Medial Patellofemoral Ligament Reconstruction

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» Recurrent patellar instability continues to be a challenging problem for surgeons as more patients are being diagnosed and managed each year.

» The majority of complications are secondary to technical error; thus, it is imperative that the surgeon has a thorough understanding of the anatomy and biomechanics of the medial patellofemoral ligament.

» The indications and algorithm for treatment continue to evolve.

» The ultimate goal for recurrent patellar instability should be to restore the native biomechanics and stability of the patellofemoral joint.

In the general population, the overall incidence of acute patellar dislocation is 5.8 per 100,000 people in the United States[1]. The rate of patellar dislocation is estimated to be highest in the age group of ten to seventeen years, with reported rates of 29% to 43%[1-3]. Women have a 33% increased prevalence of acute patellar dislocation compared with men[1]. Patellar instability typically occurs in patients with several anatomic risk factors, including both soft-tissue and osseous abnormalities. Conlan et al. studied twenty-five cadaveric specimens to analyze soft-tissue restraints associated with patellar instability and found the medial patellofemoral ligament to be a critical medial soft-tissue restraint in preventing lateral instability[4]. Furthermore, biomechanical and radiographic findings have led many surgeons to state that disruption of the medial patellofemoral ligament is the "essential lesion" required for patellar dislocation[1,4-7]. Disruption of the medial patellofemoral ligament was diagnosed on magnetic resonance imaging (MRI) in twenty-six (96%) of twenty-seven patients[8]; the lesion most commonly occurs at the femoral attachment site[9,10] (Fig. 1). In addition, the deep capsular layer, the medial patellomeniscal ligament, and the medial patellotibial ligament all have been found to contribute to the soft-tissue stabilization of the patella against lateral dislocation[4].

The stability of the patella is also determined by anatomic osseous constraints such as the morphology of the femoral trochlea and the alignment of the tibia relative to the femur. In the study by Amis et al., in vitro testing showed that the femoral trochlear lateral wall is the primary restraint to lateral translation once the patella engages the trochlea during knee flexion[6]. Therefore, the treatment of chronic patellar instability has been greatly debated. Numerous operative techniques for reconstruction of the medial patellofemoral ligament have been described; however, a consensus standard of care has yet to be defined in the literature. A medial patellofemoral ligament reconstruction creates a passive restraint to lateral displacement

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Fig. 1
T2-weighted axial MRI showing disruption of the medial patellofemoral ligament (MPFL), with increased signal along the previous site of insertion of the ligament.

of the patella and has become an accepted technique for the restoration of patellofemoral stability[11-13]. On the other hand, trochleoplasty and osseous transfers also have been used to correct the underlying abnormality leading to patellar instability. The purpose of this article is to review medial patellofemoral ligament reconstruction both as a viable stand-alone procedure and as a complementary component of a larger salvage operation involving other soft-tissue and/or osseous abnormalities in patients with chronic patellar instability. In addition, an operative technique guide is provided along with the senior author's preferred method.

Anatomy and Biomechanics

As the frequency of medial patellofemoral ligament reconstruction continues to increase, it is important to understand the anatomy and biomechanics of the medial patellofemoral ligament as well as the injury patterns that occur. Warren and Marshall described three fascial layers on the medial side of the knee: the most superficial layer includes the vastus medialis muscle and sartorial fascia, the intermediate layer comprises the medial patellofemoral ligament and the superficial medial collateral ligament, and the third layer involves the joint capsule and the medial patellotibial ligament[14].

The footprints of the femoral and patellar attachments of the medial patellofemoral ligament have been well described[4,6,15-17]. Nomura et al. found the origin of the medial patellofemoral ligament to be distal to the adductor tubercle and superior and posterior to the medial epicondyle[15]. In a cadaveric study, LaPrade et al. identified the femoral attachment to be 1.9 mm anterior and 3.8 mm distal to the adductor tubercle, arising between the medial epicondyle and the adductor tubercle[16]. This landmark can be palpated intraoperatively. Steensen et al., in a study of eleven cadaveric knees, reported the mean width of the femoral attachment of the medial patellofemoral ligament to be 15.4 mm[17].

The insertion of the medial patellofemoral ligament onto the patella has been well described. Two cadaveric studies have demonstrated the patellar insertion to be on the superior half of the medial border of the patella[4,6]. Steensen et al. found the mean width of the medial patellofemoral ligament attachment on the patella to be 17 $\pm$ 3.0 mm[17]. Furthermore, the superior edge of the medial patellofemoral ligament inserted a mean of 6.1 mm from the superior pole of the patella and the inferior edge inserted a mean of 23.1 mm from the superior pole of the patella. Overall, the medial patellofemoral ligament footprint on the patella was 38.8% of the total patellar length.

Biomechanically, the medial patellofemoral ligament is the primary soft-tissue stabilizer of the patella as it prevents lateral translation of the patella during the first 30° of flexion[6,18]. As knee flexion increases from 0° to 30°, the medial patellofemoral ligament guides the patella into the trochlear groove. At 30° of flexion, the patella should be centered in the trochlear groove and should allow $<$1 cm of lateral translation[19]. Beyond 30° of flexion, the trochlea becomes the primary stabilizer of the patella. Amis and colleagues reported an increase in lateral patellar translation when the lateral trochlear wall is flattened, further demonstrating the importance of the trochlea for patellar stability[6,20].

Indications

The indications for operative reconstruction of the medial patellofemoral ligament and the addition of concomitant soft-tissue and osseous procedures continue to be debated. In a randomized controlled trial, Palmu et al. and Hennrikus and Pylawka reported no significant difference in long-term subjective or functional results between operative and nonoperative treatment of first-time traumatic patellar dislocations[21,22]. As a result, nonoperative treatment continues to be the standard of care for first-time traumatic patellar dislocation except in cases involving osteochondral fractures, vastus medialis avulsions, large osteochondral fragments, or concomitant intra-articular abnormalities such as meniscal tears[9,23]. Conservative treatment is generally successful, with the reported rate of redislocation after simple patellar dislocation ranging from 15% to 44%[1,24-26]. Currently, most surgeons think that medial patellofemoral ligament reconstruction is indicated when there is recurrent instability with more than two documented dislocations or when conservative treatment has failed[9,22,23,27-29].

The cause of patellar instability is multifactorial, including trochlear dysplasia, malalignment of the tibia relative to the femur, and patella alta[6,18,30,31]. The role of trochlear dysplasia in the setting of patellar dislocation is controversial[32,33]. Steiner et al., in a study of thirty-four patients who were managed with isolated medial patellofemoral ligament reconstruction for the treatment of chronic patellar instability associated with trochlear dysplasia, found substantial improvements in clinical outcome scores and no recurrent dislocations[34]. The authors concluded that medial patellofemoral ligament reconstruction alone can be efficacious even in the context of trochlear dysplasia. However, this opinion remains controversial. Nelitz et al. noted that one of the primary reasons for failure after a medial patellofemoral ligament reconstruction was a higher tibial tubercle-trochlear groove distance that was not addressed during the index procedure, leading to increased forces on the reconstruction and, as a result, unsuccessful clinical outcomes[35]. Banke et al., in a study of seventeen patients with a severely dysplastic trochlea and chronic patellofemoral instability, described successful results at a minimum of two years after trochleoplasty combined with medial patellofemoral ligament reconstruction[36]. Koh and Stewart addressed osseous misalignment with a tibial tubercle osteotomy to unload the articular cartilage in addition to aiding stability[37]. Many surgeons, including the senior author, continue to recommend a primary osseous procedure with or without medial patellofemoral ligament reconstruction in the setting of high-grade trochlear dysplasia.

Wagner et al. reported on fifty patients with varying risk factors, including trochlear dysplasia, who underwent isolated medial patellofemoral ligament reconstruction[32]. The authors noted an inverse relationship between the degree of trochlear dysplasia and clinical outcomes and concluded that an osseous procedure should be considered. Likewise, Fucentese et al. found that 75% (thirty-three) of forty-four patients had a negative apprehension test after undergoing a trochleoplasty alone, suggesting the effectiveness of a solitary osseous procedure[38]. Finally, in a prospective two-year follow-up study, Banke et al. reported excellent clinical and radiographic outcomes in all but one of their patients who had undergone a combined trochleoplasty and medial patellofemoral ligament reconstruction[36]. Schöttle et al. also reported excellent clinical and radiographic results with a similar procedure[39].

In the setting of patellar instability, malalignment refers to external tibial torsion and/or excessive femoral anteversion. A tibial tuberosity-trochlear groove distance of >20 mm suggests patellar malalignment and can generally be addressed with a tibial tuberosity transfer or femoral derotation osteotomy to restore proper alignment between the trochlea and the tubercle[2,40,41]. Similar to trochlear dysplasia, there is no consensus regarding the treatment of malalignment in the setting of patellar instability.

Schöttle et al. reported successful clinical and radiographic results in a study of fifteen patients who underwent medial patellofemoral ligament reconstruction, which was combined with medialization of the tibial tuberosity if the preoperative tibial tubercle-trochlear groove distance was >15 mm[40]. However, whether isolated medial patellofemoral ligament reconstruction can provide successful results in patients with malalignment is still debatable. Matsushita et al., in a retrospective review of thirty-four patients who underwent medial patellofemoral ligament reconstruction, reported no significant difference in clinical outcomes between the patients in whom the tibial tubercle-trochlear groove distance was <20 mm (n = 15) and those in whom it was >20 mm (n = 19)[42]. These two studies demonstrate the controversy regarding the treatment of recurrent patellar instability in patients with an elevated tibial tubercle-trochlear groove distance.

Overall, the literature lacks well-controlled randomized studies in which medial patellofemoral ligament reconstruction alone is compared with medial patellofemoral ligament reconstruction combined with additional osseous or soft-tissue procedures. Many recent studies have not clearly differentiated between trochlear dysplasia and malalignment when investigating the need for additional procedures at the time of medial patellofemoral ligament reconstruction[32,34,38,43]. As a result, the indications for medial patellofemoral ligament reconstruction remain controversial and further randomized prospective studies are needed for a consensus statement. It is the opinion of the senior author that medial patellofemoral ligament reconstruction is a

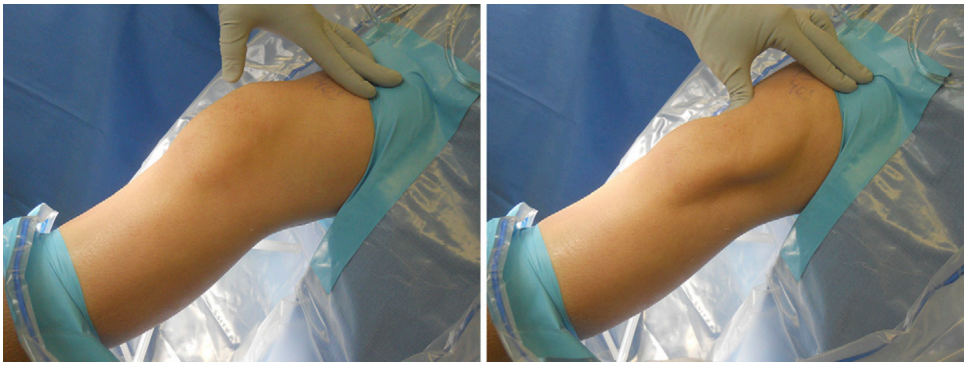

Fig. 2
Photographs made during an assessment of the patella with the patient under anesthesia. The application of a lateral force to the patella (right) identifies a lack of medial restraint, leading to patellar instability.

very successful procedure for the treatment of recurrent patellar instability. However, in cases of high-grade trochlear dysplasia or when the tibial tubercle-trochlear groove distance is >20 mm, additional soft-tissue and osseous procedures are recommended along with medial patellofemoral ligament reconstruction in order to maximize long-term clinical outcomes while decreasing the strain on the medial patellofemoral ligament. Latt et al. described the first validated cadaveric model of trochlear dysplasia to help to define treatment algorithms for patellofemoral instability[44].

Senior Author's Preferred Treatment

Medial patellofemoral ligament reconstruction involves a tendon transfer or a free graft. The graft can be a hamstring autograft or allograft involving the gracilis, semitendinosus, and/or quadriceps tendons. Risks associated with autograft harvest include pain, infection, and numbness in the distribution of the saphenous nerve during the graft harvest. The literature has yet to provide scientific support for the use of one choice over another.

Medial Patellofemoral Ligament Reconstruction with Semitendinosus Autograft (Surgical Technique)

The patient is positioned supine on a standard operating table. An examination is performed with the patient under anesthesia to confirm patellar instability and to assess any other ligamentous damage (Fig. 2). A tourniquet is then placed on the proximal part of the thigh. Diagnostic arthroscopy is then performed, with care being taken to note the articulation between the patella and the trochlea (Fig. 3)—specifically, the trochlear morphology and the ability to displace the patella laterally. Often, a superolateral or superomedial outflow portal may be used for visualization to assess the relationship between the patella and trochlea with a 70° lens in addition to the standard 30° lens.

Next, the semitendinosus is harvested; however, an allograft also can be used as the graft choice. The pes anserine is palpated, and a 1 to 2-cm vertical or oblique skin incision is made 3 cm distal to the medial joint line and 2 cm medial to the tibial tuberosity. The dissection is carried down through the soft tissue and the sartorius fascia until the semitendinosus is visualized distal to the gracilis tendon. The semitendinosus tendon is then bluntly dissected with use of a right-angle clamp. Once clearly identified, the semitendinosus tendon is sharply released from its insertion on the tibia. A whipstitch with number-2 suture is attached to secure the tendon. Sharp dissection is used to release any fascial attachments at the inferior aspect of the semitendinosus tendon. The tendon may be translated into the surgical field to ensure that no attachments are remaining along the course of the tendon. A closed tendon stripper is then used to release the tendon proximally. The wound is irrigated thoroughly and is closed according to the preference of the individual surgeon. Meanwhile, the graft is prepared on the back table. The graft is sized to 180 mm in length and then is folded in half. Once double-bundled, the graft is generally 90 × 5 or 6 mm in diameter.

Next, attention is turned to the patella. A 5-cm vertical skin incision is made along the midpoint of the medial aspect of the upper one-third of the patella and the medial epicondyle. The incision continues through the first layer to identify the medial aspect of the patella and the landmarks of the femoral attachment (the medial epicondyle and adductor tubercle). Care should be taken to avoid injury to the saphenous nerve during the approach. One may use the adductor magnus tendon insertion intraoperatively to find the saddle anterior and distal in relation to the medial epicondyle.

The graft is first anchored to the patella with use of a 3.5-mm suture anchor at the superior pole initially and another 3.5-mm anchor at the equator of the patella. A fascial plane is then created with a heavy hemostat deep to the subcutaneous soft tissue, extending medially and dorsally through the superficial and intermediate layers. The capsule (layer 3) is left intact, with the plane being kept extrasynovial to avoid graft abrasion and to facilitate complete healing. The looped end of the graft is passed through the extrasynovial tunnel

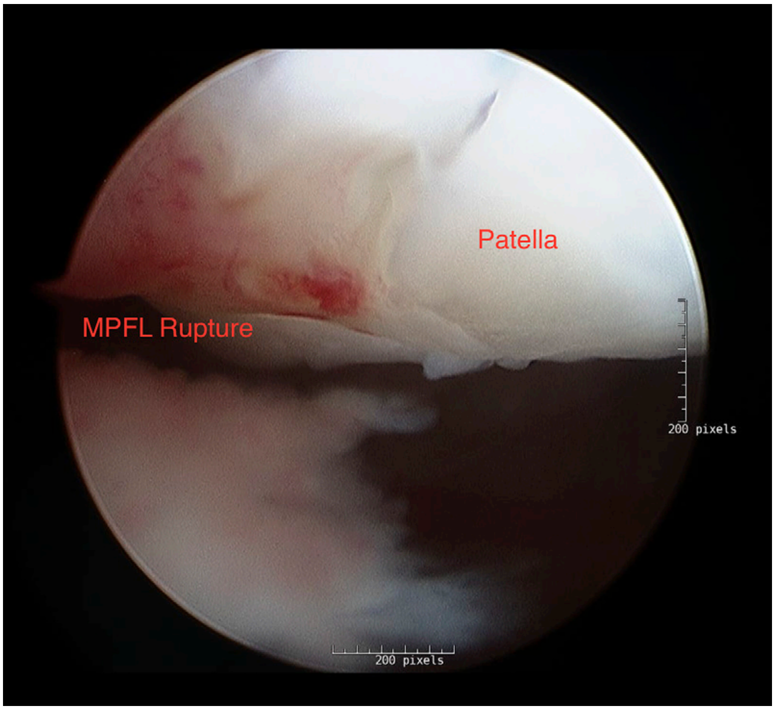

Fig. 3
Arthroscopic image showing the articulation between the patella and the trochlea. MPFL = medial patellofemoral ligament.

to the femoral insertion site by means of a Fiberwire suture (Arthrex, Naples, Florida) tied around the looped graft.

A lateral fluoroscopic image of the knee is made and a radiopaque instrument is used to identify the Schöttle point, the anatomic isometric insertion of the medial patellofemoral ligament (Fig. 4). The Schöttle point is determined on the lateral view by a line extending from the posterior cortex and another perpendicular to the first, just proximal to the posterior-most point of the Blumensaat line. The Schöttle point is 1 mm anterosuperior to the intersection of these two lines[45]. Schöttle et al. described a radiographic technique to ensure accurate placement of the femoral tunnel with the use of a guide pin (Fig. 5)[46]. Servien et al. described a tunnel placement tangent to the posterior condyle and to a perpendicular line at the posterior-most aspect of the Blumensaat line with a zone of 7 mm[47]. Steensen et al. found femoral tunnel placement to be crucial for establishing isometry of the medial patellofemoral ligament and reported that the femoral tunnel should be located at an anatomic point 6.2 ± 1.5 mm distal to the adductor tubercle and 13.3 ± 2.4 mm proximal to the medial femoral epicondyle[17]. Servien et al. and Elias and

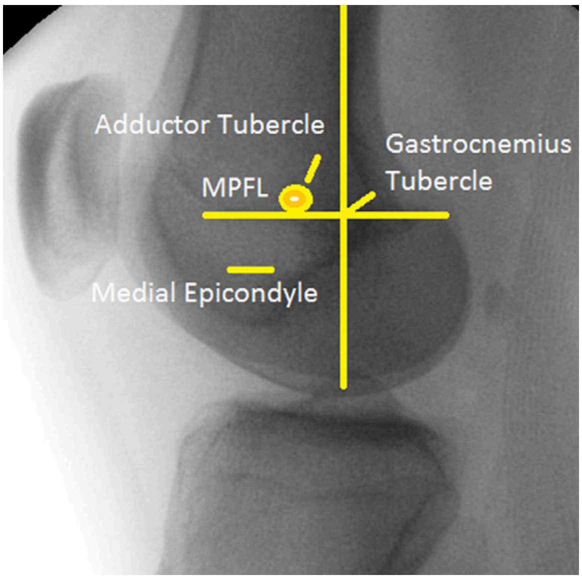

Fig. 4
Lateral fluoroscopic image identifying relevant anatomy of the distal part of the femur. MPFL = medial patellofemoral ligament.

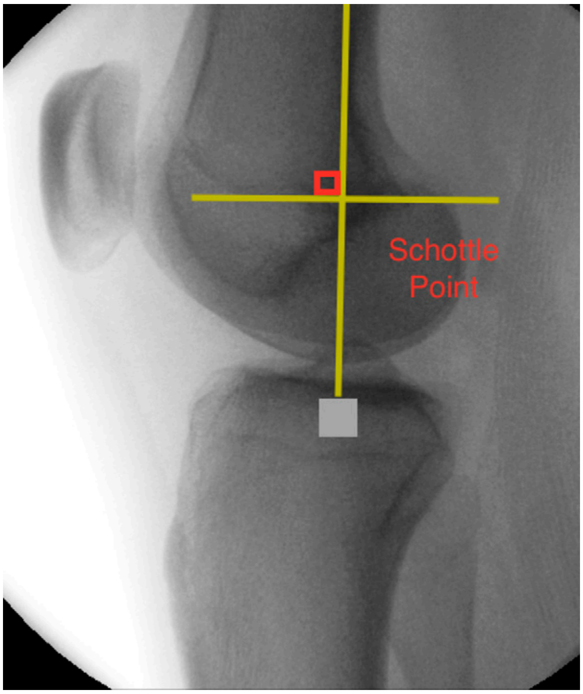

Fig. 5
Fluoroscopic image identifying the Schöttle point. The Schöttle point is determined on the lateral view by a line extending from the posterior cortex and another perpendicular to the first, just proximal to the posterior most point of Blumensaat line. The Schöttle point is 1 mm anterosuperior to the intersection of these two lines[45].

Cosgarea described the challenges associated with reestablishing the anatomic femoral tunnel, noting that failure to do so can lead to increased medial tilt and medial-side patellofemoral contact pressures, possibly resulting in patellofemoral osteoarthritis over the long term[47,48]. Therefore, a Beath pin is then inserted into the femur after confirmation of placement with fluoroscopy. A cannulated reamer size-matched to the autograft is then used to ream a minimum distance of 60 mm into the femur to allow for adequate graft tensioning.

The knee is placed in 30° of flexion, and the guide pin for the interference screw is placed into the femoral tunnel, replacing the Beath pin. The graft is then passed through the femur with the passing stitch. Anatomic dangers include the neurovascular bundle of the adductor hiatus, the saphenous nerve, and/or the saphenous branch of the descending genicular artery[49]. Slack in the graft should be removed at 30° of flexion to ensure that the graft is isometric from extension to flexion. The native medial patellofemoral ligament tightens in extension and loosens following 30° to 40° of flexion; therefore, restoration of the native anatomy is critical for a successful outcome. The degree of flexion during fixation has varied in the literature, with a systematic review showing values both below and above 60° of flexion, without a definitive conclusion[50,51]. Because biomechanical studies have shown that the medial patellofemoral ligament has maximum restraint in 30° of flexion, our fixation is tensioned and fixed in 30° of flexion[6,52,53]. Multiple methods have been reported for the fixation of the femoral portion of the medial patellofemoral ligament. Nomura et al. used staple fixation on the femoral side and reported that twenty-six of twenty-seven knees had an excellent or good result according to the Crosby and Insall grading system after a mean duration of follow-up of 5.2 years[54]. The use of a spiked washer on the femur was described in twelve patients, with no recurrent dislocation, subluxations, or positive apprehension sign at a minimum of three years of follow-up. Ellera Gomes et al. assessed sixteen knees after more than five years of follow-up and noted normal patellar tracking, a negative apprehension test, and an absence of patellar instability following medial patellofemoral reconstruction with semitendinosus autograft for the treatment of chronic instability[55].

In our technique, the knee joint and the graft are preconditioned through multiple full cycles of motion with moderate tension on the graft to allow for resolution of positional laxity and also to dissipate some level of creep that may be present in the graft. Then, while mild tension at 30° is applied to the graft, a matched-fit interference screw is inserted into the femur until it has been countersunk by several millimeters. If a transfemoral sheath is used, attention to the peroneal nerve is critical. Evaluation of the patella is then completed. The arthroscope is then inserted back into the knee, and patellar tracking is observed. Similarly, the extra-articular tracking and laxity of the patella are evaluated through the range of motion of the knee. If any adjustments need to be made, the femoral screw is backed out, any tension or positioning adjustments are made, and the screw is reinserted.

The incisions are copiously irrigated with normal saline solution. The subcutaneous tissue is closed according to the preference of the individual surgeon. A sterile dressing is applied, and the patient is managed with a knee immobilizer. The patient can resume weight-bearing as tolerated and has unrestricted range of motion.

Of particular importance is neuromuscular reeducation of the quadriceps as this muscle group has shown considerable weakness and activation deficits following knee surgery[56]. In addition, good quadriceps control is required for normal gait and optimum patellofemoral arthrokinematics[57,58]. Return to sport is based on a report of no pain, no instability, full strength with manual muscle testing, and excellent mechanics during a single-limb squat. In addition, the patient performs single limb hop tests, consisting of a single limb hop for distance, a triple limb hop for distance, a single limb hop for time, and a crossover hop for distance. The limb symmetry index must be ≥90%, and hop mechanics must be excellent as qualitatively assessed by the physical therapist.

Complications

In a recent meta-analysis, Shah et al. reported a 26.1% complication rate in association with 629 medial patellofemoral ligament reconstructions[51]. The complications included patellar fracture, failure of the reconstruction and redislocation, loss of knee flexion, wound complications, and continued pain. Brennan et al.[59], Christiansen et al.[60], Ellera Gomes et al.[55], and Lippacher et al.[61] all described iatrogenic patellar fractures with the anterior cortex of the patella being breached. Parikh and Wall[12] classified the fracture pattern into three types with corresponding treatments. Type-1 fractures, which are transverse fractures that are associated with the creation of the anterior patellar tunnel or drill-hole, are treated with the tension-band technique. Posterior placement is prevented by palpation of the articular surface and fluoroscopic imaging. Type-2 fractures, which are superior pole fractures that are associated with a lateral release and excessive dissection near the superior pole of the patella, are treated as a quadriceps tendon rupture[59]. Type-3 fractures are medial rim avulsion fractures through the drill-holes, leading to lateral patellar instability[12]. Fithian et al. and Thaunat and Erasmus reported revision surgery to repair the graft to the patella after a medial rim fracture[1,62]. Finally, Steiner et al. described a fracture of the adductor tubercle at the femoral tunnel for the medial patellofemoral ligament graft[34].

Recurrent lateral instability is generally caused by malpositioning of the femoral attachment and overtensioning or undertensioning of the graft. Positioning the femoral tunnel too anteriorly with the graft tensioned in flexion can lead to a loose graft. Conversely, the graft can fail secondary to increased strain following overtightening[63]. If the femoral tunnel is placed too distally or posteriorly, the graft will be tight in extension, leading to pain with extension that can manifest as an extensor lag. Furthermore, overtensioning of the graft can cause increased contact pressures on the medial patellar facet as well as medial patellar subluxation. Beck et al. noted that 2 N of tension is ideal for restoring patellofemoral biomechanics and allows the patella to center in the trochlear groove[64]. Overtensioning of the medial patellofemoral ligament has been implicated as a cause of stiffness. Thaunat and Erasmus reported two cases of pain and stiffness in association with overtightened medial patellofemoral ligament reconstructions[65].

In a recent systematic review, loss of motion was found to be the second-most-reported complication (representing 13.4% of all complications) following recurrent instability related to graft loosening, rupture, and/or recurrent patellar instability (representing 32% of all complications)[51]. Over half of the patients underwent manipulation under anesthesia because of loss of knee flexion. In that study, the greatest number of secondary procedures were related to manipulation under anesthesia (reported in 1.4% of 629 knees)[51]. The native medial patellofemoral ligament is not under tension during the normal arc of motion. Christiansen et al., in a series of forty-four patients who underwent reconstruction of the medial patellofemoral ligament with use of a gracilis tendon autograft and transverse patellar drill-holes, reported that four patients had a loss of flexion of >10° and one patient underwent manipulation under anesthesia because of flexion of <90°[60]. To improve motion, Parikh et al. suggested a postoperative protocol similar to anterior cruciate ligament (ACL) protocols[11]. The goal is to achieve 0° to 90° of motion by the end of the third week and 0° to 120° by the end of the sixth week. The authors recommended early manipulation with the patient under anesthesia to prevent arthrofibrosis if these goals are not met.

Wound complications are rare but have been successfully treated with irrigation and debridement in the majority of the cases[34,66,67]. To our knowledge, no cases of joint infections or deep-tissue infections have been reported in conjunction with medial patellofemoral ligament reconstruction[63].

Finally, persistent pain resulting from prominent hardware has been reported[34,60,66]. Nomura et al. reported pain at the femoral fixation site in 57% and 23% of their patients who had been managed with staples and an integrated double-staple system, respectively[66]. Christiansen et al. removed interference screws at the femoral insertion site in three of forty-four patients[60]. In the largest systematic review to date, Shah et al. reported removal of symptomatic hardware in seven of 629 knees[51].

Overall, it is difficult to draw definitive conclusions regarding the reported complications in the literature because of the heterogeneity of reconstruction techniques and the lack of standard reporting outcomes. Therefore, the surgeon must have great understanding of the anatomy and technical details of tunnel placement, graft fixation, and graft tensioning. Because of the lack of high-level studies and the array of fixation methods, it is difficult to isolate a sole reason for the high complication rates.

Overview

Recurrent patellar instability continues to be a challenging problem for surgeons as more patients are being diagnosed and managed each year. With the majority of complications being secondary to technical error, it is imperative for the surgeon to have a thorough understanding of the anatomy and biomechanics of the medial patellofemoral ligament. Furthermore, a combination of soft-tissue and osseous abnormalities contributes to the pathological process. As a result, the indications and algorithm for treatment continue to evolve. The ultimate goal for recurrent patellar instability should be to restore the native biomechanics and stability of the patellofemoral joint. The achievement of this goal may require a medial patellofemoral ligament reconstruction alone or in conjunction with additional soft-tissue and osseous procedures. Presently, evidence does not exist to support one surgical technique over another[68-70].

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