Review Article

Guidelines for Medial Patellofemoral Ligament Reconstruction in Chronic Lateral Patellar Instability

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Abstract

The standard surgical approach for chronic lateral patellar instability with at least two documented patellar dislocations is to stabilize the patella by using an anatomic medial patellofemoral ligament reconstruction with a mini-open technique and a graft that is stronger than the native ligament to compensate for the uncorrected predisposing factors underlying patellar instability. Even though medial patellofemoral ligament reconstruction has evolved notably during the past two decades, many aspects of the surgical technique need to be refined, and more information is needed toward this end. Adequate positioning of the graft on the femur, as well as inducing the appropriate degree of tension, are critical steps for the overall outcome of medial patellofemoral ligament reconstruction. Moreover, it is necessary in some cases to pair medial patellofemoral ligament reconstruction with other surgical procedures to address additional patellar instability risk factors, such as trochlear dysplasia, malalignment, and patella alta.

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Various surgical techniques have been used to treat chronic lateral patellar instability (CLPI), including bony procedures, such as the distal and/or medial transfer of the anterior tibial tubercle and trochleoplasty, and soft-tissue procedures, such as medial patellofemoral ligament (MPFL) reconstruction and medial retinacular reefing. According to several anatomic and biomechanical studies, the MPFL is the most important restraint to lateral patellar displacement from zero to 30° of knee flexion.[1-3] Moreover, it has been demonstrated that MPFL deficiency is the essential lesion in CLPI.[4] Therefore, the logical treatment approach for CLPI is to reconstruct the MPFL. Since the 1990s, interest in MPFL reconstruction has increased, and it is currently the first-choice procedure for patients with CLPI who have had at least two documented patellar dislocations.

Although patellar instability treatment has evolved significantly during the past two decades, many aspects of the surgical technique need to be refined, and more information is needed about the technical aspects of this procedure. Moreover, the complication rate of 26% associated with MPFL reconstruction is not trivial.[5] Application of guidelines supported by this article may help to optimize MPFL reconstruction.

Anatomic Versus Nonanatomic MPFL Reconstruction

Graft placement is considered crucial to achieving a good outcome in ligament surgery, and MPFL reconstruction should be no exception. However, there is little research regarding the most appropriate locations for graft attachment, and controversy exists about the importance of anatomic MPFL reconstruction. Moreover, there is also disagreement about the clinical effects of nonanatomic femoral tunnel placement in MPFL reconstruction.

Reconstruction of the Native Femoral Ligament Attachment

Several studies have demonstrated the importance of replicating the native anatomic femoral insertion in reconstructing the MPFL. In a biomechanical study using computational knee models, Elias and Cosgarea[6] analyzed how reconstruction influences patellofemoral force and pressure distributions. They concluded that technical mistakes in the femoral attachment location and graft length could substantially increase both the patellofemoral joint reaction force and pressure over the medial patellofemoral cartilage, subsequently overloading the medial cartilage and leading to patellofemoral osteoarthritis and pain. Bollier et al[7] showed in a clinical study that anterior malpositioning of the femoral tunnel can cause overloading of the medial patellofemoral cartilage. According to Camp et al,[8] a nonanatomic MPFL femoral attachment, which can be identified radiographically, is a risk factor for unsuccessful surgery. These authors found that 80% of patients with an incorrectly positioned femoral attachment suffered a dislocation within 4 years of MPFL reconstruction.

Thaunat and Erasmus[9] suggested that a femoral tunnel that is too far proximal may lead to graft laxity in extension and graft tension in flexion, with a clinical presentation of anterior knee pain and loss of flexion. Moreover, excessive graft tension with knee flexion could stretch the graft and lead to its failure, predisposing the patient to repeat patellar dislocation, even though the tendon graft used for MPFL reconstruction is substantially stronger than the native MPFL. In contrast, a femoral tunnel that is too distal may lead to graft tension in extension and laxity in flexion. Its clinical presentation would be an extension lag.[9] Finally, according to Smirk and Morris[10] and Steensen et al,[11] a femoral insertion into the adductor tubercle should be avoided because it will cause an MPFL reconstruction to be extremely tight in flexion and unacceptably loose in extension. Based on these laboratory and clinical studies, we conclude that the femoral tunnel should mimic native anatomy as closely as possible to avoid the indicated problems.

However, in a biomechanical laboratory study using cadaver knees, Melegari et al[12] found that the use of a nonanatomic attachment point (ie, adductor tubercle) alters neither the contact area nor the pressures in the patellofemoral joint compared with the anatomic femoral attachment. Servien et al[13] prospectively studied a correlation between femoral tunnel location and clinical outcome at 2 years of follow-up and found no relationship. It is possible that the malpositioning of the femoral attachment from the ideal anatomic position was not of sufficient magnitude to cause a significant clinical difference between the two parameters. Additionally, the follow-up may have been too short, and it is possible that these patients may have developed patellofemoral osteoarthritis later. Finally, Ostermeier et al[14] compared static femoral reconstruction of the MPFL with a dynamic nonanatomic femoral reconstruction using the medial collateral ligament (MCL) as a pulley. These authors found that a dynamic reconstruction medialized the patella significantly less than did a static reconstruction and protected against excess graft tension. Deie et al[15] also showed that a dynamic MPFL reconstruction could achieve notably improved clinical outcomes, without recurrent dislocations.

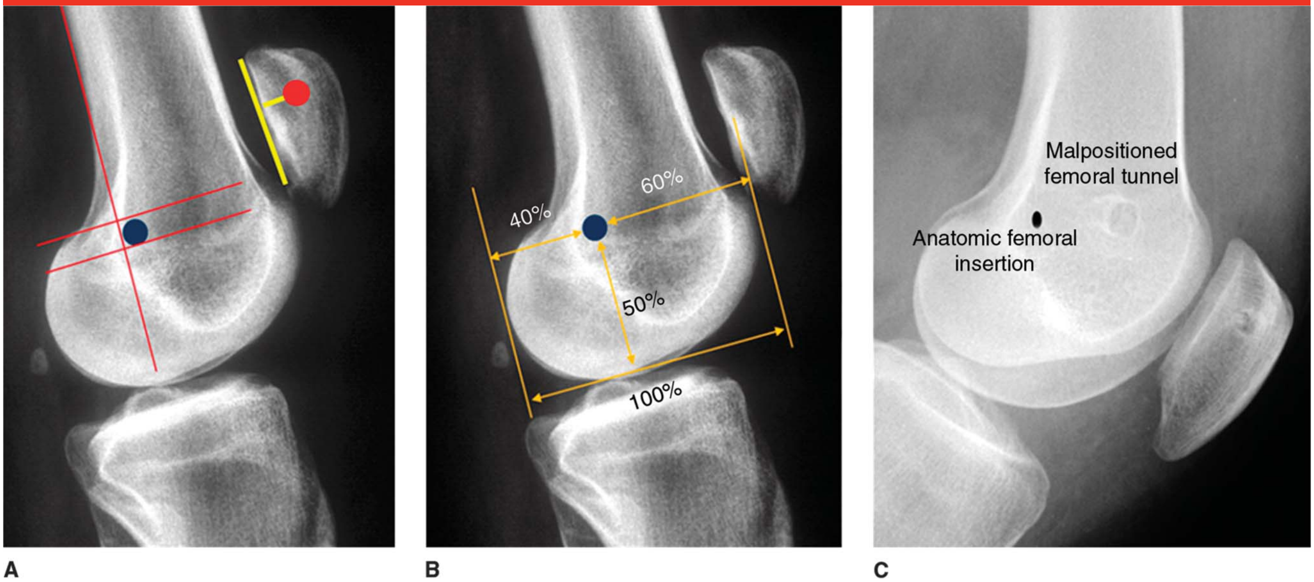
Clinical Relevance of the Patellar Attachment

The patellar attachment of the MPFL has received less scrutiny than the femoral attachment. Kang et al[16] described two functional bundles based on the patellar insertion of the ligament: the inferior and the superior. The inferior bundle is a static restraint, whereas the superior bundle is a dynamic restraint because it is associated with the vastus medialis oblique. To reproduce the MPFL's broad attachment site on the patella, Farr and Schepsis[17] advise the use of a double semitendinosus graft (ie, "anatomometric" placement). Interestingly, Mochizuki et al[18] showed that the ligament is not really an MPFL because the proximal fibers are attached to the vastus intermedius, whereas the distal fibers are attached to the medial margin of the patellar tendon, not into the patella. They suggest that contraction of the vastus intermedius induces tension on the MPFL and thus stabilizes the patella during knee extension. Consequently, reconstructing the MPFL into the patella may not be anatomic in many cases, thus bringing into question the practice of drilling into the patella to construct a ligament that does not exist.

How to Choose the Attachment Points

Servien et al[13] highlighted the difficulty of performing reproducible MPFL reconstructions. The authors analyzed 29 femoral tunnels, and

Figure 1



A, Lateral radiograph demonstrating the anatomic femoral attachment point (blue dot) according to Schöttle et al[19] and the anatomic patellar attachment point (red dot) according to Barnett el al.[20] The red lines represent the reference lines used by Schöttle et al[19] to locate the femoral attachment point. The yellow lines represent the reference lines used by Stephen et al[21] to locate the femoral attachment point. **B,** Lateral radiograph demonstrating the anatomic femoral attachment point (blue dot) according to Stephen et al.[21] Assuming that the anterior-posterior measure is 100% (bottom yellow arrow), the medial patellofemoral ligament (MPFL) attachment is 40% from the posterior, 50% from the distal, and 60% from the anterior outline. **C,** Lateral radiograph demonstrating the anatomic malpositioning of the femoral tunnel in a patient with severe anterior knee pain and medial patellar instability after MPFL reconstruction.

only 20 (69%) were considered on conventional radiographs to be well positioned.

In a 2007 laboratory study, Schöttle et al[19] were the first to describe reliable radiographic landmarks for an anatomic femoral attachment during MPFL reconstruction. They indicated that the radiographic point of the anatomic MPFL femoral attachment, on a true lateral radiograph, is located 1 mm anterior to the tangent to the posterior femoral cortex (reference line), 2.5 mm distal to the perpendicular line traced through the initial part of the medial femoral condyle, and proximal to the perpendicular line traced through the most posterior part of the Blumensaat line (Figure 1, A). In a laboratory study using human cadaver knees, Redfern et al[22] also concluded that radiographic landmarks can be used to precisely locate the anatomic femoral attachment of the MPFL.

Despite the reproducible radiographic landmarks, however, the curved outline of the posterior femoral cortex varies as a consequence of a patient's history of weight-bearing activity.[21] Therefore, Stephen et al[21] suggested that the posterior femoral cortex may not represent a consistent anatomic landmark for reliably determining the femoral attachment location. To avoid the limitations of the previous methods, Stephen et al[21] used normalized dimensions of the articular geometry and determined the anatomic femoral attachment of the MPFL in relation to the size of the medial femoral condyle: if anterior-posterior size is 100%, then the MPFL attachment is 40% from the posterior, 50% from the distal, and 60% from the anterior outline (Figure 1, B). Therefore, radiographic landmarks could be helpful intraoperatively for anatomic graft placement and postoperatively as an outcome tool in evaluating patients with persistent pain or instability after MPFL surgery (Figure 1, C). However, at best, C-arm identification of the graft placement site is an approximation and should not be the sole basis for femoral attachment location. The final placement must be based on a thorough understanding of the relevant anatomy. It is also important to make a sufficiently large incision to unequivocally identify the anatomic structures involved. It is only in this way that one can be sure of anatomic placement of the graft and perform an accurate execution of this type of surgery.

Barnett et al[20] described reliable radiographic landmarks to perform an anatomic patellar attachment during MPFL reconstruction. Based on their study, the patellar attachment is located 7.4 mm anterior to a line tangent to the posterior patellar cortical line and 5.4 mm distal to the proximal edge of the articular surface of the patella (Figure 1, A). Furthermore, the MPFL-patellar attachment encompasses 33% of the total length of the patella and is located at the junction of the proximal third and the distal two thirds of the longitudinal axis of the patella (Figure 1, A).

Another consideration to be noted is that the femoral origin and patellar insertion of the MPFL are characterized by notable individual anatomic variations.[23] Therefore, anatomic localization of both the patella and femoral insertions by a mini-open approach may be imprecise in a particular patient. According to Siebold and Borbon,[23] the MPFL footprint, both femoral and patellar, can be visualized arthroscopically using an extra-articular approach from the knee joint. This would allow personalized anatomic MPFL reconstruction and, in theory, could reduce postoperative complications.

Favorable MPFL Anisometry

The concept of isometry was developed in the 1960s in the literature of anterior cruciate ligament (ACL) surgery. An isometric placement of the ACL implied that a full range of knee motion can be achieved without evident ligament elongation, thereby allowing the graft length to remain constant throughout the range of motion. Thus, isometry would prevent graft failure due to overstretching. However, clinical experience has indicated that this assumption is invalid. Currently, the objective of ACL reconstruction is not to achieve isometry but to replicate the native ACL anatomy and function (ie, anatomometric reconstruction). If we extrapolate the lessons learned from ACL reconstruction to MPFL reconstruction, we should aim to replicate the anatomy and function of the native ligament rather than strive for absolute isometry. Therefore, knowledge about MPFL anatomy and functionality is crucial.

Most authors now state that the MPFL is nonisometric over the complete range of knee motion. Smirk and Morris[10] performed an anatomic dissection study on 25 embalmed knee specimens and evaluated the isometricity from zero to 120° of knee flexion. They defined isometry by a length change of <5 mm through the complete range of knee motion and showed that the MPFL remains isometric only between full extension and 70° of knee flexion. In another cadaver study evaluating isometry, Steensen et al[11] found a length change of 5.4 mm between the femoral and patellar attachments from zero to 90° of knee flexion; from zero to 120°, the length change was 7.2 mm. They concluded that the MPFL is nonisometric. Victor et al[24] confirmed this conclusion in a laboratory study by demonstrating differences in the nonisometry between the two MPFL bundles: the proximal bundle was tauter at zero, whereas the distal bundle was tauter at 30° of knee flexion. In contrast, Stephen et al[21] recently showed in a laboratory study that the native MPFL is almost isometric through zero to 110° of knee flexion. The experimental methods used for evaluating isometry may explain the contradictory results of the aforementioned studies, all of which were performed in cadaver normal knees.

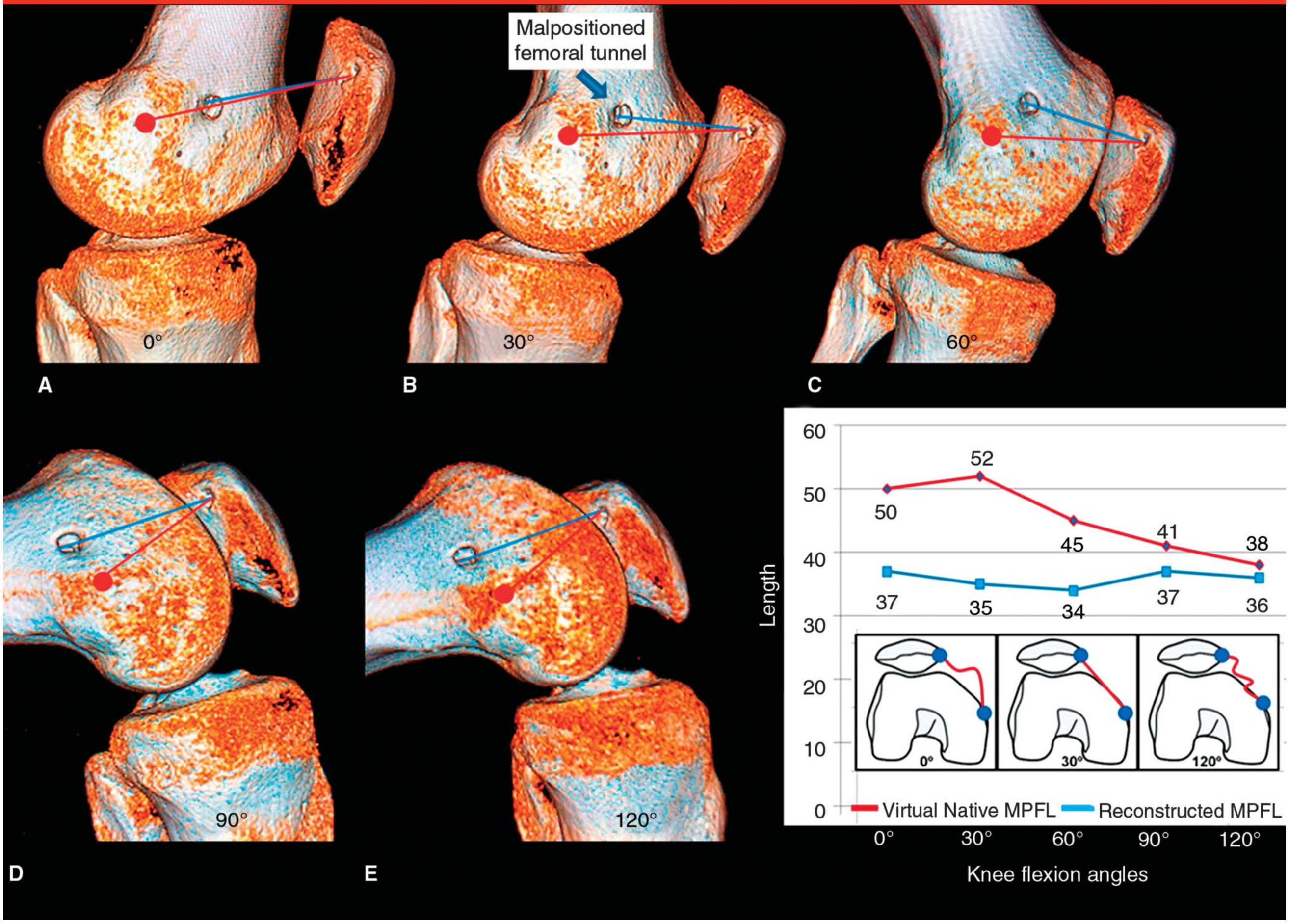
Previous studies on the ACL have shown that small changes in the femoral attachment have a large effect on the length change pattern throughout the range of motion of the knee. This is also true for the MPFL. In cadaver studies, Steensen et al[11] and Stephen et al[21] found that the position of the MPFL-graft femoral attachment substantially affected its length change pattern. In contrast, the position of the patellar attachment has very little effect.[11,21] However, these studies do not address whether the femoral tunnel position is essential to the graft length changes in an MPFL reconstruction in vivo. Tateishi et al[25] showed in a clinical study that the femoral attachment position is essential to the graft length changes in MPFL reconstruction. Moreover, they also confirmed that the center of the femoral tunnel determines the graft length change pattern. If the femoral attachment has a large effect on the graft length change pattern and this change is important for predicting a good postoperative outcome, then the femoral tunnel position appears to be crucial to achieving a good postoperative outcome.

Erasmus[26] noted that patellar height is very important in MPFL isometry; specifically, the higher the patella, the greater the nonisometry of the ligament. Therefore, a distal tibial tubercle transfer should be considered in cases of severe patella alta. In this way, the nonisometry of the MPFL would be decreased. Moreover, this transfer would permit more precise tension on the reconstructed ligament. This is in agreement with Tateishi et al,[25] who demonstrated clinically that the anisometry of the MPFL graft was related to the degree of patella alta.

Triantafillopoulos et al[27] investigated MPFL isometry after reconstruction using a semitendinosus autograft with a "dynamic" femoral fixation with two different pulleys: the medial intermuscular septum (MIS) and the posterior third of the MCL. When the MIS was used as a pulley, the average difference in graft length from zero to 90° of knee flexion was 4 mm; with the MCL as a pulley, the difference was 1 mm. However, although the MIS pulley was less isometric than the MCL pulley, MIS was more stable, restoring better patellar stability.

Parker et al[28] compared patellofemoral kinematics of isometric versus

Figure 2



A through **E,** A three-dimensional CT model at 0°, 30°, 60°, 90°, and 120°, respectively, of knee flexion. The red circle in each panel identifies the anatomic femoral attachment point of the medial patellofemoral ligament (MPFL) according to Stephen et al.[21] The red line in each panel identifies the virtual anatomic MPFL, and the blue line in each panel, the MPFL graft. The blue arrow in panel B identifies anterior malpositioning of the femoral tunnel in a patient with severe anterior knee pain and medial patellar instability after MPFL reconstruction. The length of the graft is defined as the distance between the center of the femoral attachment site and that of the patellar attachment. Inset, The isometry in the anatomic MPFL is maintained from zero to 30°, following the isometry criteria defined by Smirk and Morris[10] (<5 mm difference in length). However, the graft becomes lax with increasing knee flexion. The flexion angle at which the graft is the longest is 30°; therefore, the best flexion angle for fixation of the graft in cases with an anatomic femoral fixation point should be 30°. In our case of reconstructed MPFL with a poor outcome (blue line), the isometry is maintained during the entire range of knee motion. This, together with the graft being stronger than the native ligament to compensate for the underlying predisposing instability factors, produces greater patellofemoral compression in a joint with preexisting medial patellar chondropathy, which would eventually worsen. This fact could explain the anterior knee pain in our patient. Therefore, in a knee with a chronic lateral patellar instability, it may be desirable to obtain isometry only from zero to 30°.

anatomic MPFL reconstructions in a cadaver study and showed that isometric MPFL reconstruction did not restore normal patellofemoral kinematics at any flexion angle, whereas anatomic MPFL reconstruction restored normal patellar tracking from maximal knee extension to 28° of knee flexion. Neither technique was able to restore the normal kinematics of the patella in deeper angles of knee flexion. However, a nonisometric MPFL reconstruction restored the kinematics of the patella better than did an isometric MPFL reconstruction.

An MPFL graft should duplicate the nonisometry of the native MPFL (Figure 2). According to Thaunat and Erasmus,[29] the objective should be to have an MPFL graft isometric from zero to 30° of knee flexion, which duplicates the isometry of the native ligament. This is called favorable anisometry.[29] Therefore, a grafted ligament should tighten in extension and be lax in flexion, with a length change pattern of at least 5 mm between complete extension and deep flexion. This would protect the patella because it is more prone to dislocation from zero to 30° of knee flexion. That the graft is slack with increased knee flexion is less critical.

Graft Tension and Successful MPFL Reconstruction

Apart from the tunnel position, another crucial factor contributing to a successful MPFL reconstruction is graft tension. Even a perfectly placed graft can create problems if it is fixed too tightly. Thaunat and Erasmus[9] reported on two cases of restricted knee motion after graft overtightening; one resulted in loss of extension and the other one in loss of flexion. If the MPFL graft is too tight, it can provoke a medial patellar subluxation as the knee is flexed. Given that there is a high prevalence of medial articular lesions in these patients, care must be taken to avoid overloading the medial patellofemoral joint during reconstruction of the MPFL. Moreover, overtightening the graft can place too much strain on it and eventually cause its failure. Overtightening the graft, particularly with a concurrent lateral retinacular release, can lead to an iatrogenic medial patellar subluxation[7] and is therefore best avoided. However, a lack of adequate tension on the graft (ie, undertightening) can result in inadequate medial restraint and recurrent lateral patellar instability.

From a conceptual point of view, however, so-called tensioning of the MPFL graft is incorrect given that the MPFL is not under tension in its native state. It comes under tension only when a lateral force acts on the patella.[5] Therefore, tensioning the MPFL graft could, in fact, restrict the range of knee motion. The objective of MPFL reconstruction should be to replace the torn ligament with a graft substantially stronger than the native MPFL but with a tension similar to that before its rupture. With normal trochlear anatomy, it is easy to apply the proper tension on the MPFL graft without overconstraining the medial patellar facet. However, with severe trochlear dysplasia, there is a lack of normal anatomic landmarks for centering the patella intraoperatively, and it is more difficult to achieve the proper tension on the MPFL, with a tendency to overtighten it.

A primary question centers on identifying the most appropriate graft tension for optimal restoration of patellofemoral kinematics. From a controlled biomechanical laboratory study using cadaver knees, Beck et al[30] concluded that low tension (2 N) applied to the MPFL graft stabilized the patella without increasing medial patellofemoral pressure. Higher loads restricted lateral patellar translation and increased medial patellofemoral pressure. To calculate the most appropriate graft tension from a practical point of view, the contralateral patella could be used as a reference, but only if it is stable. The idea would be to get the same transverse patellar displacement in the reconstructed knee as in the contralateral knee. This would require draping both knees during surgery and comparing transverse displacement of the patella. In patients with bilateral symptoms, normal patellar motion should allow approximately two patellar quadrants of lateral translation.[31]

Another important question involves the most appropriate knee flexion angle for tensioning the MPFL graft. This is controversial. It seems logical to tension it at the knee flexion angle at which the length of the MPFL graft is greatest (Figure 2). Thaunat and Erasmus[29] recommended that the ligament be tightened in full knee extension. To achieve this, they pulled the patella proximally with a bone hook and achieved more tension in the patellar tendon than in the MPFL graft during maximal quadriceps contraction. Farr and Schepsis[17] tensioned the graft with the knee at 30° of flexion, which resulted in the MPFL graft being lax with knee flexion and tighter in terminal extension. According to Yoo et al,[32] the best angle for graft fixation is 30° of knee flexion, but LeGrand et al[33] recommended tensioning the graft at 45° to 60° of knee flexion. Steiner et al[34] tensioned the graft between 60° and 90° of knee flexion to ensure that the patella would engage in the trochlea. Regardless of the degree of knee flexion, the range of knee motion after graft fixation should be complete, and there should be a good end point to lateral patellar translation from zero to 30° of knee flexion. The MPFL should tighten only on lateral patellar translation.

The Importance of Additional Patellar Instability Risk Factors on Clinical Outcome

One complication following MPFL reconstruction is recurrent lateral patellar instability. It is unclear whether graft failure occurs because of rupture or loosening or whether additional patellar instability risk factors are involved. The etiology of CLPI is often multifactorial, encompassing not only MPFL incompetence but also trochlear dysplasia, malalignment (ie, tibial tuberosity–trochlear groove [TT-TG] distance >20 mm, patellar tilt >20°), and patella alta.[35] Isolated MPFL reconstruction may not be sufficient to obtain good clinical results if these risk factors impede its success, and treatment of the risk factors may be needed in conjunction with MPFL reconstruction.

Wagner et al[36] found that high degrees of trochlear dysplasia were correlated with a poor clinical outcome. This could be explained by the MPFL graft's being overloaded in trochlear dysplastic situations. Therefore, Wagner et al[36] concluded that trochleoplasty should be considered in cases with high degrees of trochlear dysplasia. However, this conclusion was based on a case series (level of evidence IV), and in a separate case series, Steiner et al[34] observed no relationship between trochlear dysplasia and MPFL reconstruction results. Even with the presence of notable trochlear dysplasia, procedures to address associated patellar instability risk factors (ie, medial soft-tissue deficiency, increased TT-TG distance, patella alta) are recommended as first-line treatment instead of trochleoplasty.[37] Correction of these factors can compensate for a deficient trochlea and can provide stability.[37] Because of high complication rates, trochleoplasty should be reserved for cases with severe dysplasia in which other surgical options cannot provide patellofemoral stability.[37] That is, trochleoplasty should be only a salvage surgical procedure.[37]

Wagner et al[36] found patella alta in 58% of the patients in their series. However, in 70% of their cases with patella alta, the patellar index ranged from 1.2 to 1.3, which could explain why this risk factor for patellar instability did not negatively influence the clinical outcome of their patients. For now, the index of patella alta that should be corrected by distal advancement of the tibial tubercle is unclear.

Finally, Wagner et al[36] also found lower scores in the clinical outcome in patients with pathologic TT-TG distance, leading these authors to advise medializing the tibial tuberosity to reestablish a normal TT-TG distance (approximately 12 mm). The ultimate objective would be to reduce the overload on the MPFL graft.

The ideal indication for an isolated MPFL reconstruction would be a recurrent lateral patellar dislocation in a patient with a TT-TG distance <20 mm, a positive apprehension test until 30° of knee flexion, a patellar Caton-Deschamps index of <1.2, and trochlear dysplasia grade A.

Summary

Currently, the standard surgical approach in patients with CLPI with at least two documented patellar dislocations is to stabilize the patella by means of an anatomic MPFL reconstruction using a mini-open technique and a graft stronger than the native MPFL to compensate for the underlying uncorrected predisposing patellar instability factors. MPFL reconstruction is a challenging surgical procedure that requires experience to avoid complications related to malpositioning of the femoral tunnel or inadequate tension on the graft. Adequate graft position in the femur as well as appropriate tension are critical steps that contribute to the overall outcome after MPFL reconstruction. Moreover, in some cases, it is necessary to pair MPFL reconstruction with other surgical procedures to address additional patellar instability risk factors, such as trochlear dysplasia, malalignment, and patella alta. Understanding of the anatomy and function of the MPFL are critical to performing successful long-term MPFL reconstruction.

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References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, reference 5 is a level II study, references 8, 13, and 34-36 are level IV studies, and references 1-4, 6, 7, 9-12, 14-33, and 37 are level V expert opinion.

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