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Lateral Patellofemoral Ligament Reconstruction: Anatomy, Biomechanics, Indications and Surgical Techniques

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With the exponential increase in the arthroscopic treatment of medial patellar instability through lateral sided "capsular" releases, the iatrogenic upsurge of lateral patellar dislocations has become more evident. Although few reports exist detailing the occurrence of this phenomenon due to traumatic or idiopathic etiologies, the vast majority (over 90%) are iatrogenic. Originally described by Kaplan and later by Reider, the lateral patellofemoral ligament (LPFL) constitutes one of the main stabilizers for medial patellar translation. Thus, understanding the anatomy and biomechanics of the LPFL is of utmost importance as reconstruction can potentially restore patellar instability and improve function in cases when this mechanism is compromised. However, few studies have sought to thoroughly describe the intricate anatomy and biomechanics of the LPFL to this end. The purpose of this article was to review the evidence on the anatomy of the LPFL and the lateral retinaculum, its biomechanical behavior, and previously reported surgical approaches to LPFL reconstruction.
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KEYWORDS Lateral patellofemoral ligament, LPFL, Reconstruction, Surgical technique, Anatomy

Introduction

Medial patellar instability is an infrequent entity (considering that lateral patellar dislocations constitute the second leading cause of traumatic knee hemarthroses)[1,2] that may result from an incompetent lateral patellofemoral ligament (LPFL) because of iatrogenic, traumatic, or idiopathic causes.[3] In this regard, more than 90% of the cases of medial patellar instability reported in the literature occurred after iatrogenic causes such as a lateral retinacular release or a tibial tubercle osteotomy.[4-6] For this reason, trends have shifted toward a preference for lateral lengthening as the controlled preservation of the lateral patellar muscle-capsuloligamentous continuity after this procedure is thought to be associated with less postoperative complications.[7]

A biomechanical study by Christoforakis et al[8] found that the mean force required to displace the patella 10-mm laterally was reduced significantly due to lateral retinacular release, suggesting that lateral retinacular release may not be appropriate in treatment of patellar lateral instability. Furthermore, Pagenstert et al in a prospective, double-blinded study demonstrated that retinacular lengthening resulted in less medial instability, less quadriceps atrophy, and better clinical outcomes at 2-year postoperatively when compared with retinacular release.[7] When medial patellar instability has already developed, several methods to surgically address a

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lateral retinacular insufficiency have been described: These include imbricating the lateral retinaculum,[5,9] soft tissue augmentation using the fascia lata,[10] or LPFL reconstruction techniques using autograft and allograft.[11-13]

Although there is an extensive body of the literature describing the medial patellar restaints,[14-16] the anatomy, structural characteristics and biomechanical implications of the LPFL remain poorly defined after its original description by Kaplan in 1962.[17] For these reasons, the purpose of this article was to provide a comprehensive review of the available evidence on the anatomy of the LPFL and the lateral retinaculum, its biomechanical behavior, and previously reported surgical approaches to LPFL reconstruction.

Anatomy of the Lateral Patellar Restraints

The lateral anatomy of the knee is a very complex structure that is didactically divided in layers for its ease of understanding. The first fascial layer is composed of the fascia lata that attaches to the patella, the patellar tendon and Gerdy's tubercle. The anterior expansion of the iliotibial band curves forward forming a group of arciform fibers and blending with the fascia lata covering the patella (Fig. 1).

Fulkerson and Gossling[18] described the anatomy of the knee lateral retinaculum in 2 distinctly separate layers. The first layer is the superficial oblique layer, which originates from the iliotibial band and interdigitates with the longitudinal fibers of the vastus lateralis (Fig. 2). The second layer is the deep layer, which consists of the deep transverse retinaculum with the LPFL and the patellotibial ligament distally (Fig. 3).

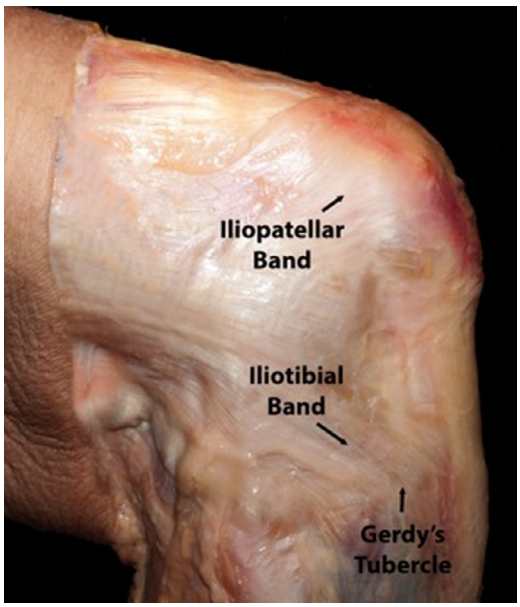

Figure 1 Anatomic dissection of a right knee demonstrating the attachments of the iliotibial band on the patella and the tibia (Gerdy's tubercle). (Color version of figure is available online.)

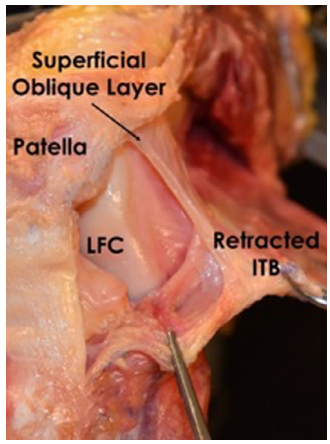

Figure 2 Anatomic dissection of a left knee demonstrating the superficial oblique layer of the retinaculum with the iliotibial band (ITB) retracted. LFC, lateral femoral condyle. (Color version of figure is available online.)

Kaplan first described the lateral epicondiylopatellar ligament as a palpable thickening of the joint capsule.[17] Almost 20 years later, Reider et al coined the term LPFL in a quantitative anatomic study of the anterior knee.[19] The authors described a palpable thickening of the joint capsule connecting the patella to the lateral femoral epicondyle. Since then, multiple authors have described mostly consistent attachments with varying ligament characteristics. Merician and Vieira[20,21] suggested that the joint capsule was thickened laterally to form the LPFL, with great variability between specimens and without defined borders. Vieira also resected the ligament in these cadavers and observed that the patella luxated medially, concluding that the LPFL played a role in medial instability of the knee.[20]

In a recent study by Capkin et al,[22] 32 embalmed cadaveric knees were analyzed to better describe the LPFL anatomy. The authors found that the mean length of the LPFL was 23.2 mm and its mean width at the insertion point on the condyle was 15.6 mm. In regard to the LPFL attachments, the authors concluded that the insertion of the LPFL into the lateral condyle was most frequently located in the central area (vertical plane: 53.1% middle, sagittal plane: 75% middle). Furthermore, the patellar insertion was found in the posterior half and upper lateral aspect of the patella. In concordance with previous anatomic studies was the finding

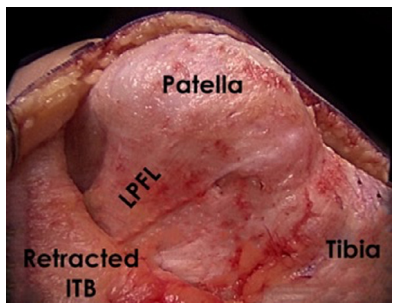

Figure 3 Anatomic dissection of a right knee demonstrating the lateral patellofemoral ligament (LPFL) with the iliotibial band (ITB) retracted. (Color version of figure is available online.)

that the ligaments do not attach directly to the epicondyles, but rather in its immediate proximity.[23-26] Shah et al[27] reported that the origin of the LPFL was distal and anterior to the lateral epicondyle and that its insertion was centered in the middle third of the patella. Interestingly, this insertion was found to be broad, measuring roughly 45% of the articular surface.[27]

Biomechanics of the Lateral Patellofemoral Ligament

Currently, there is a paucity of literature that has sought to investigate the biomechanical properties of the LPFL or that have considered the clinical consequences of abnormal LPFL function. DeFroda and colleagues[28] recently performed a cadaveric study including ten fresh-frozen human knees where the LPFL was subjected to axial loading until failure. Interestingly, they found that nine out of ten LPFL specimens failed at the midsubstance of the tendon under an average of 90 ± 67N of axial load force. The other LPFL specimen failed at the femur attachment. Furthermore, these authors determined that the midsubstance width was correlated with the load to failure; however, this relationship was not statistically significant when analyzed in a regression model. The authors concluded that in the context of these findings, future studies were warranted to determine the consequences of various reconstruction or repair techniques on the degree of constraint and resultant kinematics involving the LPFL.

Indications and Techniques for Lateral Patellofemoral Ligament Reconstruction

The indications for LPFL reconstruction are: Symptomatic (1) isolated or iatrogenic medial patellar subluxation (MPS), which often presents clinically as insidious anterior knee pain that is exacerbated with flexion; (2) lateral patellar laxity; (3) failed nonsurgical treatment; and (4) when performed in conjunction with medial stabilization procedures in cases of bidirectional patellar instability.[29] Traditionally, MPS has been corrected using reconstruction or repair of the lateral retinaculum; however, more recently, the functional importance of LPFL in preventing MPS has increasingly been recognized, and reconstruction of the LPFL has gained much attention as repair or imbrication of the lateral retinaculum alone may result in the recurrence of clinically significant medial patellar excursion.[12] Indeed, several surgical techniques which aim to resolve MPS through restoration of the anatomic and biomechanical functions of the LPFL have become popularized, all of which differ primarily with regards to graft choice and method of patellar fixation.[11,12,29-32]

One such surgical method of LPFL reconstruction utilizes a gracilis tendon allograft which is secured in a tunnel within the extensor retinaculum and periosteum over the patella using a minimally invasive technique.[29] Briefly, a gracilis allograft is utilized at a minimum length of 20 cm and whipstitched with a no.2 high strength suture. Next, a 3-4 cm incision is created over the superior one-third of the patella. Two, 1 cm incisions are then made in the periosteum at the level of the proximal patella and at the lateral border of the patella, which are connected subperiosteally. Femoral tunnel placement is chosen by identifying the location of the lateral epicondyle and creating a 2-3 cm incision longitudinally over this landmark. Subsequently, the graft is placed in the second layer of the lateral retinaculum superficial to the joint capsule. The fascia is incised and a 2.7 mm passing pin is placed at the predetermined LPFL attachment site and advanced anteriorly (and proximal) toward to medial side of the femur and out of the medial femoral cortex. A blind tunnel is then reamed into the femur to approximately the size of the doubled gracilis graft (usually 6 mm). Finally, the gracilis allograft is looped through the subperiosteal tunnel, the free end of which is passed through the retinacular tunnel exiting at the epicondyle to obtain proper graft tension, and the graft is secured to the LPFL attachment site with a 6×23 mm interface screw, while the periosteum is sutured to the graft and the retinaculum is closed over the graft. It is thought that this minimally invasive technique avoids unnecessary stress within the patella and is able to restore lateral patellar instability through avoiding bone tunnels and patella fixation.

Borbas et al[31] reported successful outcomes at one-year postoperatively for MPS after TKA using LPFL reconstruction with a free gracilis autograft. In this case report, the etiology was iatrogenic as the patient had undergone concomitant tibial tubercle osteotomy and lateral retinacular release. During LPFL reconstruction, the gracilis tendon was harvested and prepared. A 3 cm skin incision was made anterolateral to the patella and the bony insertion of the LPFL was prepared by detaching the lateral retinaculum. Two convergent drill holes were placed in the proximal and distal aspects of the lateral bony rim. After the graft was passed, a 2 cm longitudinal skin incision was made over the lateral femoral epicondyle and the layer between the lateral retinaculum and joint capsule was prepared by splitting the fascia lata and passing a suture loop through the dissected layers to allow the free end of the graft to be passed. Finally, after creating a lateral socket, the free graft ends were pulled through and fixed into the femoral hole using an absorbable 7×28 mm interface screw. The authors reported that the patient had a clinically stable patella without evidence of maltracking which was subsequently confirmed by radiographic visualization at their 1-year follow-up visit.

LPFL reconstruction has also been reported using a quadriceps tendon autograft.[11] The technique is as follows: After a diagnostic arthroscopy is performed and associated pathologies are addressed, a midline skin incision is made to expose the patellar mechanism from the tibial tubercle extending proximally 5 cm above the patella. The partial-thickness quadriceps graft is harvested from the central third of the quadriceps tendon so as not to jeopardize its patellar insertion. The graft is taken from the most superficial layer of the tendon and is cut proximally. After using previously

described methods for graft preparation and femoral tunnel placement,[29] the quadriceps tendon is then turned 90° laterally and twisted 180°, and the free ends of the loop suture and proximal end of the graft are passed through the tunnel. Subsequently, the graft is secured to the LPFL attachment site with 4.75 mm biotenodesis screw and proper tension is ensured before closure.

Beckert et al[32] reported range of motion restoration and improved clinical outcomes, as well as decreased instability apprehension, by using an LPFL reconstruction technique with a semitendinosus allograft. The authors placed a guide pin in the lateral femoral epicondyle at an isometric point that mimicked the ideal position of a medial patellofemoral ligament reconstruction which was confirmed by position of the tunnel from lateral radiographs compared to the Blumensaat line and posterior cortex in that area. The semitendinosus allograft was harvested and secured to the lateral femoral condyle using a cortical fixation device that was placed on the medial femoral condyle and was then sutured to the patella in an isometric position with the knee in flexion using high-strength sutures with a Krachow technique. Afterward, the graft was passed through the cortical fixation device loop and a decompression window was created in the IT band at the femoral origin of the LPFL reconstruction. The high strength suture attached to the allograft was then fixed to the anterior aspect of the patella with no bone anchors. At a mean 2.05-year follow-up, none of the 17 patients reported residual symptoms of patellar instability, medial patellar apprehension, or examiner induced subluxation. In addition, the mean Knee injury and osteoarthritis score (KOOS) increased from 34.39 to 69.54 ($P < 0.0001$).

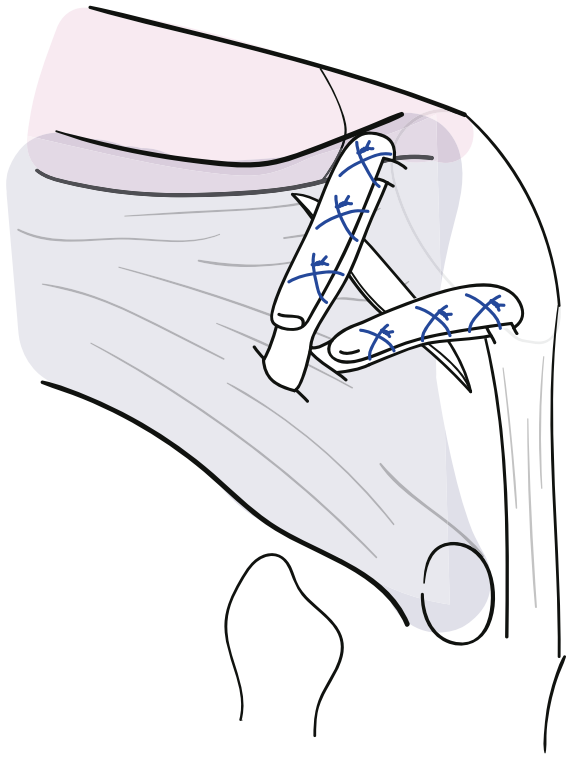

Figure 4 A diagram showing the graft folded down on itself and sutured back with nonabsorbable sutures. (Color version of figure is available online.)

Authors' Preferred Technique

Positioning: Following dynamic evaluation (progressive degrees of flexion) of the medial translation of the patella, a tourniquet is placed around the operative thigh, and the patient is placed supine with the operative leg in a holder. At this point, a diagnostic arthroscopy of the knee is performed to further evaluate concomitant pathology and address if present. The foot is then placed in a boot connected to a support arm to keep positioning consistent.

Approach: A 6 cm incision centered over the proximal pole of the patella is created along the lateral border of the patella to expose the patella and the extensor mechanism. The subcutaneous tissue is then sharply dissected with a bovie electrocautery. Once the correct layer is identified, Metzenbaum scissors are utilized to develop a plane over the IT band. At this point, there is usually a palpable defect from the prior release.

Next, two 1 cm incisions are made over the lateral epicondyle, on the IT band. Additionally, 2 small incisions at the lateral borders of the quadriceps and patellar tendon at the

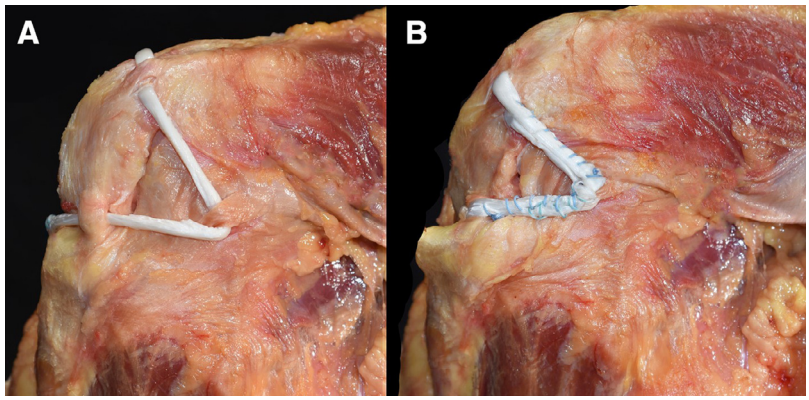

Figure 5 Anatomic dissection demonstrating an LPFL reconstruction on a left knee. (A) The graft was passed through a soft tissue tunnel over the lateral epicondyle and proximal and distal to the patella. (B) The excess of the graft is folded on its own and sutured to the bottom limbs. (Color version of figure is available online.)

superior and inferior aspect of the patella are made such that subfascial tunnels can be bluntly created between the quadriceps and patellar tendon. This is typically performed with a hemostat to ensure blunt dissection. Then, a gracillis allograft is passed in V type fashion. Once this is accomplished, the graft is folded back down on itself, and sutured back with nonabsorbable sutures (Fig. 4). With the knee in 60° of flexion and the patella reduced in the trochlea, proper graft tension should be obtained. Quadriceps contraction should be simulated to verify full excursion, and a repeat arthroscopy should be performed to identify proper anatomical placement of the patella (Fig. 5).

Postoperative care: After closure of the incisions, the patient should be placed in a knee immobilizer. In terms of postoperative rehabilitation, the patient should be encouraged to bear weight on the operative limb as tolerated with assistance of crutches for 2 to 4 weeks. Once adequate quadriceps control has been achieved by the patient, this is an indication to discontinue knee immobilizer requirement.

Conclusions

In conclusion, the lateral patellofemoral ligament constitutes the main lateral patellar restraint. Medial patellar instability is increasingly being recognized as an iatrogenic complication of lateral patellar retinacular releases. In this regard, reconstruction of the LPFL has become an accepted approach to address medial patellar instability in cases of recurrent pain and instability episodes. Despite the increasing literature on approaches to LPFL construction, it is clear that information regarding the outcomes of these select cases is lacking. Future studies are warranted to determine whether there is an association between graft choice, technique, and both the restoration of normal biomechanics and improvements in clinical outcomes after LPFL reconstruction.

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