trauma or activities of daily living.\textsuperscript{8} ACL injuries represent approximately 40–50\% of all knee ligament injuries. Patients report hearing or feeling a pop at the time of injury 70\% of the time and almost all patients notice swelling of the knee within 24–48 h of injury. The sports most commonly associated with ACL injuries are those that involve cutting or pivoting, namely soccer and skiing. Female athletes have a two to four fold higher risk of ACL injury than males.\textsuperscript{9}

**Pathoanatomy**

The majority of ACL injuries are complete disruptions. In skeletally mature patients, the most common site of the disruption is midsubstance or along the femoral insertion of the ACL. In skeletally immature patients, avulsion off the tibial attachment with or without a piece of bone is more commonly seen.

**Work up**

The first step to diagnose and treat an ACL injury is a thorough history and physical examination. Any patient with knee swelling after a sports
related knee injury should be evaluated for possible ACL tear. Diagnosis of chronic ACL injury may involve a history of recurrent knee pain, mechanical symptoms from a secondary meniscal tear or instability. A thorough history may be difficult in the acute setting due to pain and swelling associated with the injury. Patients with acute ACL injury present with a large effusion, related to hemarthrosis secondary to bleeding from the vessels within the ligaments synovial sheath. Palpation of all bony prominences should be carefully performed with special attention to the femoral origin of the medial collateral ligament. Patellar apprehension must be noted, as acute patellar dislocations often present with a similar history as ACL injury. The quadriceps and patellar tendons should also be examined as injuries to these structures may be confused with ACL injuries. Special testing for ACL injuries include the Lachman test, anterior drawer test and pivot shift test. The Lachman test is the most useful in the initial diagnosis. A sense of increased tibial translation or a lack of a solid endpoint are indicative of ACL injury. The pivot shift test is pathognomonic for ACL injury. The test begins with the knee in full extension, and the knee is the flexed while applying a valgus moment. As the iliotibial band (ITB) passes posterior to the axis of knee rotation at approximately 15° of knee flexion, the tibia (which is subluxated anteriorly on the femur) reduces with a visible shift at the lateral joint line. This should always be compared with the contralateral side, where a physiologic pivot shift or pivot glide may occasionally be present.

**Imaging**

Radiographic evaluation of a patient with a suspected ACL injury includes plain radiographs of the affected knee to rule out fracture in the acute setting. Associated injuries that may be identified on plain imaging include a Segond fracture\(^\text{10}\) (lateral capsular avulsion) and tibial eminence avulsion fractures in skeletally immature patients. Additionally, the presence of open physes is of particular importance as this can impact the surgical treatment approach. MRI is not required for the diagnosis of ACL injury, but it is useful for assessing for associated injuries to the meniscus, other ligaments, the articular surface and for the presence of subchondral bone marrow edema lesions and fractures. The characteristic edema pattern seen on MRI
with bone marrow lesions present within the posterolateral tibial plateau and the central lateral femoral condyle correspond to the pivot-shift type translational event that occurs during injury (Figure 2). In the coronal and sagittal MRI images, disruptions in the normal black ACL fibers signify ACL injury.

**Treatment**

ACL reconstruction is indicated in active patient populations who are involved in cutting, pivoting and twisting activities. The goal of ACL reconstruction is to return functional stability of the knee to allow for return to full activity as well as to prevent further damage to the menisci and chondral surfaces that can lead to early-onset arthritis. Elderly or more sedentary individuals may have a good outcome with non-surgical management. Non-surgical management involves rehabilitation to strengthen the hamstrings (HSs) and quadriceps, as well as proprioceptive training. Activity modification is an important part of non-surgical management. Contraindications to surgery include: lack of quadriceps function, significant comorbidities, or inability to tolerate surgery or the necessary post-operative rehabilitation required.

The success rate of ACL reconstructions has reached up to 90% with respect to post-operative knee stability and patient satisfaction. Graft
choice varies from surgeon to surgeon. Multiple factors are involved in the choice of ACL reconstruction graft type, including biomechanical properties, biologic incorporation, associated donor site morbidity, graft tensioning issues, graft fixation options, and clinical outcome. Available graft options can be divided into two main classes: autograft and allograft. In these classes, autograft options include bone-patellar tendon-bone (BPTB), quadriceps tendon, quadrupled semitendinosus and gracilis HS tendon. Allograft options include quadriceps, Achilles, tibialis anterior or posterior, BPTB, and HS. The gold standard is thought to be BPTB autograft due to ease of harvest, comparable structural properties to the native ACL, available rigid fixation techniques, bone to bone rather than soft tissue to bone healing, and a long track record of success.\textsuperscript{12–14} Graft healing involves both the healing at the graft attachment site as well as the process of graft revascularization and incorporation (termed ligamentization). Grafts containing bone typically resemble fracture healing with bone healing occurring within six weeks. Soft tissue grafts take longer, between eight and 12 weeks to heal into host bone. The process of graft incorporation begins with a period of inflammation in which the graft loses strength and stiffness. This phase is between day 20 and up to 3–6 months after surgery, losing up to 80% of its strength.\textsuperscript{15} Donor site complications are typically seen with BPTB grafts, include patellar fractures,\textsuperscript{16} patellar tendon ruptures,\textsuperscript{17} localized numbness and tendonitis.\textsuperscript{18} Use of allograft produces decreased donor site morbidity, shorter operative time, preservation of extensor and flexor mechanisms, and wide availability for cases involving multiligament injuries. Allograft ACL reconstructions have become popular in the treatment of patients older than 40 years of age (Figure 3).

Technical aspects of ACL reconstruction involve proper tunnel positioning, graft tensioning and initial fixation and strength. In order to restore adequate anteroposterior stability, there must be adequate tensioning of the graft, however this has been largely an unquantifiable measure due to variability in graft choices, fixation techniques, positioning of knee flexion and knee rotation during tensioning. The reproducibility of tensioning has been questioned as most surgeons do this manually and the applied force can vary significantly from surgeon to surgeon. It is recommended that between 40 and 60 N of force be applied at near-full extension for tensioning.
Fixation methods have been widely studied and there is extensive literature addressing this issue, as rigid fixation of the ACL graft is one of the most important factors determining long-term success of the operation. Options for fixation include interference screws of different materials, staples, and suture tied over buttons or screws. Fixation problems typically occur on the tibial side. This may be due to decreased bone quality of the tibial metaphysis, tunnel orientation in relation to forces the graft experiences and the direction the tibial fixation must occur.19–21

**Outcomes**

ACL reconstruction has generally excellent outcomes with more than 90% of treated patients returning to their previous level of activity. Autograft choice or one versus two incision technique do not appear to affect the outcome. Re-rupture rates vary from 2% to 5%.22 Studies have shown the instrumented laxity with KT 1000 arthrometer demonstrate 75–97% of patients have <3 mm of side to side difference in laxity.23 Complications include those related to anesthesia, infection, knee stiffness, venous thromboembolism, painful hardware, and loss of terminal extension.

The stability of the ACL reconstruction is of upmost importance. Using instrumented Lachman’s test with the KT 1000 arthrometer, we are able to measure the stability of the ACL construct. Side to side comparisons between 0 and 2 mm are considered stable. Laxity greater than 5 mm is
considered unstable and a failure of reconstruction. Clinical studies have reported both low and high stability results for both allograft and autograft. A recent meta-analysis showed a significantly greater stability of autograft compared to allograft.\textsuperscript{24} Failure rates have also been reported as high as three times greater in allograft than autograft. BPTB autografts have significantly lower failure rates than BPTB allografts.

Recovery time can be defined as early postoperative and overall recovery time. Patients with allograft have faster early postoperative recovery because of the assumption that donor site morbidity is avoided. This is more apparent when comparing allograft to HS autograft.\textsuperscript{25} When comparing overall recovery time, autograft has the advantage. This is due to the slower revascularization of allografts, which makes surgeons assign them slower rehabilitation protocols.\textsuperscript{26}

Important factors for determining successful ACL reconstruction is correct femoral and tibial tunnels without PCL and roof impingement and the use of slippage-resistant, stiff strong fixation. Positive outcome is also associated with the patients ability to undergo brace-free, aggressive rehabilitation that is self-administered at home. Less important factors are the type of graft used, the use of a brace or immobilizer and the use of formal physical therapy.

**Posterior Cruciate Ligament Injury**

**Introduction**

In contrast to ACL rupture, posterior cruciate ligament injuries are relatively infrequent. In the past, this has led to limitations in clinical studies and a general lag in basic science and clinical research that is typically present for other ligamentous injuries. As new interest in this topic has developed, our understanding has improved and treatment algorithms have evolved. As put forth by Fanelli et al., PCL injuries are more common than initially thought, comprising 3% of all knee injuries and being present in 37% of trauma patients with acute hemarthroses.\textsuperscript{23} The overall incidence in the literature has been reported to be from 1% to 40% in acute knee injuries, which has been shown to be dependent on the patient population studied. Although PCL injuries can occur in sports related injuries, they are, more common in trauma patients.\textsuperscript{27}
Anatomy

The PCL is the primary restraint to posterior translation of the proximal tibia and plays an integral part to the overall stability of the knee. It also serves as a secondary restraint to varus, valgus and external rotation forces. The ligament is comprised of two inseparable bundles (anterolateral bundle (ALB)/posteromedial bundle), and originates from a broad, crescent-shaped area on the anterolateral aspect of the medial femoral condyle within the intracondylar notch and inserts into the PCL fossa. The PCL fossa is located posteriorly, between the two tibial plateaus. Although the bundles are inseparable, they have different functions that allow the PCL to resist posterior translation in both extension and flexion. The ALB makes up the bulk of the ligament and is taut at 90° of flexion and loose in extension, whereas the posteromedial bundle (PMB) is taut at 30° of flexion and loose at 90° of flexion (Figure 4).

Traditionally, as little was understood regarding the biomechanics and treatment of PCL deficient knees, patients who were found to have isolated PCL injuries were generally treated conservatively with physical

Fig. 4.  (A) Sagital view of a cadaver knee showing PCL originating from lateral aspect of medial femoral condyle and inserting within PCL fossa on the posterior tibia. (B) Illustration showing orientation of the two bundles of the PCL at its origin on the femur and its insertion on the tibia.
therapy and bracing. This treatment algorithm has changed towards surgical intervention as the anatomy and biomechanics have become better understood and new studies have shown that a large percentage of patients who have gone untreated develop late knee arthrosis affecting the medial and patellofemoral compartments.28

History and physical examination

Posterior cruciate ligament injuries often occur via a posteriorly directed force to the tibia (dashboard type injuries), as opposed to the non-contact mechanism that typically causes ACL tears. As these are generally high-energy injuries, they rarely occur in isolation, and are often seen in multi-ligamentous knee injuries. PCL injuries can also occur concomitantly with peri-articular fractures of the knee. In these instances, Kim et al. has reported that they are missed over 60% of the time, so one must have a high index of suspicion for PCL injury when evaluating patients with a fracture about the knee. In the patient with chronic PCL insufficiency, he or she often presents with remote history of trauma or fracture to the knee and complaints of anterior knee pain, difficulty with stair ambulation, or less commonly, instability.29

On physical exam, the posterior drawer test has been shown to most accurately assess for PCL injury. It has been reported to have a sensitivity and specificity of 90% and 99%, respectively.29,30 The grade of PCL injury is determined from the posterior drawer test findings (Table 1). The tibia must be positioned in its natural position to increase the accuracy of this exam, which involves the medial tibial plateau resting approximately 1 cm anterior to the medial femoral condyle. Once the knee is positioned appropriately, the examiner applies a posteriorly directed force to proximal tibia and looks for posterior translation of the tibia in relation to the

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<th>Grade</th>
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In addition to the posterior drawer test, the Godfrey posterior sag test and quadriceps active test are helpful adjuncts. The dial test can be used to evaluate for concomitant injuries to the posterolateral corner (PLC). Increased external rotation at 30° and 90° of flexion suggest a combined PCL and PLC injury.

**Imaging**

Once a PCL injury is suspected by history and examination, imaging must be obtained to confirm the diagnosis. Plain radiographs are performed to assess for posterior tibial subluxation, posterior tibial slope, avulsion fractures, and tibial plateau fractures. Varus malalignment is common in chronic PCL injuries and so if suspected, long leg alignment films can be obtained to assess the overall mechanical axis of the limb. Stress radiographs have been described as a way of differentiating between complete and partial PCL tears.

Magnetic resonance imaging (MRI) has become the preferred imaging test of choice when a PCL tear is suspected. Reports have shown that it can have a sensitivity of up to 100% in the diagnosis of acute PCL tears,\textsuperscript{31,32} however, has been found to be less accurate in the diagnosis of chronic PCL tears.\textsuperscript{33} Another advantage to MRI as the imaging modality of choice is that it offers information on the menisci, articular cartilage, and other ligaments within the knee, all of which can impact the treatment plan (Figure 6).
There is no general consensus among orthopedic surgeons on how to manage isolated PCL injuries. Currently, most studies present in the literature are retrospective studies that use various outcome measures, which makes comparisons difficult. Despite the fact that knee kinematics and biomechanics are undeniably altered by PCL injury, successful non-operative treatment of isolated PCL injuries has been reported in several studies. It has been speculated that good results seen with non-operative management in many studies are likely explained by the inclusion of patients primarily with grade I or II injuries. It is thought that in these patients, the secondary restraints to posterior tibial translation can adequately compensate for PCL insufficiency.

Although numerous studies show favorable early outcomes with non-operative treatment of PCL injuries, the long term outcomes of PCL deficient knees is still unclear. Boynton et al. reported deterioration at extended follow-up of those patients who initially had favorable early results. In addition to pain and swelling, many of these patients showed
signs of articular degeneration on plain radiographs at the time of long-term follow-up.

Although no gold standard for the treatment of PCL injuries currently exists, based on current literature and trends, non-operative management is generally recommended for the treatment of grades I and II PCL injuries. Operative management is reserved for grade III injuries in patients with symptoms of pain or instability that have failed an adequate course of conservative treatment. Another indication for operative intervention is PCL insufficiency in the setting of a multiligamentous knee injury.

**Surgical technique**

Once a patient has been indicated for operative treatment of a PCL injury, surgical planning must begin for reconstruction. The two surgical options include a femoral tunnel with the use of a transtibial tunnel or a tibial inlay technique. In addition, a reconstruction can be either single-bundle or double-bundle. There is much debate as to which of these techniques best optimizes patient outcome. Despite what technique is utilized, the primary goal of surgical reconstruction of the PCL is to restore its normal anatomy and function.

The position of the femoral tunnel(s) depends on whether a one- or two-bundle reconstruction technique is used. In a single-bundle technique, the goal is to reconstruct only the AL bundle of the PCL, while in the double-bundle technique, the AL and the PM bundles are individually reconstructed. The AL tunnel is centered at about the 1 o’clock position (right knee), which places it roughly between the roof and the medial wall of the intercondylar notch. Its anterior edge should be located approximately 2–3 mm behind the articular margin. For a double-bundle reconstruction, in addition to the AL tunnel, a second, PM tunnel is also drilled. It is centered on the PCL footprint between 3 and 4 o’clock (Figure 7).

**Transtibial technique**

Traditionally, the goal of arthroscopic transitibial techniques has been to reconstruct the stronger and more functionally important ALB. In this technique, a tunnel is drilled from anterior to posterior on the tibia. The tibial stump of the PCL must be removed prior to drilling. The guide pin is the
centered in the tibial insertion of the PCL within the PCL fossa. Adequate arthroscopic visualization is key during this step to ensure proper tibial tunnel positioning and minimize the risk of neurovascular injury within the popliteal fossa. A posteromedial portal is often used for visualization. In order to minimize the risk of neurovascular injury, it is crucial for insertion of the guide pin and drilling to take place with at least 90\degree of knee flexion and for it to be performed under fluoroscopic guidance.

The skin incision for the tibia tunnel may be either medial or lateral to the tibial tubercle. Regardless of incision site (medial versus lateral), the tunnel should be started approximately 4 cm below the joint line. The lateral route, which is more posterior than the medial route, is advantageous because it reduces the angulation of the graft when entering the joint. When drilling the tunnel, the tip of the pin is protected with a curette or a retractor to prevent any protrusion of the pin within the popliteal area (Figure 8).

**Tibial inlay technique**

The underlying principle of the tibial inlay technique is to allow direct lag screw fixation of a bone plug at the tibial attachment site of the PCL while
minimizing the risk of graft thinning and failure by eliminating the acute angled turn the graft must take in the transtibial tunnel technique. Patient positioning is critical in order to perform this technique successfully. The lateral decubitus position is most commonly used as a posterior approach to the tibia is facilitated in this position. The medial head of the gastrocnemius can be laterally retracted and Steinmann pins can be placed into the posterior cortex of the tibia to facilitate exposure and keep neurovascular structures at a safer distance. A trough is created in the posterior tibial cortex within the PCL fossa and the graft bone plug is inserted into the trough prior to being fixed into place with screws. The graft is then passed anteriorly through the femoral tunnel, where it is tensioned and held in position with an interference screw.

**Outcome**

In general, it is accepted that isolated PCL injuries should have a trial of non-operative treatment prior to deciding to proceed with surgical intervention. However, when accompanied with other ligamentous injuries about the knee, the same course of non-operative treatment is no longer recommended and acute surgery is advisable.
In 1996, Boynton et al., found that the prognosis for isolated posterior cruciate ligament deficient knee varies. They concluded that some patients experience significant symptoms and articular deterioration, while others are essentially asymptomatic and maintain their usual knee function. When treated surgically, Garofalo et al. found that these patients were able to return to moderate or strenuous activity, with mild residual laxity with posterior stress. This cohort only included those patients treated with transtibial double-bundle PCL reconstruction technique. Shon et al. evaluated outcomes of tibial inlay technique and found that single and double bundle PCL reconstructions using this technique gave satisfactory clinical results in those patients with an isolated PCL injury. In 2010, May et al. performed a systematic review of the literature comparing tibial inlay technique to transtibial technique for PCL reconstruction and found satisfactory clinical and functional results for both surgical techniques. They concluded that surgeon preference should dictate surgical technique utilized. Long-term studies are still needed to fully evaluate these injuries and better determine which surgical technique may have the best prognosis at long-term follow up.

**Posterolateral Corner Injury/LCL**

**Anatomy**

The lateral and posterolateral aspects of the knee have a complex anatomy that has recently attracted wider interest due to increased understanding of their anatomy and biomechanical importance. Among the structures on the lateral and posterolateral aspect of the knee are the ITB, the lateral collateral ligament (LCL), the popliteus muscle–tendon complex, the politeofibular ligament (PFL), and the long and short head of the biceps femoris. These can be divided into static and dynamic stabilizers of the knee. The dynamic stabilizers are the ITB, biceps femoris, popliteus and lateral head of the gastrocnemius muscle. The static stabilizers are the LCL, politeofibular ligament and popliteus tendon (Figure 9).

The ITB is a complex structure that has been described to act as an anterolateral sling to the knee. It acts as a secondary stabilizer to the lateral aspect of the knee. It is not commonly injured, however it serves as
Fig. 9. Figure of anatomy demonstrating the PLC.

an important landmark during surgery. The LCL is the primary restraint to varus opening of the knee.\textsuperscript{45–48} The proximal attachment is located slightly posterior and proximal to the lateral femoral epicondyle and its distal attachment is on the superior and lateral apex of the proximal fibula. It passes deep to the superficial layer of the ITB and long head of the biceps. The popliteus muscle originates at a broad insertion on the posteromedial aspect of the proximal tibia and inserts at the proximal half and anterior one fifth of the popliteus sulcus of the femur. It passes deep to the LCL. The PFL originates on the popliteus muscle complex and attaches on the posterior aspect of the fibular styloid.

\textbf{Biomechanics}

The posterolateral structures serve to mainly provide varus rotation and posterolateral translation stability. They also serve as secondary stabilizers to anteroposterior translation. In patients with an intact ACL, the posterolateral
structures serve a small role in internal and external rotation stability in the knee. However, in an ACL deficient knee, the posterolateral structures serve an increasing role as secondary stabilizers to rotation.

**Epidemiology**

Injuries to the structures on the lateral aspect of the knee are much less common than those to the medial side of the knee or the cruciate ligaments. The exact incidence is difficult to determine as many of these injuries go undetected on initial examination. Between 7% and 16% of knee ligament injuries are to the lateral ligamentous complex.\(^4^2\)

**Work up**

The majority of injuries to the lateral and posterolateral aspects of the knee are sustained during athletic participation (40%)\(^4^9\) or as a result of motor vehicle accidents. They result from either a direct blow or forces to the weight-bearing knee, resulting in excessive varus stress, tibial rotation and/or hyperextension. The most common mechanism is a posterolaterally directed forces to the medial tibia with the knee in extension. Isolated injury is uncommon, with most injuries associated with cruciate ligament tears. As a result, patients commonly experience instability noted in full extension. They may have difficulty with stairs, both ascending and descending, as well as with pivoting activities. Patient may also complain of lateral joint line pain.

A complete physical exam should be performed with particular attention to testing ligamentous laxity of all ligaments around the knee. LCL injury will demonstrate isolated laxity at 30° of knee flexion. When laxity occurs at both 0° and 30° of knee flexion, there may be an additional injury to the cruciate ligaments. The posterolateral drawer test is specific for rotatory instability and injury to the posterolateral corner. This test is performed at both 30° and 90° of knee flexion. A positive test at 30° is most consistent with PLC injury. The dial test is considered positive when the involved foot and ankle exhibit greater than 10° of external rotation compared to the normal side. Gait is important to examine, as chronic injuries may cause patients to walk with a lateral thrust. A careful assessment of neurovascular
status is important, as injuries to the LCL and PLC are associated with common peroneal nerve injury or popliteal artery injury (Figure 10).

**Imaging**

Careful radiographic evaluation must be performed for all patients with suspected injuries to the lateral and posterolateral structures of the knee. Plain radiographs should include anteroposterior and lateral images of the knee in both extension and flexion. These may be normal in the majority of patients but they must rule out associated osteochondral fractures, fibular head avulsion, Gerdy’s tubercle avulsion or fracture of the lateral tibial plateau. Segond fractures are often seen with ACL injuries. Chronic injuries may show degenerative changes in the lateral tibiofemoral compartments. MRI is the modality of choice to evaluate the LCL, popliteus muscle complex, PFL, and the cruciate ligaments. MRI will provide information about the location, and severity of the injury (Figure 11).

**Treatment**

Instability can be divided into varus rotational instability in the coronal plane versus rotatory instability in multiplanar laxity. Isolated LCL injuries are rare, and lead to coronal plane laxity. Combined injury to the LCL and posterolateral structures in junction with cruciate ligament injury lead
to anterolateral or posterolateral instability. In chronic injuries, combined instability patterns may result. Posterolateral corner injuries are classified as grade I, II or III, depending on if there is minimal, partial or complete ligament disruption. A more accurate classification system is based on quantifiable lateral joint line opening with applied varus stress. Grade I varus instability has less than 5 mm of opening. Grade II varus instability has 5–10 mm of opening. Grade III has greater than 1 cm of opening.

Non-operative treatment of ligamentous injuries to the lateral side of the knee is limited to partial, isolated injuries of the LCL without involvement of the cruciates. These patients have little functional instability, especially if they possess normal physiologic valgus knee alignment. Non-operative treatment involves limited immobilization combined with protected weight bearing for the first two weeks. Rehabilitation focused on progressive range of motion, quadriceps strengthening, and proprioceptive training are used. When the injury is classified as grade III, or injuries also involving the arcuate complex, surgical treatment should be considered.

Surgical indications for lateral and posterolateral injuries to the knee include: complete injuries or avulsions of the LCL, rotatory instability
Surgical Techniques for Knee Joint Repair

involving the LCL and the cruciate ligaments, popliteus tendon and fabellofibular ligament, or combined instability patterns involving the LCL/PLC and ACL or PCL. Surgical intervention should be done in the acute phase, after the initial swelling has subsided.

Repair techniques for posterolateral corner injuries include advancement or recession of the PLC and intrasubstance PLC repair. In the acute setting, in the treatment of femoral-based PLC injuries, the popliteus tendon or LCL may be recessed. After surgical exposure, the avulsed ends of the LCL or popliteus tendon are whip stitched with 2-0 non-absorbable suture. A cannulated reamer is then used to drill over an eyelet-tipped guide pin. The guide pin is used to pass the sutures medially and then they are tied over a button on the medial femur. For intrasubstance LCL injuries, direct repair is possible.

Reconstructive techniques have been broken down into anatomic and non-anatomic reconstructions. These techniques may be used to reconstruct acute and chronic PLC-deficient knees. The non-anatomic reconstructions include: biceps femoris tenodesis, the Larson technique, and Stannard’s modified two-tailed technique. The anatomic reconstruction described by LaPrade aims to re-create the ligament length relationships of the lateral knee in proper isometric positions to create a mechanical advantage and thus resist varus stresses and posterolateral tibial rotation.

Biceps tenodesis was popularized by Clancy by augmenting the primary repair of the LCL and PFL to the intact long head of the biceps tendon. By transferring the biceps femoris to the anterior aspect of the lateral femoral epicondyle, there is a reduction of external tibial rotation and varus laxity. The peroneal nerve is in danger with this approach and must be carefully isolated before the biceps femoris tendon is brought anteriorly and fixed to the lateral femoral epicondyle.

The modified two tailed technique described by Stannard, uses a tibialis anterior or posterior allograft to reconstruct the popliteus, the popliteofibular ligament and the LCL. The allograft tendons are passed through intraosseous tunnels and fixed with bioabsorbable screws.

Anatomic reconstruction of the posterolateral corner involves reconstruction of the popliteus tendon that can be performed with a HS tendon allograft or autograft. Harvesting the HS tendons is well described, with preference given to the use of semitendinosus due to its increased stoutness.
and less risk of damage to the saphaneous nerve during harvest.\textsuperscript{44} The HS graft is brought into the femoral socket and fixed with a bioabsorbable screw, wrapped around the musculotendinous junction of the popliteus complex, and pulled anteriorly through the tibial tunnel. The graft is fixed in place with a screw and staple.\textsuperscript{57} Reconstruction of the LCL can also be performed with HS tendon graft. Tunnels are drilled at the sites of the anatomic attachments on the femur and proximal fibula. Tensioning is done with the knee in 30° of flexion and neutral rotation while a valgus force is applied to decrease any varus opening (Figure 12).

**Outcome**

Potential complications with PLC surgery include wound breakdown and infection. This is particularly worrisome in open knee dislocations and acute injury. Peroneal nerve injuries can be avoided with meticulous surgical technique. Posterolateral knee injuries involves between 15% and 29% incidence of peroneal nerve injury. Proper examination and documentation of neurovascular status is important prior to surgery. Other
potential complications include arthrofibrosis, persistent laxity, deep vein thrombosis, chronic pain and symptomatic hardware.

LaPrade et al. reported on their outcomes after surgical treatment of grade III posterolateral corner injuries by either repair of avulsions or reconstruction of midsubstance ligament tears and found that these patients had improved objective stability. Their series included 25 patients with posterolateral corner injuries and found that their International Knee Documentation Committee (IKDC) scores and Cincinnati scores were improved in patients who underwent repair or reconstruction. These patients also had acute ACL reconstruction at the same time if they had an associated ACL tear. Stress radiographs also showed a significant decrease in opening compared to preoperative stress radiographs. Early reports regarding acute repair of posterolateral corner injuries found 88–100% fair to good results. Based on these results, it is recommended that these injuries be reconstructed acutely.

Primary repairs of the main posterolateral corner structures have show failure rates of 37–40%. Acute reconstruction has been reported to have successful outcomes in 94% of patients. These studies did not have consistent protocols for the timing of concomitant ACL tears, which may have attributed to different results. With increased understanding of the anatomy and function of posterolateral corner tears and the importance of reconstruction, especially in the setting of concomitant ACL injury, the current recommendations are to perform an acute reconsutrction of the posterolateral corner structures as well as acute ACL reconstruction if an ACL injury is present.

Meniscal Injuries

Introduction

In 1897, Bland-Sutton first described the meniscus as “functionless remnants of intra-articular leg muscles.” Since this first description of the menisci many years ago, our understanding and knowledge of their function has dramatically improved. Today, the meniscus is commonly known as the “shock absorber” of the knee joint, however, in actuality, the meniscus has multiple functions. These include absorbing shock, providing stability, increasing the articular congruity, aiding in lubrication, preventing synovial
impingement and limiting flexion/extension extremes. Of its many known functions, the most important purpose of the meniscus is to act as a load-sharing device across the knee joint. It accomplishes this by increasing contact areas and transmitting and distributing load over the tibial plateau.

Meniscus injuries are among the most common injuries seen by orthopedists. They have been reported to have an annual incidence of 60–70 per 100,000. Meniscal tears are more common in males with a male:female ratio that ranges from 2.5:1 to 4:1. The peak incidence in males occurs between the ages of 21–30 years old. In women, the peak incidence has been found to be between the ages of 11 and 20 years old. There is also a high prevalence of meniscal tears seen in the setting of other injuries about the knee (i.e. acute rupture of ACL or a tibial plateau fracture).64

Anatomy

The menisci are C-shaped or semicircular fibrocartilaginous structures with bony attachments at the anterior and posterior aspects of the tibial plateau. The medial meniscus is C-shaped with the posterior horn larger than the anterior horn. Slight variations in meniscal morphology and their attachments are commonly seen. The lateral meniscus has more of a semicircular shape and is anchored anteriorly and posteriorly through bony attachments to the tibia plateau. It covers a larger portion of the tibial articular surface than does the medial meniscus. The lateral compartment is the more common site of the discoid meniscus, which can be found in 1–3% of the population.64 In a discoid meniscus, the semicircular shape of the lateral meniscus is exchanged for a more circular shaped meniscus, which puts it at risk of injury, making it a common source of knee pain in these patients (Figure 13).

The fibers of the menisci have circumferential orientation with radial tie fibers preventing longitudinal splits. In cadaver studies, the lateral meniscus has been found to cover 84% of the condyle surface while the medial meniscus covers approximately 64% of the condyle surface. The menisci are comprised of up to 75% water. Their extracellular matrix is mostly made of type 1 collagen and proteoglycans.

In extension, as much as 50% of the load across the knee joint is absorbed by the meniscus, with the percentage of load-sharing increasing
Fig. 13. (A) Arthroscopic view of a discoid lateral meniscus. (B) Arthroscopic view after saucerization of discoid meniscus performed.

To 90% at 90° of flexion. Beyond 90° of flexion, most of the force is transmitted to the posterior horns of the menisci. Of the two menisci, the lateral meniscus has been shown to provide more biomechanical support to the joint than does the medial meniscus.

In order to understand the treatment of meniscal tears, one must understand the vascularity of the menisci, as the two go hand-in-hand. Arnoczky and Warren studied the adult blood supply to the meniscus and found that only the outer 10–25% of the lateral meniscus and 10–30%
of the medial meniscus have a vascular supply.65 This vascularity arises from the superior and inferior branches of the medial and lateral genicular arteries, which form a perimeniscal capillary plexus. Because of the lack of vascularity of the inner two thirds of the meniscus, cell nutrition is believed to occur mainly through diffusion or mechanical pumping from the surrounding synovial fluid. It is widely accepted that the vascular zones of the menisci can be broken into thirds. The outer third comprises the red-red zone (zone of vascularity), the middle third is the red-white zone, and inner third is the white-white zone (avascular zone). As vascularity is directly related to the meniscus’ ability to heal, it is only those tears that occur in the outer, red-red zone that are able to heal and are thus considered repairable (Figure 14).

Table 2. Vascular zones of the meniscus.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Location</th>
<th>Vascular status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red-red</td>
<td>Peripheral third of the meniscus</td>
<td>Vascularized</td>
</tr>
<tr>
<td>Red-white</td>
<td>Middle third of the meniscus, at the border of the red vascularized zone</td>
<td>Avascular</td>
</tr>
<tr>
<td>White-white</td>
<td>Central third of the meniscus</td>
<td>Avascular</td>
</tr>
</tbody>
</table>

Fig. 14. Illustration demonstrating the vascularity of the meniscus. Blood flow originates from the periphery (red-red zone) and diminishes as reaches the white-white zone.
History and physical

The diagnosis of meniscal tear can frequently be made from a careful history and physical exam. The onset of symptoms and mechanism of injury are often clues to the diagnosis. Most meniscal tears occur in adolescents and young adults and occur with a twisting injury or with an abrupt change in direction. In the middle age and older adults, it is more common to incur a meniscal tear from squatting or falling. With an acute meniscal tear, an effusion may develop slowly several hours after the injury occurred. This timing of the effusion can aid in deciphering between meniscal injuries and ACL injuries, as the latter typically develop swelling and effusion rapidly after injury. Patients with meniscal injuries localize the pain to the joint line or posterior to the knee. He or she may also describe mechanical symptoms, such as locking, catching, or clicking. Loss of motion with a mechanical block to extension is commonly the result of a displaced bucket handle meniscal tear. In chronic meniscus tears, the patient typically describes intermittent effusions with or without the presence of mechanical symptoms.

A full examination of the lower extremity should be performed in any patient suspected of having a meniscal injury. Inspection should be done to assess for joint effusion, quadriceps atrophy and any joint line swelling. Next range of motion should be assessed to determine if there is a mechanical block to extension or a loss of flexion in comparison to contralateral side. Once this has been performed, menisci specific tests can be initiated.

Typically, palpation of both the joint lines is the first test. Weinstabl et al., found tenderness of the joint line to be the best clinical sign of a meniscal tear with a 74% sensitivity and 50% positive predictive value. The flexion McMurray test is another test used to assess for meniscal pathology. With this test, the patient is lying supine and the examiner flexes his or her knee up, while keeping one hand on the heel and another hand on the knee. When testing for a lateral meniscal tear, the examiner externally rotates the tibia and applies a valgus force to the knee while bringing it into extension. For medial meniscal examination, the examiner must internally rotate the tibia while applying a varus force to the knee. If the examiner feels or hears a click in the knee, the test is considered positive. The McMurray sign has been found to correlate well with meniscal pathology. The Apley
grind test has also been well described. In this test, the patient lies prone on the table with his or her knee flexed to 90°. The examiner then applies an axial load to the heel and internally and externally rotates the tibia. If an audible or palpable click is heard or felt, then the test is considered positive.

**Imaging**

Once a meniscal tear is suspected on exam, the diagnosis can be confirmed with imaging. Plain radiographs should first be obtained to rule out any bony pathology or any pre-existing joint space narrowing secondary to degenerative arthritis. A standard series should include a 45° postero-anterior (PA) weight bearing view of both knees, a true lateral, and a Merchant or sky-line view.

Once radiographs are obtained, more advanced imaging can be performed. With an MRI, the physician has the ability to assess the knee in multiple planes. This test does not involve exposing the patient to any ionizing radiation, and it has the capacity to evaluate other structures within the joint. The main limitation of MRI is its relatively high cost and potential for mis-interpretation or error secondary to artifact and/or technical inadequacies.

The normal appearance of the meniscus on MRI is that of a uniformly low-signal structure. Areas of increased signal within the meniscus occur in children and increase with age in adults. These changes are commonly found within the intra-substance of the meniscus and can be misinterpreted as a meniscal tear. The meniscus grading system was developed in an attempt to minimize the occurrence of MRI misreads. This grading system delineates grades 0, I, II and III (see figure below). Only grade III changes (low signal intensity that abuts the free edge of the meniscus) are consistent with meniscal tearing.64 The classification of meniscal tears is generally based on the pattern of the tear seen at time of arthroscopy. Commonly described patterns include vertical longitudinal, oblique, complex, transverse, and horizontal (Figure 15).

**Treatment**

Despite the perception that all meniscal tears require arthroscopic surgery, there is a role for non-surgical management of these injuries. The management of these patients is predominantly predicated on symptoms. If
Fig. 15. Meniscal tears are typically described based on their morphology and direction of tear.

A meniscal tear does not cause major symptoms or pain, and does not limit the individual in their desired activities, than it is reasonable to manage them non-operatively. It is typically the stable longitudinal tears of less than 10 mm in length with less than 3–5 mm of displacement that are treated non-operatively. Short radial tears and stable partial tears can also be treated non-operatively. The non-surgical management of these patients includes activity modification, ice, NSAIDs, physical therapy and range of motion with general strengthening of the lower extremity.

The surgical indications for patients with meniscal pathology include the patient whose activities of daily living, work and/or recreational activities are impacted and limited by continued pain, swelling and/or mechanical symptoms. The patient may also have positive physical examination findings of joint line tenderness, joint effusion, limitation of motion and provocative signs, such as pain with squatting or positive flexion McMurray or Apley grind test. Typically, surgery is indicated after a course of non-operative treatment and activity modification has failed to relieve his or her symptoms.
Once a patient has been indicated for surgical intervention, it must be decided which type of surgery would best suit the patient. The three surgical options are excision, repair and transplant. Excision (partial meniscectomy) is by far, the most commonly chosen arthroscopic surgery for the treatment of meniscal tears. Previous studies have shown that completely removing the meniscus subjects the knee joint and the specific knee compartment to excessive shear forces, which predisposes the patient to getting advanced degenerative arthritis. Being cognizant of this, during meniscectomy the goal is to only excise the offending area of meniscus and leave behind normal tissue. An attempt is also made to re-constitute the shape and contour of the meniscus such that the native biomechanics of the knee can potentially be restored. This technique is appealing to patients because there is minimal post-operative rehabilitation required and the patient does not need to have limitations on weight bearing status post operatively. In addition, the surgery can typically be done through the two standard (anteromedial and anterolateral) arthroscopic knee portals.

Metcalf et al., have provided general guidelines for arthroscopic resection that apply to most resectable meniscal lesions: (1) All mobile fragments that can be pulled past the inner margin of the meniscus into the center of the joint should be removed. (2) The remaining meniscal rim should be smoothed to remove any sudden changes in contour that might lead to further tearing. (3) A perfectly smooth rim is not necessary. Northmore-Ball et al. evaluated the outcome of patients undergoing partial meniscectomies and found that by adhering to the above principles, 90% of patients had good to excellent results with regards to pain and functionality at short-term follow up (Figure 16).

In order for a patient to be a candidate for a meniscal repair, the tear must occur within the peripheral 10–30% of the meniscus or within 3 or 4 mm of the meniscocapsular junction. Typically, these tears are complete vertical longitudinal tears greater than 10 mm long and ones that can easily be displaced with probing. Repairs should be reserved for the young, active patients with no concomitant intra-articular degeneration and those with an otherwise, ligamentously stable knee.

The inside out arthroscopic technique was popularized in the 1980’s by Dr. Henning and still remains the method of choice for many surgeons today. The inside out technique utilizes double armed sutures with long flexible
Fig. 16.  (A) Arthroscopic view of a torn medial meniscus. Note the displaced tear with fraying of the edges. (B) Arthroscopic debridement taking place of partially torn medial meniscus. (C) Arthroscopic view after partial medial meniscectomy. Note the round, evenly contoured edges with no loosely frayed edges of meniscus.

needles positioned with arthroscopically directed cannulas. A posterolateral or posteromedial incision (depending on which meniscus is being repaired) is used to safely retrieve the suture needles as they exit the joint capsule. The main advantage of this technique is that it can treat all types of tears and affords excellent visualization and fixation (Figure 17).

The outside-in technique was developed in an attempt to decrease the risk to neurovascular structures associated with the inside-out technique. It involved the passage of an 18-gauge spinal needle across the tear from outside to inside the joint. An 0 polydioxanone suture is then passed into the joint through the needle and brought out through an anterior portal, where a knot is tied in the suture. The knot is then pulled back into the joint
Fig. 17. (A) Arthroscopic view of a patient with a left ACL tear who was also found to have a medial meniscal tear (seen above). (B) and (C) View of same patient after an inside out technique was used to fix the torn medial meniscus.

against the meniscus in order to hold it in a reduced position. The free ends of adjacent sutures are then tied together over the joint capsule.70

The all-inside technique is generally indicated for unstable vertical longitudinal tears of the peripheral posterior horns of the menisci. It is accomplished with the use of special devices, with the main goal of reducing surgical time and minimizing complications associated with surgical dissection. The most recent all inside technique devices allow placement of sutures in the meniscus without the aid of an external
incision or a suture fixator system. Typically, an anchoring system is arthroscopically deployed through the meniscus and then a sliding knot is used to tension down the torn meniscus. Regardless of the repair technique, the rehabilitation for meniscal repairs has traditionally been conservative, with protected weight bearing and restriction on range of motion being common.

Meniscal repair success rates vary depending on the criteria selected to evaluate surgical outcome and the presence or absence of concomitant ligamentous injury. A review of the literature found that meniscal tears with rim widths of less than 3 mm, those resulting from acute injuries, and those involving the lateral meniscus seem to have a greater potential for healing. Although patient’s undergoing meniscal repair can have reliable outcomes, these repairs still have a risk a failure. Grant et al. found a 17% incidence of repair failure with the inside-out technique, which is currently considered to be the standard of care.\textsuperscript{71} When evaluating the outside-in technique, Abdelkafy et al. found 12% of patients required subsequent partial meniscectomy.\textsuperscript{72} The all inside technique has shown that fixation with the most recent repair devices is as strong and as reliable as outside-in technique.\textsuperscript{73} Currently, all three techniques are considered effective options for tear fixation and can be used with equal clinical effectiveness.

Meniscal allograft transplantation is a reasonable treatment option for the young patient with symptomatic meniscal insufficiency. Meniscal transplantation is indicated in patients aged less than 40 years with an absent or non-functioning meniscus. The upper limit is 50 years of age for patients who are highly active with only limited arthritis and who are not good candidates for arthroplasty. These patients have pain localized to the affected compartment with activities of daily living or sports and normal mechanical alignments. There are numerous techniques for transplantation, however, the typical principle is to arthroscopically debride the posterior horn and body off the affected meniscus to a 1–2 mm synovial rim, leaving a vascular bed to aid in graft healing. Once this is done, the prepared size-matched allograft meniscus is passed through a small medial or lateral parapatellar arthrotomy into the affected compartment. Bridge in slot and bone plug techniques have been described for meniscal allograft transplantations, allowing for bony healing to the tibial plateau. The soft tissue portion of the meniscus allograft is then fixed in place
by suturing it to the remaining synovial rim via an inside-out technique (Figure 18).\textsuperscript{74}

Sekiya et al. evaluated 25 patients who underwent isolated lateral meniscal transplantation at an average follow-up of 3.3 years.\textsuperscript{74} In these patients, 79% had normal or nearly normal scores according to IKDC knee function, activity level and overall subjective ratings. The average scores for the singe-leg hop and vertical jump tests were 90% and 85%, respectively, of the contralateral limb and there was no joint space narrowing seen over time on radiographic examination. Despite these promising results, meniscal allograft transplantation is technically demanding and should be considered a salvage operation for symptomatic meniscal deficiency in the young patient. In the correct patient population, this procedure can predictably relieve compartmental pain and may also partially restore native meniscal function, as is seen with slowing of the degenerative arthritic process in transplanted meniscus-deficient knee compartments.

**Cartilage Injury**

*Introduction*

Injuries to articular cartilage can be difficult to diagnose and treat. They can range from trauma causing impaction damage to the articular surface
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to full thickness cartilage lesions. On one side of this spectrum; softening, fibrillation, flap tears, cracking or delamination of the articular surface can be treated with protected weight bearing, or arthroscopic evaluation and chondroplasty of any unstable flaps or loose fragments. This section will focus on osteochondritis dissecans and full thickness cartilage lesions.

Osteochondritis dissecans (OCD) is a lesion of the articular cartilage that involves the subchondral bone. The cause of OCD lesions is unknown, but may be due to repetitive trauma, ischemia, genetics and problematic ossification. The involved area may develop delamination, sequestration or instability. The exact incidence is unknown, but it is estimated between 15 and 29 per 100,000. OCD lesions are more common in males, and found to be bilateral in up to 25% of patients. In the knee, most OCD lesions are found in the lateral aspect of the medial femoral condyle (Figure 19).

Full-thickness cartilage lesions caused by blunt trauma or shear stress are a different entity than OCD lesions. They have limited potential for self-healing. The majority of patients report an athletic event as the inciting event

Fig. 19. OCD lesion seen on MRI, located on lateral aspect of medial femoral condyle.
associated with the diagnosis of a chondral lesion. Most commonly, they are encountered during arthroscopy and are associated with meniscal tears, ACL tears and patellar dislocations. The most common location of these lesions are the medial femoral condyle and the patella.\textsuperscript{80,81} The continuum of contusion to cartilage damage can be classified based on the Outerbridge classification.\textsuperscript{82}

**Work up**

A meticulous history and physical examination is necessary as patients with OCD lesions can have poorly localized pain. There may not be a history of injury or trauma. Patients may report pain with higher activity levels and sports participation. If mechanical symptoms are present, such as locking or catching this may represent a loose osteochondral fragment. Patients may complain of intermittent knee swelling. On the contrary, patients with full thickness cartilage lesions will describe a traumatic event or previous surgery. The pain is often localized to the affected compartment. In some instances, synovitis develops and more diffuse pain is present. Mechanical symptoms maybe present if there is a loose body in the knee joint, however the predominant physical exam findings are effusion, tenderness to palpation and limited range of motion due to pain.

Plain radiographs should be obtained for all patients with suspected articular cartilage damage. Joint space narrowing, subchondral fractures, and/or limb malalignment may be present. Weight bearing views may help detect subtle affected compartment narrowing. Multiple views should be obtained including anteroposterior, lateral and sunrise views to have a full evaluation of all joint surfaces in the knee. Posteroanterior flexion views may help delineate posterior femoral condyle lesions. X-ray findings may be underwhelming compared to the symptomatology the patient is experiencing.

MRI can be useful to further evaluate the articular surface in more detail. MRI findings consistent with cartilage lesions include surface irregularities or reduction of thickness. Bone reaction can be observed in higher grade cartilage lesions as well. Friemert \textit{et al.} conducted a study aimed at evaluating the efficacy of MRI to diagnose chondral lesions. Comparing the findings of MRI with the gold standard of diagnostic arthroscopy, it
was found that the sensitivity of MRI was 33–53% and the specificity was 99% and 98% in both of their study groups, respectively.83

**Surgery**

The treatment algorithm for OCD lesions can be broken up based on age of the patient, site and stage of involvement. Non-surgical management is indicated for stable OCD lesions in a child or adolescent with open physes due to their high healing potential. Non-surgical management involves a period of non-weight bearing with crutches, followed by rehabilitation exercises. Protected weight bearing should be carried out for a minimum of 6–12 weeks and once clinical or radiographic signs of healing appear, then a gradual increase in activity and weight bearing can be done. In juvenile OCD cases, there are reported success rates of up to 50–75% with non-surgical treatment. Indications for surgical treatment include size and locations of the lesion, skeletal maturity and lesion instability as these have been showing to have lower success rates with non-surgical management. The goal of surgery is to maintain or restore joint congruity and to have rigid fixation of unstable fragments. Surgical procedures involve anterograde or retrograde arthroscopic drilling of stable lesion and debridement of unstable lesions. Marrow stimulation techniques are indicated for lesions less than 2 cm in size. Fixation for unstable, salvageable lesions can be performed with Herbert screws, cannulated screws, bioabsorbable screws or pins, or osteochondral transplants. Osteochondral allograft transfer system (OATS), osteochondral allograft reconstruction and autologous chondrocyte implantation (ACI) are also options for OCD lesion treatment.

Non-surgical treatment of full thickness cartilage lesions is also tried initially. This consists of activity modification, rest, ice, compression and non-steroidal anti-inflammatory medications. Physical therapy may be helpful, particularly if quadriceps and hamstring atrophy is present. In certain patients, intraarticular corticosteroid injections, viscosupplementation and unloader braces can be useful.

Surgical treatment is indicated if non-operative treatment fails. Two broad categories of surgical interventions exist: reparative marrow stimulation techniques and restorative techniques. Marrow stimulation techniques include drilling, abrasion condroplasty and microfracture. They induce
bleeding, hematoma formation, stem cell migration and production of a fibrocartilaginous repair tissue. While marrow stimulation techniques help restore the congruity of the articular surface, the resultant fibrocartilage repair has poorer biomechanical and biologic properties than hyaline cartilage. Restorative techniques includes autogenous chondrocyte implantation (ACI) or osteochondral allograft transplantation (OATS). These aim to replace the injured articular cartilage with hyaline cartilage. ACI involves the arthroscopic harvest of cartilage from areas of lesser weight bearing in the knee. Chondrocytes are then extracted and expanded in culture in the lab. In a second surgery, the defect is prepared and the cultured chondrocytes are injected under a patch over the defect. The goal is to provide the defect with better histologic tissue than microfracture, however the results are comparable to microfracture. OATS replaces the cartilage defect with live chondrocytes along with underlying bone. The grafts may be large, bulk allografts that are fixed with screws or smaller shell allografts. The goal is to match the size and radius of curvature of the donor tissue with that of the defect. OATS provides the ability to address larger defects and is useful in revision settings. However, there is limited availability of the donor tissue and it is associated with high cost.

**Outcome**

Marrow stimulation techniques are criticized due to the replacement of hyaline cartilage defects with fibrocartilage, however, if treating smaller defects (<4 cm$^2$), good results are seen in 60–80% of patients.$^{84,85}$ Autologous chondrocyte implantation has reported results of up to 80% of patients with good to excellent results.$^{86}$ Osteochondral autograft transplantation has shown good to excellent results in 90% of condylar lesions, 80% of tibial defects, and 70% of trochlear lesions.$^{87}$ Nevertheless, there is a paucity of evidence that shows one procedure is better than the other.

**Medial Collateral Ligament Injury**

**Introduction**

The MCL is the most commonly injured ligament in the knee. As such, there are basic treatment principles of these injuries that are important for
both primary physicians and orthopedic surgeons alike. The true incidence may be underestimated due to lack of reporting for lesser grades of injury. Concomitant ligamentous injuries occur in 20% of grade III injuries.

**Anatomy**

The medial capsuloligamentous complex is comprised of a three-layered sleeve of static and dynamic stabilizers. Its main function is to resist valgus and external rotation loads. The static stabilizers are comprised of the superficial MCL, the posterior oblique ligament and the deep MCL. The superficial MCL is the primary restraint to valgus loads, while the posterior oblique and deep MCL and cruciates are the secondary restraints to valgus loads about the knee. The dynamic stabilizers are the semimembranosus complex, the pes anserinus muscle group, the vastus medialis, and the medial retinaculum. These dynamic stabilizers provide abduction stability when the knee is in motion.

**Evaluation**

As any injury about the knee, a detailed history is crucial to the evaluation. In lesser degree MCL sprains, the injury is typically a non-contact valgus, external rotation force. This is in contrast to the complete disruption of the MCL, which is usually the result of a direct blow the lateral aspect of the knee. The ability to ambulate and continue to participate in athletic activities depends on the degree of disruption and the presence of any concurrent injuries.

On physical exam, the knee should be inspected for any ecchymosis, localized tenderness, or presence of an effusion. Valgus stress testing should be performed with the knee at both 0° and 30° of flexion. With the knee at 30° of flexion, the superficial MCL (the primary restraint to valgus stress) can be isolated. Comparison with the contralateral knee is necessary to compare the amount of joint line opening. Based on the American Medical Association classification, an injury grade is defined by the amount of joint line opening with valgus stress. In grade I injuries, there is <5 mm of medial joint line opening. In grade II injuries, there is 5–10 mm of joint line opening. While grade III injuries are comprised of those knees with greater than 10 mm of joint line opening. If valgus laxity is noted with
the knee in full extension, then this may imply a concurrent injury to the posteromedial capsule and/or cruciate ligaments.

The degree of MCL injury can also be assessed through physical exam by evaluating the quality of the end point felt with valgus stress. A patient with a first-degree sprain presents with tenderness over the MCL but no instability. With a second-degree sprain, there is increased valgus laxity, but a firm end point still exists. A third-degree sprain has no end point to valgus stress. One should remember that “grade” and “degree” are two distinct terms, however, in the literature and in discussion, they are often incorrectly used interchangeably. As these injuries are often associated with concurrent knee injuries, a full ligamentous and meniscal exam should be performed for all patients with suspected MCL injury.

**Imaging**

Plain radiographs are typically normal in these patients, however, should still be obtained and thoroughly inspected for fractures, lateral capsular avulsions (Segond fracture), and Pellegrini Stieda lesions, which are indicative of prior MCL injury. Stress radiographs may also be indicated in skeletally immature individuals to rule out possible physeal injuries. Once radiographs are obtained, the next imaging modality commonly utilized is magnetic resonance imaging. MRI has become the imaging modality of choice for all soft tissue injuries about the knee. The main advantage of MRI in evaluating MCL injuries is that an MRI is able to identify the location and extent of injury. It is also useful in ruling out associated meniscal, chondral and cruciate injuries. Despite this advantage, one must be mindful that an MRI is reader-dependent, and may overestimate the degree of injury. For this reason, imaging should never supersede patient symptomatology and physical findings.

**Treatment**

Typically, isolated MCL injuries are treated conservatively. Conservative management includes the use of crutches, ice, compression, elevation, anti-inflammatory medications and activity modification. The extra-articular location of the MCL allows for abundant blood supply to be increased in times of stress, unlike intra-articular injuries such as cruciate ligament or meniscal
For grade 1 injuries, no brace is required and the patient can use crutches as necessary. A knee immobilizer or hinged knee brace is often recommended for grades II and III injuries. Quadriceps strengthening exercises (i.e. straight-leg raises) can be initiated immediately for all injuries. Cycling and progressive resistance exercises can be started when tolerated. In grades II and III injuries, a low profile, hinged knee brace should be used while initially returning to sports.

Despite the fact that a majority of these injuries are treated non-operatively, there are certain instances in which surgery is indicated. These include isolated grade III injuries with persistent instability despite attempted supervised rehabilitation and bracing, grade II injuries with valgus laxity in full extension, ligament entrapment within the medial compartment seen on MRI, chronic valgus instability with associated cruciate deficiency, and grade III injuries with ACL, PCL or ACL/PCL combined injuries.

In acute injuries that meet one of the above surgical indications, an acute MCL repair can be performed. If the injury sustained was a ligament avulsion, the ligament should be reattached with suture anchors while the knee is in $30^\circ$ of flexion. This will ensure that there is no remaining laxity of the superficial MCL following repair. If there is interstitial disruption, than attachment of the MCL to its femoral and tibial origins is warranted with anterior advancement. Some authors also recommend advancing the posterior oblique ligament (POL) anterosuperiorly to the adductor tubercle and distally to the tibial metaphysis. As found by Hughston et al., this technique provided improved stability to valgus stress at $45^\circ$ of flexion. Diagnostic arthroscopy is recommended to rule out any associated intra-articular damage that may not be seen on preoperative MRI.

In chronic injuries, if sufficient tissue remains, proximal advancement of the femoral origin of the MCL with attached bone block and advancement of the POL can be performed. If there is insufficient remaining tissue to perform this technique, a semitendinosus autograft may be used to reconstruct the superficial MCL with isometric fixation using a screw and washer to the medial epicondyle. Other options for grafts include allograft HS, tibialis anterior or Achilles tendon.

Surgical repair/reconstruction has routinely shown acceptable outcomes. Yoshiya et al. found normal or nearly normal knee scores in 24 out of
27 patients according to the International Knee Documentation Committee criteria. Additionally, under valgus stress testing, all patients had a side-to-side difference of less than or equal to 2 mm. Reconstruction of the anterior fibers of the superficial MCL was found to be of primary importance in this cohort.92

Multi-Ligament Knee Injury

Knee dislocations represent a small subset of hospital admissions throughout the United States. This is largely under-reported as most knee dislocations probably spontaneously reduce prior to presentation. Knee dislocations are associated with frank disruption of multiple aspects of the knee, including both the ACL and PCL, one or both of the collateral ligaments, as well as significant capsular, meniscal and bony injuries. They typically present after high energy trauma, however low energy mechanisms have been observed for patients with baseline ligamentous laxity and obesity.

The treatment goals of knee dislocations and multiligament knee injuries are to create a reduced, stable joint initially. Ligament reconstruction is now recommended since non-operative treatment of these injuries have been associated with poor outcomes. The timing, operative technique, graft selection and rehabilitation options have garnered significant debate and controversy. There exists a relative paucity of data to direct surgeons due to inconsistent treatment protocols, small and poorly defined patient populations and a variety of surgical techniques described in the literature.

Summary

Knee injuries represent a large part of all medical visits in the United States. The majority are related to injuries suffered from athletic activity or trauma. The incidence is under-represented in the literature as many of these injuries are underdiagnosed. It is important to develop a systematic way to evaluate a patient with a suspected knee injury in order to detect pathology and treat it accordingly. The treatment for knee injuries is largely non-operative, however when ligament, cartilage or meniscal injuries have continued pain, instability and disability, surgical intervention is warranted. The diversity
of surgical interventions available for these injuries require the practitioner to be familiar with many different techniques and with outcome measures in order to employ the appropriate treatment for their patients. The goal of surgery is to restore mechanical alignment, stability, and prevent further degeneration of the knee joint. Outcomes are generally good to excellent with most patients able to return to work and sport.

References


