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Management of Medial-Sided Ligamentous Laxity and Posteromedial Corner

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Anatomy and Function

Medial collateral ligament (MCL) knee injuries are closely linked to participation in sports such as soccer, American football, ice hockey, and skiing. Because participation in these activities continues to increase, the incidence of MCL injuries continues to grow [1, 2]. In order to understand injuries to the medial aspect and posteromedial corner (PMC) of the knee, it is important to appreciate the local anatomy.

Fig. 11.1 Sagittal magnetic resonance image depicting the convex on concave articulation of the medial knee

The medial and PMC primarily act to prevent valgus motion of the knee. The PMC extends from the medial aspect of the patellar tendon to the medial border of the gastrocnemius tendon. It has five major structures, the superficial MCL (sMCL), deep MCL (dMCL), posterior oblique ligament (POL), oblique popliteal ligament (OPL), and posterior horn of the medial meniscus (PHMM) [3]. Additionally, the semimembranosus and its respective expansions provide dynamic stability to the PMC. The bony anatomy of the medial aspect of the knee is formed by the medial femoral condyle and the medial tibial plateau, which articulate in a convex on concave fashion (Fig. 11.1). This inherently stable articulation helps facilitate healing of the MCL concurrent with its dense vascularization [3].

The *superficial medial collateral ligament* (sMCL) is the largest structure of the medial aspect of the knee and serves as the primary restraint to valgus forces. The femoral attach-

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ment is centered approximately 3.2 mm proximal and 4.8 mm posterior to the medial epicondyle. These landmarks are particularly important during reconstructive procedures. There are two distinct tibial attachments. The proximal tibial attachment is found directly over the anterior arm of the semimembranosus, approximately 11.2 mm distal to the joint line. The distal tibial insertion attaches directly to the medial aspect of the tibia, 61.2 mm distal to the joint line. In total, the sMCL is approximately 9–10 cm in length and is the largest structure on the medial aspect of the knee (Figs. 11.2 and 11.3) [3].

The *deep medial collateral ligament* (dMCL) is essentially a thickening of the medial joint capsule. It is deep and mildly adherent to the sMCL. The dMCL has a distinct meniscofemoral portion that attaches distal and deep to the femoral attachment of the sMCL. It also has a meniscotibial portion that is much shorter and thicker, which attaches just distal to the edge of the articular cartilage of the medial tibial plateau [3].

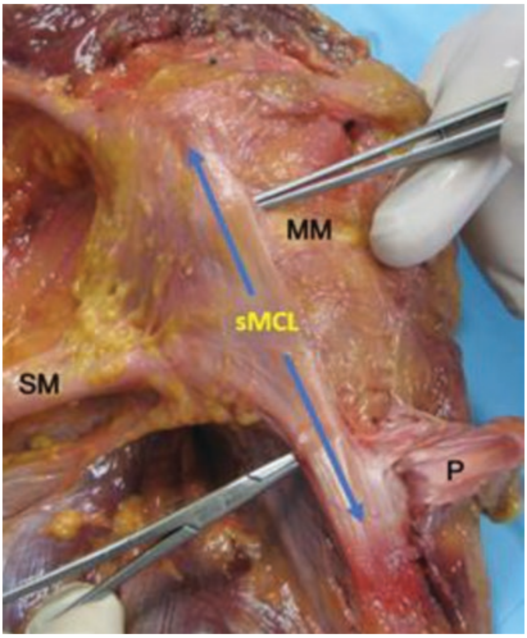


Fig. 11.2 Dissection of the major structures of the medial knee with the pes tendons reflected. *sMCL* superficial medial collateral ligament, *MM* medial meniscus, *SM* semimembranosus, *P* pes tendons

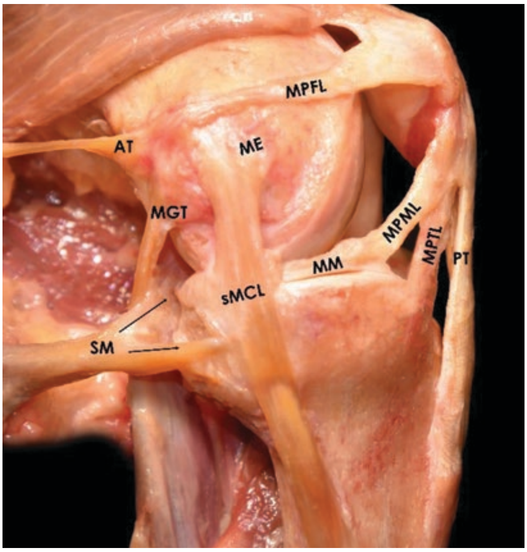


Fig. 11.3 Dissection of the major structures of the medial knee. *AT* adductor magnus tendon, *MPFL* medial patellofemoral ligament, *ME* medial epicondyle, *MGT* medial gastrocnemius tendon, *SM* semimembranosus, *sMCL* superficial medial collateral ligament, *MM* medial meniscus, *MPML* medial patellomeniscal ligament, *MPTL* medial patellotibial ligament, *PT* patellar tendon

The *posterior oblique ligament* (POL) consists of three fascial attachments: the superficial, central, and capsular arms. They course from the distal aspect of the semimembranosus tendon and travel longitudinally across the joint line. The POL attaches on the femur 7.7 mm distal and 6.4 posterior to the adductor tubercle and 1.4 mm distal and 2.9 mm anterior to the gastrocnemius tubercle [3–5]. These anatomical landmarks are particularly important as the POL is reconstructed during anatomic reconstruction of the PMC. The superficial arm of the POL blends with the central arm proximally, and distally it courses parallel to the posterior aspect of the sMCL until it blends with the distal tibial expansion of the semimembranosus and its respective tibial attachment [3, 6]. The central arm of the POL is the largest and strongest of the fascicles and originates from the distal aspect of the semimembranosus tendon. During its course, the central arm provides reinforcement for both the meniscofemoral and meniscotibial portions of the posteromedial capsule, with a robust attachment to the medial meniscus. Anteriorly, the central arm merges with the sMCL. The capsular arm of the POL originates off the distal aspect of the semimembranosus tendon, just posterior and lateral to the meniscofemoral capsular attachments of the central arm. This arm primarily blends with the posteromedial joint capsule and the medial aspect of the OPL. Moreover, it has lesser attachments to the medial gastrocnemius tendon, the adductor magnus tendon expansion, and the adductor magnus tendon femoral attachment site. Of note the capsular arm has no osseous attachment site. Functionally, the POL provides both static and dynamic resistance to valgus forces and has a secondary role to prevent posterior tibial translation (Fig. 11.4) [3].

The *semimembranosus tendon* bifurcates just distal to the joint line and forms anterior and direct arms. The direct arm inserts distally into a small groove just distal to the tuberculum tendinis, which lies posterior to the medial tibial crest. The anterior arm passes deep to the POL and attaches to the tibia in an oval fashion, just distal to the joint line and deep to the proximal tibial attachment of the sMCL. The anterior branch of the tendon blends with the capsular arm of the POL, which then merges with the posteromedial joint capsule with a reported attachment to the posterior inferior margin of the PHMM [3, 7, 8]. The distal border of the semimembranosus bursa can be found along the proximal edge of the tibial attachment site of the direct arm. The semimembranosus bursa is found medial to the anterior arm of the semimembranosus tendon, until the anterior arm attaches to the posteromedial aspect of the tibia.

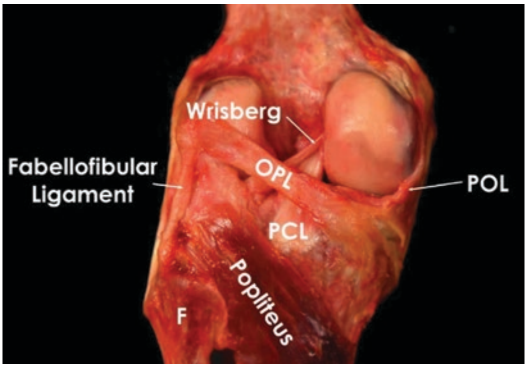


Fig. 11.4 Dissection of the posterior knee. One can visualize the course of the posterior oblique ligament (POL) along the posterior aspect of the knee. *OPL* oblique popliteus ligament, *PCL* posterior cruciate ligament, *F* fibula; Wrisberg, ligament of Wrisberg

The *oblique popliteal ligament* (OPL) is a broad fascial band that courses longitudinally across the posterior aspect of the knee. It arises from the capsular arm of the POL and the lateral expansion of the semimembranosus tendon and extends laterally until reaching its two attachment sites. The proximal and lateral attachment site is to an osseous or cartilaginous fabella, the meniscofemoral portion of the posterolateral joint capsule and the plantaris muscle. The distal and lateral attachment location is just lateral to the posterior cruciate ligament and distal to the posterior root attachment of the lateral meniscus on the tibia. The average length of the OPL has been reported to be 48 mm (Fig. 11.4) [3].

The *posterior horn of the medial meniscus* (PHMM) is intimately associated with the posteromedial capsule, the POL, and the semimembranosus tendon expansion. Together, these structures form a cascade-type system in which the function of each structure is dependent on the neighboring structures. The posteromedial capsule has an average reported length of 21.3 mm, whereas the PHMM has an average length of 20.2 mm and is essentially confluent with the entire length of the posterior capsule [8]. The posterior horn is stabilized further by the meniscotibial portion of the dMCL which helps prevent anterior tibial translation. The PHMM is the most important weightbearing portion of the meniscus [3].

The *medial gastrocnemius tendon* is rarely injured, which makes it an important surgical landmark. The medial gastrocnemius originates from a small depression just proximal and adjacent to the gastrocnemius tubercle at an osseous prominence located over the posteromedial edge of the medial femoral condyle [3]. The tendon courses posterior to the sMCL and deep to the semimembranosus tendon. Distally, this tendon extends to form the muscle belly of the medial gastrocnemius muscle (Fig. 11.5) [3].

The *adductor magnus tendon* attaches at a small bony depression 3 mm posterior and

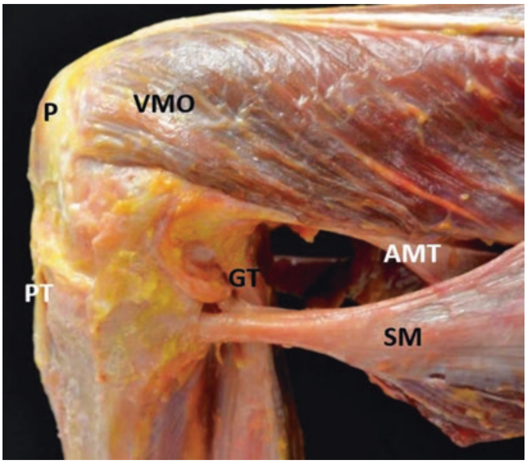


Fig. 11.5 Dissection of medial knee with knee flexed. *P* patella, *PT* patellar tendon, *VMO* vastus medius obliquus, *GT* medial gastrocnemius tendon, *AMT* adductor magnus tendon, *SM* semimembranosus

2.7 mm proximal to the adductor tubercle. This is rarely injured, and thus it is usually used as an anatomical reference for medial-sided reconstructions. Additionally, it has a thick fascial attachment which extends posteriorly from the distal aspect of the tendon to attach to the proximal aspect of the medial gastrocnemius tendon and posteromedial joint capsule [3].

The *vastus medius obliquus* (VMO) has its primary origin from the adductor tubercle in addition to lesser origins from the adductor magnus tendon and the medial intermuscular septum. The distal border of the VMO has an intimate relationship with the proximal edge of the medial patellofemoral ligament (MPFL) as they course together until reaching the patella at which point the fibers of the VMO begin to merge into the quadriceps tendon (Fig. 11.5).

The *pes anserinus* tendons attach at the anteromedial aspect of the proximal tibia. From proximal to distal, the tendons attach in the following order: sartorius, gracilis, and semitendinosus. Collectively, they form the roof of the pes anserine bursa, which can be implicated in a variety of pathologies (Fig. 11.6) [9].

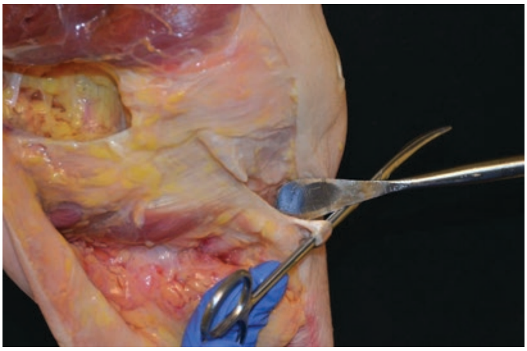


Fig. 11.6 Medial dissection of a left knee demonstrating the anatomical location of the pes tendons (hamstring tendons)

The *saphenous nerve* is the largest cutaneous branch of the femoral nerve and arises from the femoral nerve between the gracilis and semitendinosus tendons. The saphenous nerve further branches into the *infrapatellar branch* just distal to the adductor canal [10, 11]. The infrapatellar branch of the saphenous nerve provides sensory innervation to the proximal part of the lower leg, the anteroinferior part of the knee joint capsule, and the anterior aspect of the knee. It courses either posterior or anterior or through the main saphenous nerve [12].

The *medial superior and inferior genicular arteries* are both found on the medial aspect of the knee. The superior medial genicular artery originates from either the superficial femoral artery or popliteal artery and joins with the superior lateral genicular artery slightly superior to the patella and just anterior to the quadriceps tendon [13, 14]. The inferior medial genicular artery originates from the popliteal artery and courses deep to the sMCL between its two tibial attachment sites below the medial tibial plateau. From there, it rises on the anterior aspect of the tibial plateau where it forms and anastomoses with the peripatellar anastomotic ring [14].

Biomechanics

Although the medial aspect of the knee contains numerous structures, the sMCL, dMCL, and POL serve as the primary functional static stabilizers. Collectively, their main function is to resist valgus forces, with secondary roles in resisting internal and external rotation and resisting anterior and posterior tibial translation [15, 16].

Biomechanical studies have shown that in a MCL-deficient knee, the ACL has secondary valgus stabilizing responsibilities and faces a 185% increase in tension with the application of a valgus force [17]. As such, MCL stability and functionality have an integral role in preventing ACL graft failure following reconstruction [18].

The proximal division of the sMCL is the primary static stabilizer to valgus rotation at 0–90°. Further, at 90° of flexion, it acts as a secondary stabilizer to external rotation, and at 0–90°, the proximal aspect of the sMCL is a secondary stabilizer against internal rotation [15, 19]. The distal division acts primarily on rotational stabilization, as it is the primary stabilizer against external rotation when the knee is at 30° of flexion, and internal rotation at 20–90° of flexion [15]. Previous literature has reported that the mean load at failure for the sMCL with the intact femoral and distal tibial attachments is 557 N. Mean load at failure is 88 N for the intact femoral and proximal tibial divisions of the superficial MCL.

The meniscofemoral division of the dMCL, which is the most common location for structural failure of the dMCL, provides primary stability against internal rotation at 20–90° and secondary external rotational stability at 30° and 90° [4, 19]. Further, the meniscofemoral division provides valgus stabilization at 0–90° and secondary internal rotational stability at 0–30°. The meniscotibial arm of the dMCL functions as a secondary valgus stabilizer at 60° of flexion and a stabilizer against internal rotation at 0–90° of flexion. Collectively, the average load at failure for the dMCL was 100.5 N [19].

The POL is the primary restraint to internal rotation and acts as a secondary stabilizer against valgus force [15]. Further, the POL has a minor role in resisting anterior and posterior tibial rotation [15]. In sectioning studies, the average load at failure for the POL was 256.2 N [19].

Case Presentation: Subjective

Patient is a 65-year-old female that presented to clinic with chronic right knee pain and instability. The patient has a past medical history significant for right knee ACL reconstruction 2 years prior with a different surgeon. The patient notes that at that time she fell off a ladder and her right leg got caught in the ladder; she felt her knee bend inward. At that time, she was diagnosed with a combined ACL and MCL tear. Her ACL was reconstructed acutely, and her MCL tear was managed conservatively with a hinged knee brace. Upon current presentation, she reports significant functional limitations when not wearing the knee brace. Her pain and side-to-side instability are significantly impacting her ability to do work around the house and attend fitness classes.

Mechanism of Injury and Clinical Presentation

Patients with medial knee injuries usually present after having sustained a valgus stress to the knee, typically in the setting of contact or sport. As such, it is essential to obtain a thorough injury history, including inciting events, chronicity, and the reported localization of the symptoms. They typically have localized pain and swelling along the meniscofemoral or meniscotibial division of the MCL. For patients with severe, grade III, full-thickness sMCL ruptures, they typically have side-to-side instability with a valgus thrust on gait analysis and may have difficulty with physical activity [20].

The physical exam can be highly diagnostic for a MCL tear, particularly in the acute setting. Care should be taken to inspect the skin for any signs of abrasions, lacerations, contusions, or localized swelling [3]. Next, the clinician should palpate the joint, making sure to individually palpate the meniscofemoral and meniscotibial divisions of the medial structures of the knee. In addition to the classic knee exam to rule out concomitant injury, there are several medial knee-specific clinical exam maneuvers to consider. The valgus stress test is performed when a valgus force is applied to the knee in full extension and also at 20°. The medial joint line should be palpated to help estimate the amount of medial compartment gapping. Typically, increased medial compartment gapping in full extension is characteristic of a more significant injury with a possible cruciate ligament tear. Valgus stress testing at 20° predominately isolates the sMCL. The anteromedial drawer test is performed with the knee flexed to 90° and the foot external rotated 10°. In this position, a coupled anterior and external rotary force is applied to the knee. An increased amount of anteromedial rotation during this test heightens the suspicion for an injury to the distal aspect of the sMCL, POL, and meniscotibial portion of the dMCL. Finally, the dial test should also be performed at both 30° and 90° of knee flexion. The dial test is considered positive when there is greater than 15° of increased external rotation compared to the contralateral limb at both 30° and 90°. Of note, it is important for the clinician to perform this test while palpating the joint and with the patient in both the supine and prone positions to help differentiate between a posterolateral corner injury, posteromedial corner injury, and meniscal root tear [20]. It is also essential to assess gait on patients with suspected medial-sided instability.

Further, medial-sided knee injuries can present secondary to ACL deficiency. In sectioning studies, Lujan et al. [21] reported that after sectioning the ACL, the load on the MCL was significantly larger at peak anterior translation, while the tension was not significantly affected after a valgus applied force [21]. Specifically, at 30° of flexion with anterior translation, the load on the MCL was significantly greater. This conclusion suggests that ACL deficiency can contribute to medial-sided laxity and should be addressed in order to prevent increased load on the MCL.

Case Presentation: Physical Exam

On physical examination, the patient had a 1+ Lachman's test. Her valgus stress test at 30° was a 3+, and at full extension, she had 2+ valgus gapping. Her anteromedial drawer test was normal. Her dial test demonstrated approximately 20° of side-to-side difference at both 30 and 90°. The patient had an obvious valgus thrust gait when not wearing a hinged knee brace.

Diagnosis and Imaging

Any suspicion for medial knee injury, either acute or chronic, warrants bilateral physician-applied valgus stress radiographs. Typically, these are performed with the knee at 20° flexion with a foam bolster under the knee. With a 10 N clinician-applied valgus stress, the radiographs are assessed for side-to-side differences compared to the normal contralateral knee in medial compartment gapping [20]. LaPrade et al. [22] reported that at 20° an isolated grade III sMCL tear results in 3.2 mm of increased side-to-side medial compartment gapping. A complete tear of the sMCL, dMCL, and POL resulted in 9.8 mm of increased side-to-side medial compartment gapping at 20° [22]. Valgus stress radiographs are particularly valuable in the chronic setting when the results of the clinical exam are unclear [20]. Further, they are particularly of value as the results are both objective and reproducible (Fig. 11.7).

Standard anteroposterior and lateral radiographs should also be obtained to assess for concomitant fracture or avulsions. Avulsions near the native attachment sites of the sMCL should increase the clinical suspicion for medial-sided instability. Additionally, the Pellegrini-Stieda syndrome, which is characterized by intra-ligamentous calcification in the region of the attachment sites of the sMCL, can be identified radiographically and addressed with either observation or surgical excision [23–25]. Further, full-length weightbearing radiographs should be obtained to assess for coronal plane limb alignment for chronic MCL tears because valgus alignment leads to an increased risk for medial instability. If valgus alignment is identified in chronic cases, alignment correction via osteotomy should be considered prior to or concurrent with surgical intervention for the medial soft tissues because the grafts would otherwise be at risk of stretching out [26].

Magnetic resonance imaging (MRI) is also useful to help diagnose injuries to the medial knee, particularly in the acute setting. Generally, MR images have been reported to have an accuracy and sensitivity of 86% for diagnosing acute

Fig. 11.7 Stress radiographs used to identify medial knee laxity. The left image demonstrates 11.59 mm of medial gapping on pre-operative valgus stress testing. The image on the right is at 6 months post-operation and demonstrates 8.36 mm of medial gapping on valgus stress radiographs

grade III sMCL injures [27, 28]. Besides sMCL attenuation or increased signal intensities, clinicians should look for the presence of lateral compartment bone bruises which have been reported to be present in 45% of isolated sMCL tears [29]. Further, MRI can help diagnose concomitant knee injuries that may have a significant impact on medial-sided laxity and will compromise any potential surgical intervention (i.e., cruciate or meniscal pathology).

Case Presentation: Imaging

On valgus stress radiographs at 20° of knee flexion (Fig. 11.7), the patient had 11.6 mm of medial compartment gapping and 6.8 mm of increased side-to-side difference. Further, MRI results revealed the ACL graft was intact with mild widening of both femoral and tibial tunnels, there was mild lateral compartment osteoarthritis, she had a moderate knee effusion, and a chronic tear of the MCL was evident. Full-length weightbearing radiographs demonstrated that the patient was in neutral alignment.

Classification

The degree of MCL injury is most commonly classified by the amount of medial compartment gapping noted with the application of valgus stress, either subjectively on clinical exam or objectively on valgus stress radiographs. Subjectively, grade I injuries have medial knee tenderness with mild soft tissue swelling and no instability; grade I injuries have 1–5 mm of increased, side-to-side medial compartment opening. Grade II injuries have broad tenderness and partially torn medial structures; they have 5–10 mm of increased, side-to-side medial compartment opening. Grade III injuries have complete medial knee disruption with no clear endpoint on valgus stress examination with the knee at 20° of flexion; these injuries demonstrate greater than 10 mm of subjective increased, side-to-side medial compartment opening [26].

The objective radiographic classification of a complete isolated MCL tear is diagnosed when there is greater than 1.7 mm side-to-side gapping with the knee at 0° of flexion or greater than 3.2 mm of gapping at 20° of flexion. Further, a complete medial knee tear (sMCL, POL, dMCL) is diagnosed with greater than 6.5 mm gapping with the knee at 0° flexion or greater than 9.8 mm gapping with the knee at 20° flexion [22].

Case Presentation: Classification

Given the physical exam and corroborating imaging results, the patient was diagnosed with a grade III, or complete, medial-sided injury. Given the literature and the findings on her stress radiographs, it is likely that her sMCL, POL, and dMCL are each involved.

Treatment Options

Precise identification of the tear location is imperative in the treatment decision process. Recognizing the specific injury location becomes important because tears involving the distal tibial attachment site of the sMCL have been reported to be less likely to heal with conservative management [30–32]. Further, injuries that present with medial compartment gapping when the knee is in full extension are likely more significant with either grade III sMCL or concomitant cruciate or meniscal injury. These injuries are less likely to heal with conservative management [15, 22].

Conservative Management

Almost all isolated grade I or II sMCL injuries can initially be treated conservatively, particularly those that occur in the acute setting [5, 33]. Furthermore, treatment of isolated sMCL tears has been reported to provide good or excellent subjective patient-reported outcomes as defined by the Hospital for Special Surgeries Knee Score [34–38]. Cast immobilization in these types of patients should be avoided to prevent residual stiffness and to encourage ligament healing. Animal models have reported that immobilization of the collateral ligaments has detrimental effects on their cellular metabolism [39, 40].

Non-operative intervention with physical therapy begins with symptom management, which includes relative rest, cryotherapy, joint compression, and early range of motion (ROM) in a varus-valgus constrained knee brace. Early ROM is desirable because it has been found to promote increased collagen proliferation and organization that contribute to increased tissue strength while simultaneously avoiding the deleterious effects of immobilization (ground substance leaching at ligament attachment sites and decreased biomechanical properties of the ligament) [41, 42]. Patients may be restricted to partial weightbearing in the early stages of treatment if they are unable to walk without a limp or experience increased symptoms of joint pain and/or swelling with gait. The brace is worn with gait to minimize valgus or rotational stress through the medial knee. Early goals are to create a protective environment for healing, reduce joint irritability (pain and swelling), and gradually restore full joint range of motion, a strong volitional quadriceps activation, and normal functional movement patterns. Electrical stimulation to the quadriceps muscle is beneficial early on, because it is effective in over-riding the volitional quadriceps activation deficit that occurs secondary to knee ligament injury [43, 44]. Hamstring muscle activation and strengthening should be phased in gradually, as the medial hamstring's insertion proximity to the zone of injury may contribute to pain and irritation with heavy resisted training. A gradual and progressive muscle training program for quadriceps and hamstring muscles, as well as the other large muscle groups of the hip and lower limb, should be conducted, graduating from muscular activation to endurance, hypertrophy, strength, and finally power exercises. Postural stability and balance should be addressed to improve limb and trunk motor control and reduce the risk of reinjury [45]. Sport-specific training progressions may be implemented as individual muscle strength testing and athletic performance measures (Y-balance, hop testing) demonstrate first >80% limb symmetry index (LSI) and eventually >90% LSI. Objective testing should guide decision-making for progressions through higher levels of physical therapy as well as decision-making regarding return to sport participation and competition [46–48]. Studies have reported that a structured, progressive, and goal-based rehabilitation protocol results in excellent long-term subjective results in patients [48]. Conservative treatment can also be considered in patients with grade III tears that reside in neutral or slightly varus alignment [5]. However, more severe injuries, particularly those distal to the joint line, are less likely to succeed with conservative management.

Biological Augmentation

The literature regarding the use of biological agent augmentation in the setting of MCL injury is controversial. Yoshioka et al. reported significantly increased ultimate load and a trend toward improved stiffness in unrepaired rabbit MCLs at 6 weeks post-injury treated with a single PRP injection when compared to a no PRP control group. Of note, this study included only three subjects per cohort, and the control group included separate subjects rather than the contralateral limb [49]. Similarly, da Costa et al. reported significant increases in tensile strength following PRP injection compared to saline injection at either 3 or 6 weeks in rats with grade III MCL tears [50]. Further, two clinical case reports describe positive outcomes for the treatment of acute isolated MCL tears following three sequentially spaced PRP injections within 1 month. The patients reported return to sport at 18 days and 31 days post-injury [51, 52].

Conversely, LaPrade et al. demonstrated no significant improvement in healing of 160 rabbit MCLs following experimentation with varying concentrations of platelets. This study demonstrated that PRP at four times blood concentration levels negatively affected both strength and histological appearance of the damaged tendon at 6 weeks post-injury [53]. Similarly, Amar et al. reported no significant difference with the use of PRP in acute MCL injury after analysis at 3 weeks post-operation in rats [54].

Operative Treatment

Failed conservative management of sMCL tears, or chronic medial-sided laxity, can result in debilitating, persistent instability, ACL dysfunction, weakness, and progression/development of osteoarthritis. In these cases, surgical intervention is usually the most appropriate next option. A number of surgical techniques have been described: direct suture repair of the sMCL and POL [55], primary repair with augmentation [56], advancement of the tibial insertion site of the superficial medial collateral ligament [57], pes anserinus transfer [58], proximal advancement of the superficial medial collateral ligament [59], non-anatomic reconstruction techniques [60], and anatomic reconstruction techniques [61]. The surgical options discussed in the current chapter will focus on the current authors' preferred technique.

Case Presentation: Treatment Decision

Given the patient's severe instability and 2 years of failed conservative management, the current authors recommended surgical reconstruction of the PMC. This involved reconstruction of the sMCL and POL using the surgical technique described in the current chapter.

Authors Preferred Operative Treatment

Anatomic Reconstruction, Double Bundle

Coobs et al. [61] developed, and biomechanically validated, an anatomical reconstruction of the PMC by reconstructing the proximal and distal fascicles of the sMCL and POL using two independent grafts and four total bone tunnels: two femoral and two tibial tunnels [61]. Soft tissue (hamstrings or anterior tibialis) allografts or gracilis and semitendinosus autografts are the preferred graft choices for this technique. On average, the sMCL graft should be 16 cm in length, and the POL graft should be 12 cm in length. The original technique describes a single anteromedial incision, but other adaptations use three smaller incisions for this procedure. The first step is to identify the distal insertion of the sMCL on the tibia. It can be found deep to the pes anserinus bursa, approximately 6 cm distal to the joint line. Once the tibial footprint is identified, the hamstring tendons can be harvested if desired. After graft harvesting, a pin is placed transversely across the tibia 6 cm distal to the joint line, and a 7 mm tunnel is reamed to a depth of 25 mm. Next the central arm of the POL is located at the posteromedial tibia, slightly anterior to the insertion of the semimembranosus tendon and at the posterior margin of the anterior arm. With the footprint located, a pin is placed in an oblique direction toward Gerdy's tubercle, followed by a 7 mm tunnel reamed to a depth of 25 mm.

Next, attention is turned to the femur. Identification of key anatomic landmarks on the femur may require fluoroscopy to assist with proper identification [62]. In order to accurately identify the femoral landmarks, one should first identify the distal attachment of the adductor magnus tendon. The adductor magnus tendon is utilized to dissect down to and identify the adductor tubercle, and because it is rarely injured, it has been called "the lighthouse of the medial aspect of the knee." From there, the medial epicondyle can be identified 12.6 mm distal and 8.3 mm anterior to the adductor tubercle. The sMCL attachment site is 3.2 mm proximal and 4.8 posterior to the medial epicondyle (Fig. 11.8). Once identified, an eyelet pin is placed anterolaterally across the distal thigh, but the tunnel should not be reamed until the femoral footprint of the POL is also identified in order to avoid tunnel convergence. The POL attachment site is 7.7 mm distal and 2.9 mm anterior to the gastrocnemius tubercle. This can be more easily identified if the posteromedial capsule is torn off the femur, but if this is still intact, a small incision can be made just posterior to the remnants of the sMCL, vertically and into the joint to identify its femoral attachment site. Once the POL attachment site is identified, an eyelet passing pin can be placed, and both femoral tunnels can be reamed with a 7 mm reamer to a depth of 25 mm.

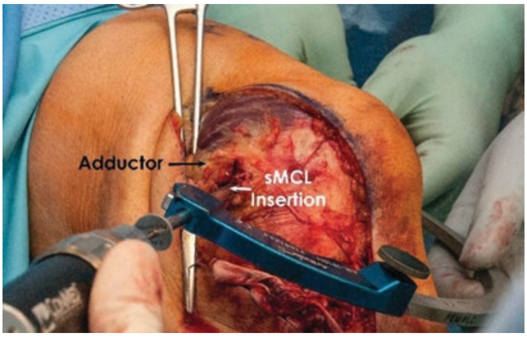


Fig. 11.8 Image showing the anatomical location of the femoral insertion of the superficial medial collateral ligament identified during reconstruction

Anatomic Augmented Surgical Repair with Semitendinosus Tendon Autograft

For the sMCL augmentation repair technique alone, after superficial medial dissection, the semitendinosus tendon is identified at its tibial attachment for graft harvesting. The tendon is then anchored to the tibia at the dMCL distal attachment site (approximately 6 cm distal to the joint line) [3] using both suture anchors and additional sutures to reattach the graft to the underlying remnant of the distal sMCL. The graft is then passed proximally, deep to the intact sartorius fascia, to the femoral attachment site of the sMCL. At this anatomic footprint, a femoral tunnel is reamed with a 7 mm reamer to a depth of 25 mm. The free end of the graft is then measured, and 3 cm of the graft is whipstitched to fit this tunnel. The graft is then fixed using screw fixation, while a 60 N traction force is applied with the knee at 20° of flexion, in neutral rotation, and a slight varus force. Finally, a suture anchor is used to anatomically restore the proximal tibial division of the sMCL, 12 mm distal to the joint line, directly over the anterior arm of the semimembranosus [3, 61–64].

Multistage Surgical Management

When valgus alignment is identified on full-length weightbearing radiographs for chronic PMC tears, surgeons should consider a two-stage intervention, with an osteotomy prior to surgical intervention for the soft tissue laxity to correct the alignment to neutral [65]. One biomechanical study demonstrated a 36% reduction in the amount of medial compartment gapping with the application of a valgus force following a lateral, opening-wedge distal femoral osteotomy for the correction of a valgus deformity [66].

Rehabilitation

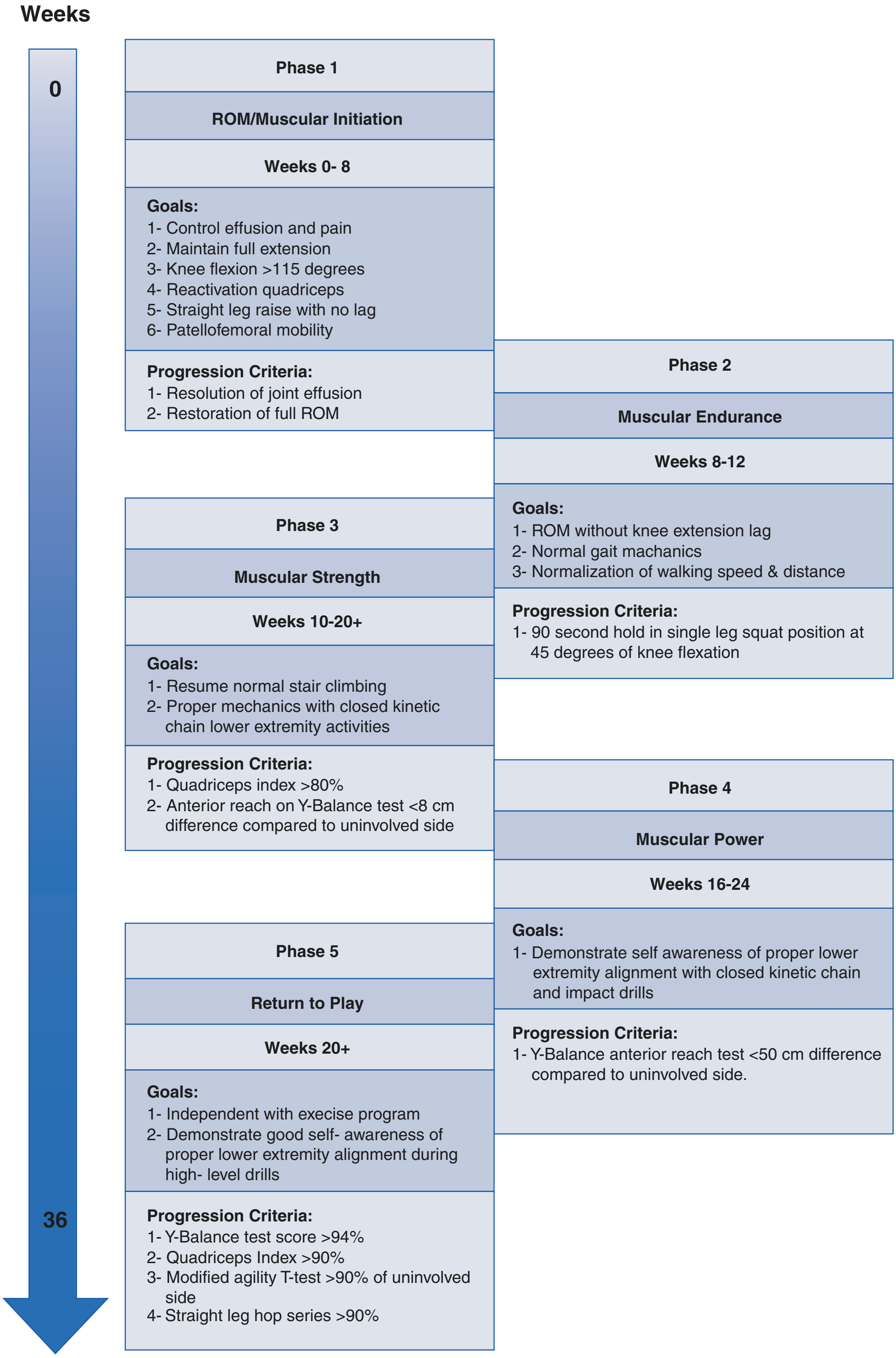
Early post-operative range of motion with physical therapy has been shown to decrease stiffness [20, 45]. Specific rehabilitation protocols are dependent on the concomitant surgical procedures, but isolated PMC reconstruction rehabilitation entails non-weightbearing with crutches and the use of a stabilizing knee brace for the first 6 weeks post-operatively. During this time, patients should undergo intensive physical therapy with focus on pain and swelling reduction, passive to active assisted knee range of motion, and quadriceps activation exercises [67–70]. Compared to non-operative management, post-operative rehabilitation is more restricted in the early recovery period to honor soft tissue trauma associated with surgery and protect the joint for adequate healing at bone tunnel and suture graft fixation sites. Goals for therapy progression and return to activity/sport are similar to those of the non-operative management pathway, but with delayed timeframes. Assuming progressive functional milestones are met, including passing the Sport Performance TRAC Testing (Testing for Return to Athletic Competition), patients with isolated PMC injuries are expected to return to sport 6–9 months following PMC reconstruction. The step-by-step milestones for MCL rehabilitation are provided in Fig. 11.9.

Outcomes

Historically, repairs were the preferred surgical technique, but recently it has been recognized that reconstructions are associated with less failures and allow for earlier knee motion which reduces the subsequent risk of arthrofibrosis. Clinical outcomes following surgical repair of PMC injuries in the setting of multiligament knee injuries have been reported to demonstrate a failure rate of 20%, compared to a failure rate of 4% with reconstruction techniques [71].

Kim et al. [72] described clinical outcomes of non-anatomic reconstructions of the PMC using a semitendinosus autograft with a preserved tibial attachment in a 24-patient case series. They reported a reduction from 7.8 mm of medial compartment opening on valgus stress radiographs to less than 2 mm post-operatively in 91.7% (22/24) of patients. Further, they reported IKDC scores graded as normal or nearly normal (IKDC grade A or B) in 92% of patients and mean post-operative Lysholm score of 91.9 [72]. Ibrahim et al. [73] also performed non-anatomic reconstructions of the sMCL in 15 patients, 5 of which demonstrated 1+ residual valgus laxity at average 43-month follow-up [73]. In 61 patients with grade III or IV medial instability at the time of surgery, Lind et al. [74] reported a 98% normal or nearly normal medial stability and reported a 91% satisfaction rating with non-anatomic reconstruction at 2-year follow-up [74].

Other studies used a non-anatomic double bundle technique to reconstruct isolated sMCL injuries. Post-operatively, Liu et al. [75] reported a relative increase of 1.1 mm in side-to-side difference on stress radiographs, but excellent subjective patient-reported outcomes scores post-operatively, and Dong et al. [76] reported anteromedial rotary instability in 9.4% of patients, with an average of 2.9 mm of residual side-to-side medial compartment opening on stress radiographs [73, 74].



Phase 1

ROM/Muscular Initiation

Weeks 0- 8

Goals:
1- Control effusion and pain
2- Maintain full extension
3- Knee flexion >115 degrees
4- Reactivation quadriceps
5- Straight leg raise with no lag
6- Patellofemoral mobility

Progression Criteria:
1- Resolution of joint effusion
2- Restoration of full ROM

Phase 2

Muscular Endurance

Weeks 8-12

Goals:
1- ROM without knee extension lag
2- Normal gait machanics
3- Normalization of walking speed & distance

Progression Criteria:
1- 90 second hold in single leg squat position at 45 degrees of knee flexation

Phase 3

Muscular Strength

Weeks 10-20+

Goals:
1- Resume normal stair climbing
2- Proper mechanics with closed kinetic chain lower extremity activities

Progression Criteria:
1- Quadriceps index >80%
2- Anterior reach on Y-Balance test <8 cm difference compared to uninvolved side

Phase 4

Muscular Power

Weeks 16-24

Goals:
1- Demonstrate self awareness of proper lower extremity alignment with closed kinetic chain and impact drills

Progression Criteria:
1- Y-Balance anterior reach test <50 cm difference compared to uninvolved side.

Phase 5

Return to Play

Weeks 20+

Goals:
1- Independent with execise program
2- Demonstrate good self- awareness of proper lower extremity alignment during high- level drills

Progression Criteria:
1- Y-Balance test score >94%
2- Quadriceps Index >90%
3- Modified agility T-test >90% of uninvolved side
4- Straight leg hop series >90%

Fig. 11.9 Step-by-step rehabilitation milestones

Outcomes for biomechanically validated anatomic reconstruction techniques [61] have been generally very positive. LaPrade and Wijdicks reported on 28 patients who had single-stage anatomic reconstructions of the PMC (POL and sMCL), with concurrent cruciate ligament reconstruction. Patients reported improved subjective IKDC scores, and all patients demonstrated resolution of side-to-side medial instability at 2-year follow-up. On valgus stress radiographs, there was improvement from 6.3 mm to 1.3 mm in side-to-side medial compartment gapping [20]. The most common reported complications for anatomic reconstruction techniques include deep implant removal, persistent pain, superficial wound infection, joint stiffness, and arthrofibrosis [67, 77, 75].

Case Presentation: Follow-Up

At her most recent 3-month follow-up, the patient reported being able to walk without a limp. Her follow-up stress radiographs demonstrated 0.7 mm of side-to-side difference in medial compartment gapping. Her physical examination was significant only for a mild effusion in her right knee. The patient was instructed to return to clinic in 3 months.

Management in Concomitant Cruciate Injury

Management for patients with medial knee injuries and concomitant cruciate injury is controversial. Moreover, this is a particularly important topic as it has been reported that 78% of patients with grade III MCL injuries have a concomitant cruciate injury [76, 78]. Of note, a previous study reported that in patients with combined sMCL and ACL tears, confirmed operatively, 95.7% (22/23) of patients were also found to have a POL injury [79].

Previous studies report positive outcomes following delayed ACL reconstruction with early MCL surgical management and subsequent rehabilitation to regain valgus stability [80]. Conversely, biomechanical analysis suggests that in the ACL-deficient knee, there is increased tension on the MCL with 30° of flexion and anterior translation suggesting that ACL deficiency may compromise the MCL graft [21]. Further analysis demonstrates that both persistent anteromedial rotatory instability and valgus instability lead to increased forces on the ACL suggesting that reconstructing the ACL in isolation with a deficient MCL may compromise the ACL graft. As such, the majority of literature supports operative treatment of complete PMC injuries at the time of cruciate ligament reconstruction, especially for those patients with residual valgus laxity after non-operative management of medial knee injury [19, 80–85].

In the case of combined PCL and MCL injury, it is important to surgically reconstruct all damaged ligaments in the acute setting, with thorough exploration of the PMC structures [16]. Specifically, the POL plays an important role in the stability of the PCL, and failure to address any injury to this structure of the PMC could compromise the PCL reconstruction [86].

Conclusion

Management of medial-sided ligamentous knee injuries includes both conservative and operative treatment, with anatomic reconstruction demonstrating both biomechanical validation and favorable clinical outcomes. Clinical examination and including the use of valgus stress radiographs and MRI allow for an appropriate diagnosis and classification of medial-sided knee ligament injuries. Despite the complexity of posteromedial corner injuries, relying on surgically relevant anatomical landmarks is key for a successful surgical reconstruction.

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