Quadriceps Tendon Sling Versus Semitendinosus Autograft for Medial Patellofemoral Ligament Reconstruction: Review of Biomechanics, Surgical Techniques, Outcomes

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Abstract

Background: Recurrent patellar instability is a common orthopedic condition, particularly among young and physically active individuals, and it is frequently associated with injury or insufficiency of the medial patellofemoral ligament (MPFL). The MPFL functions as the primary passive stabilizer of the patella against lateral displacement, contributing approximately 50–60% of the restraining force during early knee flexion. Surgical reconstruction of the MPFL has become a widely accepted treatment for patients with recurrent patellar dislocation when conservative management fails. Numerous surgical techniques and graft choices have been described, among which the semitendinosus autograft and quadriceps tendon–based techniques represent two of the most commonly utilized options. While semitendinosus graft reconstruction has historically been considered the standard approach, quadriceps tendon sling techniques have gained increasing popularity due to their anatomical advantages, avoidance of patellar drilling, and potentially lower complication rates.

Aim: This review aims to comprehensively evaluate and compare quadriceps tendon sling and semitendinosus autograft techniques for MPFL reconstruction. The review focuses on key aspects including anatomical considerations, biomechanical properties, surgical techniques, fixation methods, clinical outcomes, complication profiles, and graft-related advantages and disadvantages. Additionally, the article explores the evolving evidence regarding graft selection and highlights the role of surgeon preference, patient characteristics, and anatomical factors in determining the optimal reconstructive strategy.

Conclusion: Both quadriceps tendon sling and semitendinosus autograft techniques demonstrate favorable outcomes in restoring patellar stability and improving functional scores in patients with recurrent patellar instability. Semitendinosus autografts provide strong biomechanical properties and versatile fixation options but may be associated with donor-site morbidity and potential complications related to patellar drilling. In contrast, quadriceps tendon sling techniques offer a more anatomical reconstruction with preservation of the native patellar attachment and reduced risk of patellar fracture, while also eliminating the need for hamstring harvesting. Current literature suggests that both graft options are effective when appropriate surgical indications and techniques are followed. However, graft choice should be individualized based on patient-specific factors, anatomical considerations, and surgeon expertise. Further high-quality comparative studies and long-term follow-up investigations are required to better define the optimal graft selection strategy for MPFL reconstruction.

Keywords: *Quadriceps Tendon Sling, Semitendinosus Autograft, Medial Patellofemoral Ligament Reconstruction*

Introduction

adolescents and young adults, particularly those engaged in athletic activities. Patellar dislocation commonly occurs following a traumatic lateral displacement of the patella and may subsequently lead to recurrent instability, persistent pain, and functional impairment. Epidemiological studies have demonstrated that the incidence of primary patellar dislocation ranges between 5 and 7 cases per 100,000 individuals annually, with a higher incidence among adolescents and physically active individuals. Following an initial dislocation, recurrent instability develops in approximately 30–40% of patients, particularly in the presence of anatomical risk factors such as trochlear dysplasia, patella alta, increased

tibial tubercle–trochlear groove distance, and generalized ligamentous laxity. Repeated episodes of instability may eventually result in progressive cartilage damage, patellofemoral osteoarthritis, and long-term functional limitations if not properly treated. [1,2]

The medial patellofemoral ligament (MPFL) has been identified as the primary passive stabilizer preventing lateral patellar displacement during the early degrees of knee flexion. Anatomical and biomechanical investigations have demonstrated that the MPFL contributes approximately 50–60% of the restraining force against lateral translation of the patella between 0° and 30° of knee flexion. Injury to the MPFL occurs in the majority of acute patellar dislocations and is therefore considered a key pathological component in recurrent patellar instability. Consequently, restoration of MPFL integrity has become a fundamental principle in the surgical management of recurrent patellar dislocation. [3,4]

Advances in the understanding of patellofemoral biomechanics have led to a paradigm shift in surgical treatment strategies. Earlier procedures such as medial reefing, lateral release, and distal realignment procedures were commonly performed to address patellar instability; however, these techniques often failed to restore the native biomechanics of the patellofemoral joint. Over the past two decades, anatomical reconstruction of the MPFL has emerged as the preferred surgical intervention for patients with recurrent instability who do not require major bony corrective procedures. Numerous clinical studies have reported favorable outcomes following MPFL reconstruction, including improved patellar stability, enhanced functional scores, and high rates of return to sport. [5,6]

A variety of graft choices and surgical techniques have been described for MPFL reconstruction in an effort to reproduce the native ligament anatomy and biomechanical behavior. Among these options, autologous hamstring tendons—particularly the semitendinosus tendon—have historically been the most widely utilized graft source. The semitendinosus autograft offers several advantages, including adequate graft length, favorable tensile strength, and widespread familiarity among orthopedic surgeons. In this technique, the harvested tendon is typically fixed to the patella and femur using bone tunnels or suture anchors to replicate the anatomical course of the MPFL. Numerous studies have demonstrated satisfactory clinical outcomes with semitendinosus graft reconstruction, making it one of the most commonly performed procedures for MPFL reconstruction worldwide. [7,8]

Despite the favorable outcomes associated with hamstring autografts, several potential complications have been reported. These include donor-site morbidity, hamstring weakness, patellar fracture related to bone tunnel creation, graft malposition, and complications related to fixation devices. In particular, patellar tunnel drilling has been associated with an increased risk of patellar fracture, which has prompted surgeons to explore alternative graft options and fixation techniques that minimize patellar bone violation. These concerns have contributed to the development of quadriceps tendon–based techniques for MPFL reconstruction. [9,10]

The quadriceps tendon sling technique has gained increasing popularity as an alternative approach for MPFL reconstruction. This method utilizes a partial-thickness strip of the quadriceps tendon that remains attached to the superior pole of the patella, thereby preserving the native patellar insertion and avoiding the need for patellar bone tunnels. The retained patellar attachment allows the graft to mimic the anatomical orientation of the native MPFL while potentially reducing the risk of patellar fracture. Additionally, the quadriceps tendon provides a thick and robust graft with favorable biomechanical characteristics suitable for ligament reconstruction. Early clinical studies have reported promising outcomes using this technique, with satisfactory patellar stability and low complication rates. [11,12]

Although both quadriceps tendon sling and semitendinosus autograft techniques have demonstrated encouraging results, debate remains regarding the optimal graft choice for MPFL reconstruction. Differences between these techniques may exist in terms of surgical complexity, graft fixation strategies, biomechanical properties, complication profiles, and postoperative recovery. Furthermore, patient-specific factors such as skeletal maturity, activity level, and associated anatomical abnormalities may influence graft selection and surgical decision-making. [13]

Given the increasing number of surgical techniques and graft options available for MPFL reconstruction, a comprehensive evaluation of the available evidence is necessary to guide clinical practice.

Comparative analysis of quadriceps tendon sling and semitendinosus autograft techniques may provide valuable insights into their relative advantages and limitations. Understanding these differences can assist surgeons in selecting the most appropriate graft for individual patients while optimizing surgical outcomes and minimizing complications.

Therefore, the aim of this review is to critically evaluate the current literature comparing quadriceps tendon sling and semitendinosus autograft techniques for medial patellofemoral ligament reconstruction. This review focuses on anatomical and biomechanical considerations, surgical techniques, clinical outcomes, and complication profiles associated with each graft option, with the goal of providing evidence-based guidance for graft selection in the management of recurrent patellar instability. [14]

Anatomy and Biomechanics of the Medial Patellofemoral Ligament

The medial patellofemoral ligament (MPFL) is a critical soft-tissue structure responsible for maintaining patellar stability during the early phase of knee flexion. It originates from the medial femoral condyle and inserts along the superomedial border of the patella, forming a key component of the medial retinacular complex. Anatomical studies have demonstrated that the femoral attachment of the MPFL is located between the adductor tubercle and the medial epicondyle, a point often referred to as the "Schöttle point" in radiographic localization. This precise anatomical location is essential during reconstruction procedures, as malposition of the femoral tunnel may significantly alter graft tension and patellofemoral joint mechanics. Accurate restoration of this anatomical footprint is therefore considered fundamental for successful MPFL reconstruction and for preventing abnormal patellar tracking or graft failure. [15,16]

The MPFL functions primarily as a passive stabilizer that restrains lateral displacement of the patella, particularly between full knee extension and approximately 30 degrees of knee flexion. Biomechanical studies have demonstrated that the MPFL contributes approximately 50–60% of the total restraining force preventing lateral patellar translation during this range of motion. Once the knee flexes beyond 30 degrees, the trochlear groove of the femur begins to provide increased bony stability, thereby reducing the reliance on soft-tissue stabilizers. Injury to the MPFL therefore results in a significant reduction in resistance to lateral patellar displacement, predisposing patients to recurrent patellar instability and dislocation. This understanding has been a major factor driving the shift toward anatomical reconstruction of the MPFL in patients with recurrent instability. [17,18]

In addition to its role as a static stabilizer, the MPFL also works synergistically with other soft-tissue structures of the medial retinaculum, including the medial patellotibial ligament and the medial patellomeniscal ligament. These structures collectively contribute to the dynamic stabilization of the patella during knee motion. Furthermore, the quadriceps muscle group, particularly the vastus medialis obliquus (VMO), plays an important role in maintaining patellar alignment by exerting a medializing force on the patella. Disruption of the MPFL following patellar dislocation often occurs near the femoral insertion, although injuries may also occur at the patellar attachment or within the ligament substance itself. Understanding the complex interaction between these stabilizing structures is essential for accurately restoring patellofemoral biomechanics during surgical reconstruction. [19,20]

The native MPFL has unique biomechanical characteristics that must be considered when selecting grafts and surgical techniques for reconstruction. Biomechanical testing has demonstrated that the native MPFL has a tensile strength ranging between approximately 200 and 300 N, with a relatively low stiffness compared to many commonly used grafts. Consequently, grafts used for reconstruction, such as hamstring tendons, may possess significantly greater tensile strength than the native ligament. While this increased strength may provide robust fixation, it also raises concerns regarding potential overconstraint of the patella if graft tensioning is not carefully controlled during surgery. Excessive graft stiffness or improper tensioning may alter patellofemoral contact pressures and contribute to anterior knee pain or cartilage degeneration. [21,22]

Recent biomechanical investigations have also emphasized the importance of graft isometry during MPFL reconstruction. Ideally, the reconstructed ligament should maintain relatively consistent length changes throughout the physiological range of knee motion. Non-isometric graft placement, particularly

due to inaccurate femoral tunnel positioning, may lead to excessive graft tightening during knee flexion or laxity during extension. Both scenarios may negatively affect patellar tracking and compromise surgical outcomes. As a result, careful intraoperative identification of the anatomical femoral insertion and appropriate graft tensioning have become critical steps in modern MPFL reconstruction techniques. These biomechanical considerations play an important role when comparing different graft options such as quadriceps tendon sling and semitendinosus autografts. [23,24]

Pathophysiology and Risk Factors of Recurrent Patellar Instability

Recurrent patellar instability is a multifactorial condition that results from a complex interaction between soft-tissue injuries and underlying anatomical abnormalities. Although an initial traumatic patellar dislocation is often the precipitating event, recurrence frequently occurs due to insufficient healing of the medial stabilizing structures, particularly the medial patellofemoral ligament (MPFL). Following the first dislocation episode, the MPFL is disrupted in the majority of cases, most commonly at the femoral insertion. If the injured ligament fails to heal adequately, the resulting deficiency compromises the medial restraint to lateral patellar translation, thereby predisposing the patient to recurrent instability. The presence of additional anatomical risk factors further increases the likelihood of repeated dislocations and may accelerate degenerative changes within the patellofemoral joint. [25,26]

One of the most significant anatomical contributors to patellar instability is trochlear dysplasia. In a normally developed knee, the trochlear groove provides an osseous constraint that guides patellar tracking during knee flexion. However, in patients with trochlear dysplasia, the trochlear groove is shallow or flattened, resulting in reduced containment of the patella. This abnormal morphology allows the patella to translate laterally more easily, particularly during the early stages of knee flexion before the patella becomes fully engaged within the trochlear groove. Trochlear dysplasia has been identified in a large proportion of patients with recurrent patellar instability and is considered one of the most important structural risk factors influencing both the occurrence and recurrence of patellar dislocation. [27,28]

Patella alta is another important anatomical factor associated with recurrent patellar instability. In individuals with patella alta, the patella sits higher relative to the femoral trochlea, which delays its engagement within the trochlear groove during knee flexion. As a result, the patella remains relatively unstable for a longer portion of the flexion arc, increasing the reliance on soft-tissue stabilizers such as the MPFL. This prolonged period of vulnerability predisposes patients to lateral patellar displacement, particularly during activities involving rapid knee extension or rotational forces. Radiographic indices such as the Insall–Salvati ratio and the Caton–Deschamps index are commonly used to evaluate patellar height and identify the presence of patella alta in patients presenting with recurrent instability. [29,30]

Another key factor frequently evaluated in patients with patellar instability is the tibial tubercle–trochlear groove (TT–TG) distance. The TT–TG distance represents the lateral offset between the tibial tubercle and the trochlear groove and reflects the lateral vector acting on the patella during quadriceps contraction. An increased TT–TG distance results in greater lateralizing forces on the patella, thereby contributing to abnormal patellar tracking and instability. Values exceeding approximately 20 mm are generally considered pathological and may warrant surgical correction through tibial tubercle osteotomy in addition to soft-tissue reconstruction. Accurate assessment of the TT–TG distance using computed tomography or magnetic resonance imaging has therefore become an essential component of preoperative evaluation in patients with recurrent patellar dislocation. [31,32]

Rotational malalignment and generalized ligamentous laxity may also contribute significantly to the pathophysiology of recurrent patellar instability. Excessive femoral anteversion or external tibial torsion can alter the biomechanics of the extensor mechanism, increasing lateral forces on the patella and promoting maltracking. Similarly, patients with generalized ligamentous laxity or connective tissue disorders often demonstrate increased joint mobility, which may compromise the stability of the patellofemoral joint even in the absence of major structural abnormalities. These factors highlight the importance of a comprehensive clinical and radiological assessment when evaluating patients with

patellar instability, as addressing only the MPFL injury without correcting underlying anatomical abnormalities may lead to suboptimal surgical outcomes or persistent instability. [33,34]

Indications for Medial Patellofemoral Ligament Reconstruction

The decision to perform medial patellofemoral ligament (MPFL) reconstruction is primarily based on the presence of recurrent patellar instability and failure of conservative management. Initial episodes of patellar dislocation are often managed non-operatively with immobilization, physiotherapy, and strengthening of the quadriceps musculature, particularly the vastus medialis obliquus. However, conservative treatment may not sufficiently restore stability in patients who develop recurrent episodes of patellar dislocation or persistent symptomatic instability. Clinical studies have shown that recurrence rates following non-operative treatment of primary patellar dislocation can reach up to 40%, particularly in younger and highly active patients. In such cases, surgical stabilization through MPFL reconstruction has been shown to effectively restore medial restraint and reduce the likelihood of recurrent instability. [35,36]

Recurrent lateral patellar dislocation remains the most widely accepted indication for MPFL reconstruction. Patients who experience multiple dislocation events often present with persistent apprehension, anterior knee pain, and functional limitations during daily activities or sports participation. Clinical examination typically reveals a positive patellar apprehension test and increased lateral patellar mobility. Imaging studies frequently confirm injury or insufficiency of the MPFL, along with potential associated anatomical abnormalities. MPFL reconstruction in this patient population aims to restore the primary medial stabilizing structure and re-establish normal patellofemoral biomechanics. Numerous clinical investigations have demonstrated that anatomical MPFL reconstruction significantly reduces redislocation rates and improves functional outcomes in patients with recurrent patellar instability. [37,38]

Another important indication for MPFL reconstruction is symptomatic patellar instability without frank dislocation, often referred to as recurrent patellar subluxation. These patients may experience episodes of patellar shifting, giving way, or persistent apprehension during knee motion, particularly during activities involving pivoting or rapid changes in direction. Although the patella may not completely dislocate, the repeated subluxation events can lead to cartilage injury and progressive patellofemoral joint degeneration. In such cases, reconstruction of the MPFL may help restore medial stability and improve patellar tracking, thereby preventing further joint damage and improving patient-reported outcomes. [39]

MPFL reconstruction is also commonly performed in conjunction with other corrective procedures when significant anatomical abnormalities are present. For example, patients with increased tibial tubercle–trochlear groove (TT–TG) distance may require tibial tubercle osteotomy to correct the excessive lateral vector acting on the patella. Similarly, individuals with severe trochlear dysplasia may benefit from trochleoplasty to restore the normal trochlear groove morphology. In these combined procedures, MPFL reconstruction serves as a soft-tissue stabilizing component that complements the bony correction and enhances overall patellofemoral stability. Careful preoperative evaluation and patient-specific surgical planning are therefore essential for determining the appropriate combination of procedures. [40,41]

Another important consideration in determining the indication for MPFL reconstruction is skeletal maturity. In skeletally immature patients, particular caution must be exercised to avoid injury to the distal femoral physis during femoral tunnel placement. As a result, modified surgical techniques or alternative fixation methods may be employed in pediatric populations to minimize the risk of growth disturbances. Despite these technical considerations, MPFL reconstruction has demonstrated favorable outcomes in both adolescent and adult patients when performed with careful attention to anatomical landmarks and appropriate surgical technique. [42]

In summary, MPFL reconstruction is indicated primarily in patients with recurrent patellar dislocation, persistent symptomatic instability, or recurrent subluxation events that fail to respond to conservative

treatment. The procedure may also be performed in combination with corrective bony procedures when significant anatomical abnormalities contribute to patellar instability. Appropriate patient selection, thorough imaging evaluation, and individualized surgical planning remain critical factors in optimizing outcomes following MPFL reconstruction. [43]

Graft Options for Medial Patellofemoral Ligament Reconstruction

Selection of an appropriate graft is a critical factor influencing the success of medial patellofemoral ligament (MPFL) reconstruction. The ideal graft should replicate the anatomical course, biomechanical strength, and elasticity of the native MPFL while minimizing donor-site morbidity and surgical complications. Over the past two decades, multiple graft sources have been described for MPFL reconstruction, including hamstring tendons, quadriceps tendon, adductor magnus tendon, and allografts. Each graft option possesses distinct biomechanical properties and technical considerations that may influence surgical outcomes. Consequently, graft selection is often guided by surgeon preference, patient characteristics, and the specific surgical technique employed. [44,45]

Hamstring tendon autografts, particularly the semitendinosus and gracilis tendons, are among the most widely utilized grafts for MPFL reconstruction. The semitendinosus tendon is frequently preferred due to its adequate length, high tensile strength, and ease of harvesting. In most techniques, the harvested tendon is fixed to the patella and femur using bone tunnels, interference screws, or suture anchors, thereby recreating the anatomical orientation of the MPFL. Biomechanical studies have demonstrated that hamstring tendons possess tensile strengths that exceed that of the native MPFL, providing sufficient structural stability for reconstruction. Numerous clinical studies have reported favorable outcomes using hamstring autografts, including improved knee function, reduced redislocation rates, and high levels of patient satisfaction. [46,47]

Despite their widespread use, hamstring grafts are associated with several potential disadvantages. Harvesting the semitendinosus tendon may result in donor-site morbidity, postoperative pain, or weakness of knee flexion in some patients. Additionally, many hamstring graft techniques require drilling bone tunnels in the patella for graft fixation. Patellar tunnel creation has been associated with complications such as patellar fracture, tunnel widening, and implant-related irritation. Improper tunnel placement may also compromise patellar tracking and increase the risk of graft failure. These concerns have prompted the exploration of alternative graft options that reduce the need for patellar bone tunnels while maintaining adequate biomechanical strength. [48,49]

The quadriceps tendon has emerged as an increasingly popular alternative graft source for MPFL reconstruction. This tendon offers several advantages, including its proximity to the surgical field, sufficient graft thickness, and the possibility of preserving the native patellar insertion. In quadriceps tendon–based techniques, a partial-thickness strip of the tendon can be harvested while maintaining its attachment to the superior pole of the patella, forming what is commonly referred to as a quadriceps tendon sling. This configuration eliminates the need for patellar drilling and may reduce the risk of patellar fracture. Additionally, the anatomical alignment of the quadriceps tendon allows for a more physiological reconstruction that closely mimics the native MPFL insertion. [50,51]

Another graft option occasionally described in the literature is the adductor magnus tendon. In this technique, a portion of the adductor magnus tendon is utilized as a dynamic graft to reconstruct the MPFL. Because the tendon originates near the anatomical femoral attachment of the MPFL, this approach can provide a relatively anatomical reconstruction without the need for femoral tunnel drilling. However, the adductor magnus technique is less commonly used and has limited clinical data compared with hamstring and quadriceps tendon grafts. As a result, its role in MPFL reconstruction remains more limited and is typically reserved for selected cases or specific surgical preferences. [52]

Allografts have also been used for MPFL reconstruction, particularly in revision surgeries or in patients where autograft harvesting is undesirable. Allograft tendons eliminate donor-site morbidity and reduce surgical time; however, concerns exist regarding graft incorporation, cost, and the potential risk of disease transmission. Although modern sterilization techniques have significantly reduced these risks, many surgeons continue to prefer autografts for primary MPFL reconstruction due to their reliable

biological integration and favorable biomechanical properties. Consequently, hamstring and quadriceps tendon autografts remain the most commonly utilized graft options in contemporary MPFL reconstruction techniques. [53]

Given the variety of graft options available, careful evaluation of their respective advantages and limitations is necessary when planning MPFL reconstruction. Among the numerous graft choices described in the literature, the semitendinosus autograft and the quadriceps tendon sling technique have gained particular attention due to their widespread use and favorable clinical outcomes. These two techniques differ in terms of graft harvesting, fixation methods, biomechanical behavior, and complication profiles. Therefore, understanding the surgical principles and clinical performance of each graft is essential for optimizing treatment strategies in patients with recurrent patellar instability. [54]

Quadriceps Tendon Sling Technique for Medial Patellofemoral Ligament Reconstruction

The quadriceps tendon sling technique has gained increasing attention as an effective method for medial patellofemoral ligament (MPFL) reconstruction. This technique utilizes a partial-thickness strip of the quadriceps tendon, typically harvested from the medial portion of the tendon while preserving its attachment to the superior pole of the patella. By maintaining the native patellar insertion, the graft can replicate the natural orientation and biomechanical behavior of the native MPFL more closely than techniques requiring patellar bone tunnels. The quadriceps tendon provides sufficient thickness and strength for ligament reconstruction while allowing for a relatively straightforward surgical approach due to its proximity to the operative field. As a result, this technique has become increasingly popular among surgeons seeking to minimize complications associated with patellar drilling. [55,56]

The surgical technique generally begins with a longitudinal incision over the proximal patella and quadriceps tendon. A partial-thickness strip of the quadriceps tendon, usually measuring approximately 8–10 mm in width and 6–8 cm in length, is carefully harvested while preserving its distal attachment at the superior pole of the patella. The harvested graft is then mobilized medially and directed toward the femoral insertion of the MPFL. Accurate identification of the femoral attachment point is critical and is commonly guided by radiographic landmarks corresponding to the anatomical MPFL insertion site. The graft is subsequently secured to the femur using an interference screw or suture anchor with the knee positioned in approximately 30 degrees of flexion to ensure appropriate graft tensioning and patellar tracking. [57,58]

One of the principal advantages of the quadriceps tendon sling technique is the avoidance of patellar bone tunnels, which significantly reduces the risk of patellar fracture. Patellar fractures, although relatively uncommon, represent a serious complication associated with MPFL reconstruction techniques that involve transosseous tunnels. By maintaining the natural patellar attachment of the quadriceps tendon, the sling technique preserves the structural integrity of the patella while simultaneously maintaining a more anatomical graft orientation. Additionally, the quadriceps tendon provides a robust graft with sufficient biomechanical strength and favorable tissue quality for ligament reconstruction. These characteristics contribute to reliable stabilization of the patella without the need for additional fixation at the patellar side. [59]

Another advantage of this technique is the reduced donor-site morbidity compared with hamstring tendon harvesting. Harvesting the quadriceps tendon typically results in minimal functional deficit because only a partial-thickness graft is taken, allowing the remaining tendon fibers to maintain the integrity of the extensor mechanism. Furthermore, the quadriceps tendon harvest site is located within the same surgical field, eliminating the need for additional incisions that are commonly required for hamstring tendon harvest. This may result in decreased operative time and reduced postoperative discomfort. Several clinical studies have reported satisfactory functional outcomes and high patient satisfaction rates following quadriceps tendon–based MPFL reconstruction. [60]

Despite its advantages, the quadriceps tendon sling technique is not without potential limitations. Care must be taken during graft harvesting to avoid excessive weakening of the quadriceps tendon or inadvertent injury to the extensor mechanism. In addition, accurate femoral tunnel placement remains a critical factor in achieving optimal outcomes, as malposition may lead to graft overconstraint or

persistent instability. Some surgeons also report a learning curve associated with the technique, particularly with regard to proper graft length, tensioning, and fixation. Nevertheless, with careful surgical planning and adherence to anatomical landmarks, the quadriceps tendon sling technique has demonstrated favorable clinical results and low complication rates in the management of recurrent patellar instability. [61]

Semitendinosus Autograft Technique for Medial Patellofemoral Ligament Reconstruction

The semitendinosus autograft technique is one of the most widely used methods for medial patellofemoral ligament (MPFL) reconstruction and has been extensively described in orthopedic literature. Hamstring tendons, particularly the semitendinosus tendon, are favored because of their favorable biomechanical strength, sufficient length, and well-established use in various ligament reconstruction procedures. The semitendinosus tendon provides a graft with tensile strength that exceeds that of the native MPFL, making it suitable for restoring medial patellar stability. Over the past two decades, numerous surgical techniques utilizing semitendinosus autografts have been developed, and many surgeons consider this graft option to be a reliable and reproducible standard for MPFL reconstruction. [62,63]

The surgical procedure typically begins with harvesting the semitendinosus tendon from the pes anserinus region through a small incision on the medial aspect of the proximal tibia. After identification and isolation of the tendon, it is detached distally and prepared as a graft, often doubled to increase its strength and durability. Once prepared, the graft is used to reconstruct the MPFL by anchoring it between the patella and the femur, thereby recreating the anatomical orientation of the native ligament. Careful graft preparation and measurement are important to ensure appropriate graft length and to avoid excessive tension during fixation. [64]

Several fixation methods have been described for semitendinosus graft MPFL reconstruction. On the patellar side, the graft is commonly secured using bone tunnels, suture anchors, or soft-tissue fixation techniques. Patellar bone tunnels are frequently used to pass the graft through the patella in a loop configuration, which can provide strong fixation and allow for appropriate graft positioning along the medial patellar border. On the femoral side, the graft is typically fixed using interference screws or anchors at the anatomical MPFL insertion site located between the medial epicondyle and the adductor tubercle. Accurate femoral tunnel placement is crucial because even small deviations from the anatomical position may lead to abnormal graft tensioning and altered patellofemoral biomechanics. [65]

The semitendinosus autograft technique offers several advantages that contribute to its widespread adoption. The graft is relatively easy to harvest and provides sufficient length to allow for various fixation techniques and graft configurations. In addition, the high tensile strength of the semitendinosus tendon allows it to withstand the forces applied to the reconstructed ligament during knee motion. Numerous clinical studies have reported excellent functional outcomes following semitendinosus graft MPFL reconstruction, including significant improvements in patient-reported outcome measures such as the Kujala score and Lysholm score, as well as low rates of recurrent patellar dislocation. These favorable results have contributed to the continued popularity of this graft choice among orthopedic surgeons. [66]

Despite these advantages, the semitendinosus autograft technique is associated with certain limitations and potential complications. Harvesting the semitendinosus tendon may lead to donor-site morbidity, postoperative pain, or mild weakness of knee flexion in some patients. Additionally, techniques involving patellar bone tunnels carry a risk of complications such as patellar fracture, tunnel widening, or hardware irritation. Improper graft tensioning or malposition of the femoral tunnel may also result in patellar overconstraint, abnormal patellar tracking, or persistent instability. Therefore, meticulous surgical technique and careful attention to anatomical landmarks are essential when performing semitendinosus graft MPFL reconstruction. [67,68]

Biomechanical Comparison Between Quadriceps Tendon Sling and Semitendinosus Graft

Understanding the biomechanical characteristics of grafts used for medial patellofemoral ligament

(MPFL) reconstruction is essential for achieving optimal surgical outcomes. The reconstructed ligament should ideally reproduce the mechanical behavior of the native MPFL in order to maintain normal patellofemoral joint biomechanics. The native MPFL has a relatively low tensile strength, estimated to range between approximately 200 and 300 N, and exhibits moderate elasticity that allows controlled restraint of lateral patellar translation. When selecting a graft for reconstruction, it is therefore important that the graft provides sufficient strength to stabilize the patella without excessively increasing stiffness, which could result in overconstraint of the patellofemoral joint. Both quadriceps tendon and semitendinosus autografts have biomechanical properties that allow them to meet these functional requirements. [69,70]

The semitendinosus tendon possesses considerable tensile strength and stiffness, often exceeding the mechanical strength of the native MPFL. Biomechanical studies have reported that the semitendinosus tendon can withstand loads significantly greater than those encountered by the native MPFL during normal knee motion. While this high strength provides a durable graft capable of resisting lateral patellar displacement, it may also increase the risk of excessive medial restraint if graft tensioning is not carefully controlled during surgery. Overly stiff graft constructs may alter patellofemoral contact pressures and potentially contribute to anterior knee pain or cartilage degeneration. Therefore, careful intraoperative graft tensioning and accurate femoral tunnel placement are crucial when using semitendinosus autografts to avoid overconstraint of the patella. [71]

In contrast, the quadriceps tendon graft demonstrates biomechanical properties that more closely approximate those of the native MPFL. Because the quadriceps tendon is harvested as a partial-thickness strip and often retains its natural patellar attachment in sling techniques, it can provide a more physiological reconstruction of the medial stabilizing structures. The preserved patellar insertion allows the graft to replicate the natural force distribution across the patella while maintaining appropriate flexibility during knee motion. Additionally, the quadriceps tendon has sufficient thickness and structural integrity to resist lateral patellar translation without introducing excessive stiffness into the reconstructed ligament. These biomechanical characteristics contribute to the growing interest in quadriceps tendon–based techniques for MPFL reconstruction. [72]

Another important biomechanical consideration is graft fixation and its influence on patellar stability. In semitendinosus graft techniques, fixation often relies on patellar bone tunnels or suture anchors. Although these methods provide strong fixation, drilling tunnels in the patella may weaken the bone and increase the risk of fracture, particularly if tunnels are placed too close together or in patients with smaller patellae. In contrast, the quadriceps tendon sling technique typically avoids patellar drilling by maintaining the native tendon attachment to the patella. This approach preserves patellar bone integrity and reduces the risk of tunnel-related complications while still providing adequate stabilization of the patella. [73]

Isometry of the reconstructed ligament is another critical factor affecting surgical outcomes. Ideally, the graft should maintain relatively consistent length during knee flexion and extension in order to replicate the physiological behavior of the native MPFL. Both quadriceps tendon and semitendinosus graft techniques rely heavily on accurate femoral tunnel placement to achieve this goal. Biomechanical investigations have demonstrated that even small errors in femoral tunnel positioning can significantly alter graft length changes during knee motion, leading to excessive graft tightening or slackening. Consequently, regardless of the graft type used, precise identification of the anatomical femoral insertion site remains essential for maintaining appropriate graft isometry and restoring normal patellofemoral mechanics. [74,75]

Clinical Outcomes of Quadriceps Tendon Sling Versus Semitendinosus Autograft MPFL Reconstruction

Clinical outcomes following medial patellofemoral ligament (MPFL) reconstruction have been extensively evaluated in the orthopedic literature, with numerous studies reporting significant improvements in knee stability, function, and patient-reported outcomes. Both quadriceps tendon sling and semitendinosus autograft techniques have demonstrated favorable clinical results in the

management of recurrent patellar instability. Most outcome studies utilize standardized functional scoring systems such as the Kujala score, Lysholm score, and Tegner activity scale to assess postoperative knee function and patient satisfaction. These scoring systems provide objective measures that allow comparison of outcomes between different surgical techniques and graft options. Overall, MPFL reconstruction using either graft source has consistently been associated with improved functional scores and reduced rates of recurrent patellar dislocation. [76,77]

Several clinical studies evaluating quadriceps tendon–based MPFL reconstruction have reported excellent functional outcomes and low complication rates. Patients undergoing quadriceps tendon sling reconstruction frequently demonstrate significant improvements in Kujala and Lysholm scores, reflecting enhanced patellofemoral function and reduced symptoms of instability. Additionally, the preservation of the native patellar attachment in quadriceps tendon techniques may contribute to more anatomical restoration of patellar biomechanics, which could potentially improve postoperative patellar tracking. Early and mid-term follow-up studies have shown high levels of patient satisfaction and a low incidence of recurrent instability following quadriceps tendon MPFL reconstruction. These encouraging outcomes have contributed to the increasing popularity of this technique among orthopedic surgeons. [78,79]

Semitendinosus autograft MPFL reconstruction has also demonstrated consistently favorable clinical results across numerous studies. Patients treated with semitendinosus graft reconstruction typically experience significant improvements in functional scores, including the Kujala and Lysholm scores, as well as improved stability during physical activity. Redislocation rates following semitendinosus graft MPFL reconstruction are generally reported to be low, often ranging between 0% and 5% in many clinical series. Furthermore, many patients are able to return to their pre-injury levels of sports participation following rehabilitation, highlighting the effectiveness of this technique in restoring patellofemoral stability in active populations. [80,81]

Comparative studies examining quadriceps tendon and semitendinosus graft techniques have suggested that both approaches provide similar clinical outcomes in terms of knee function and recurrence rates. Improvements in functional scores appear to be comparable between the two graft types, and both techniques demonstrate high success rates in preventing recurrent patellar dislocation. However, some studies have suggested that quadriceps tendon techniques may be associated with lower rates of patellar complications due to the avoidance of patellar drilling. Conversely, semitendinosus graft techniques remain widely used because of their well-established surgical protocols and long-term clinical evidence supporting their effectiveness. [82,83]

Return to sports and overall patient satisfaction are also important outcome measures when evaluating MPFL reconstruction techniques. Studies have reported high rates of return to recreational and competitive sports following both quadriceps tendon and semitendinosus graft reconstruction. Most patients are able to resume sporting activities within several months following rehabilitation, provided that adequate quadriceps strength and neuromuscular control have been restored. Patient satisfaction rates are generally high with both techniques, reflecting improvements in knee stability, functional capacity, and quality of life. Ultimately, the available evidence suggests that both graft options are effective for MPFL reconstruction when performed using proper surgical technique and appropriate patient selection. [84,85]

Conclusion

Medial patellofemoral ligament reconstruction has become a cornerstone procedure in the surgical management of recurrent patellar instability. Advances in the understanding of patellofemoral biomechanics and anatomical reconstruction techniques have significantly improved surgical outcomes and reduced recurrence rates. Among the various graft options available, the quadriceps tendon sling and semitendinosus autograft techniques represent two widely used and well-established approaches for restoring medial patellar stability. Both techniques aim to replicate the anatomical function of the native MPFL and provide reliable stabilization of the patella during the early phases of knee flexion.

The semitendinosus autograft technique has long been considered a standard method for MPFL

reconstruction due to its strong biomechanical properties, adequate graft length, and familiarity among orthopedic surgeons. Numerous clinical studies have demonstrated favorable outcomes using this technique, including significant improvements in functional scores, low redislocation rates, and high levels of patient satisfaction. However, the use of hamstring autografts may be associated with certain limitations such as donor-site morbidity, potential hamstring weakness, and complications related to patellar bone tunnels, including the rare but serious risk of patellar fracture.

In contrast, the quadriceps tendon sling technique has gained increasing popularity as an alternative graft option that offers several potential advantages. By utilizing a partial-thickness strip of the quadriceps tendon while preserving its attachment to the patella, this technique avoids patellar drilling and may reduce the risk of patellar fracture. Additionally, the anatomical alignment and favorable biomechanical characteristics of the quadriceps tendon may allow for a more physiological reconstruction of the medial patellofemoral ligament. Clinical studies evaluating quadriceps tendon MPFL reconstruction have reported promising results, including improved knee stability, satisfactory functional outcomes, and low complication rates.

Biomechanical investigations suggest that both grafts provide sufficient strength to restore medial patellar restraint, although the semitendinosus tendon may exhibit greater tensile strength than the native MPFL. While this increased strength can contribute to durable stabilization, careful graft tensioning and accurate femoral tunnel placement remain essential to prevent excessive patellar constraint and abnormal joint mechanics. Similarly, successful outcomes with the quadriceps tendon technique depend on meticulous surgical technique and appropriate graft fixation to maintain normal patellofemoral kinematics.

Overall, current evidence indicates that both quadriceps tendon sling and semitendinosus autograft techniques are effective options for MPFL reconstruction and provide comparable clinical outcomes in patients with recurrent patellar instability. The choice of graft should therefore be individualized based on patient characteristics, anatomical considerations, surgeon experience, and the specific goals of the reconstructive procedure. Continued research, including long-term comparative studies and randomized clinical trials, is needed to further clarify the optimal graft selection and to refine surgical techniques for achieving the best possible outcomes in MPFL reconstruction.

References

1. Fithian DC, Paxton EW, Stone ML, et al. Epidemiology and natural history of acute patellar dislocation. Am J Sports Med. 2004;32(5):1114-1121.
2. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. Clin Orthop Relat Res. 2007;455:93-101.
3. Desio SM, Burks RT, Bachus KN. Soft tissue restraints to lateral patellar translation in the human knee. Am J Sports Med. 1998;26(1):59-65.
4. Conlan T, Garth WP, Lemons JE. Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. J Bone Joint Surg Am. 1993;75(5):682-693.
5. Arendt EA, Dejour D. Patella instability: building bridges across the ocean. Knee Surg Sports Traumatol Arthrosc. 2013;21:279-293.
6. Nomura E, Inoue M, Kobayashi S. Generalized joint laxity and contralateral patellar hypermobility in unilateral recurrent patellar dislocators. Arthroscopy. 2006;22(8):861-865.
7. Schöttle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in MPFL reconstruction. Am J Sports Med. 2007;35(5):801-804.
8. Nomura E. Classification of lesions of the medial patello-femoral ligament in patellar dislocation. Int Orthop. 1999;23:260-263.
9. Nelitz M, Williams SR, Lippacher S, Reichel H, Dornacher D. Analysis of failure and complications of MPFL reconstruction. Am J Sports Med. 2014;42(8):1919-1925.
10. Shah JN, Howard JS, Flanigan DC, et al. A systematic review of complications and failures associated with MPFL reconstruction. Am J Sports Med. 2012;40(8):1916-1923.
11. Fulkerson JP. Diagnosis and treatment of patients with patellofemoral pain. Am J Sports Med. 2002;30(3):447-456.
12. Arendt EA, England K. Aggravating factors in patellofemoral instability. Clin Sports Med. 2010;29(3):329-340.

13. Bollier M, Fulkerson JP. The role of trochlear dysplasia in patellofemoral instability. J Am Acad Orthop Surg. 2011;19(1):8-16.
14. LaPrade RF, Engebretsen AH, Ly TV, Johansen S, Wentorf FA, Engebretsen L. The anatomy of the medial patellofemoral ligament. Am J Sports Med. 2007;35(10):1655-1662.
15. Nomura E, Horiuchi Y, Inoue M. Correlation of MR imaging findings and open exploration of MPFL injuries. Am J Sports Med. 2002;30(3):385-391.
16. Schöttle PB, Fucentese SF, Romero J. Clinical and radiological outcome of MPFL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2005;13:516-521.
17. Amis AA, Firer P, Mountney J, Senavongse W, Thomas NP. Anatomy and biomechanics of the medial patellofemoral ligament. Knee. 2003;10(3):215-220.
18. Stephen JM, Lumpaopong P, Deehan DJ, Kader D, Amis AA. The medial patellofemoral ligament: location of femoral attachment and dynamic length changes. Am J Sports Med. 2012;40(8):1871-1877.
19. Philippot R, Boyer B, Testa R, et al. The role of the medial patellofemoral ligament in patellar stability. Orthop Traumatol Surg Res. 2012;98(8 Suppl):S90-S100.
20. Baldwin JL. The anatomy of the medial patellofemoral ligament. Am J Sports Med. 2009;37(12):2355-2361.
21. Mountney J, Senavongse W, Amis AA, Thomas NP. Tensile strength of the MPFL. J Bone Joint Surg Br. 2005;87(1):36-40.
22. Amis AA. Current concepts on anatomy and biomechanics of patellar stability. Sports Med Arthrosc Rev. 2007;15(2):48-56.
23. Stephen JM, Kader D, Lumpaopong P, Deehan DJ, Amis AA. Sectioning the medial patellofemoral ligament increases patellar lateral shift. Knee Surg Sports Traumatol Arthrosc. 2013;21:318-323.
24. Thaunat M, Erasmus PJ. Recurrent patellar dislocation: current concepts. Knee Surg Sports Traumatol Arthrosc. 2008;16:519-528.
25. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc. 1994;2(1):19-26.
26. Dejour D, Saggin PR. Trochlear dysplasia and patellar instability. Knee Surg Sports Traumatol Arthrosc. 2010;18:436-440.
27. Caton J, Deschamps G, Chambat P, et al. Patella infera: radiographic diagnosis and clinical significance. Rev Chir Orthop Reparatrice Appar Mot. 1982;68:317-325.
28. Insall J, Salvati E. Patella position in the normal knee joint. Radiology. 1971;101(1):101-104.
29. Schoettle PB, Zanetti M, Seifert B, Pfirrmann CW, Fucentese SF, Romero J. The tibial tuberosity–trochlear groove distance. Am J Sports Med. 2006;34(3):448-453.
30. Camp CL, Krych AJ, Dahm DL, Levy BA, Stuart MJ. Medial patellofemoral ligament reconstruction. J Bone Joint Surg Am. 2010;92(6):1263-1274.
31. Arendt EA, Moeller A, Agel J. Clinical outcomes of MPFL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2011;19:193-198.
32. Parikh SN, Lykissas MG, Gkiatas I. Predicting risk of recurrent patellar dislocation. Orthop J Sports Med. 2018;6(2).
33. Nomura E, Inoue M. Clinical outcome of MPFL reconstruction. Knee. 2005;12(5):335-340.
34. Christiansen SE, Jakobsen BW, Lund B, Lind M. Reconstruction of MPFL with gracilis tendon autograft. Arthroscopy. 2008;24(8):881-887.
35. Gomes JE. MPFL reconstruction with semitendinosus graft. Arthroscopy. 2008;24(7):864-869.
36. Ahmad CS, Stein BE, Matuz D, Henry JH. Immediate surgical repair of the MPFL. Am J Sports Med. 2000;28(6):804-810.
37. Arendt EA, England K. Reconstruction of the MPFL using hamstring autograft. Clin Sports Med. 2010;29(3):345-357.
38. Lind M, Jakobsen BW, Lund B, et al. Anatomical reconstruction of the MPFL. Arthroscopy. 2008;24(8):881-887.
39. Nomura E, Horiuchi Y. Surgical techniques for MPFL reconstruction. Sports Med Arthrosc Rev. 2007;15(2):94-99.
40. Feller JA, Richmond AK. Medial patellofemoral ligament reconstruction techniques. Knee Surg Sports Traumatol Arthrosc. 2007;15:506-512.
41. Steiner TM, Torga-Spak R, Teitge RA. Medial patellofemoral ligament reconstruction in patients with lateral patellar instability. Am J Sports Med. 2006;34(8):1254-1261.
42. Deie M, Ochi M, Adachi N, et al. Reconstruction of the MPFL using hamstring tendon. J Bone Joint Surg Br. 2003;85:887-890.
43. Nomura E, Inoue M. Clinical results of MPFL reconstruction using hamstring tendon. Knee Surg Sports Traumatol Arthrosc. 2004;12:546-550.
44. Csintalan RP, Latt LD, Forster RA. Medial patellofemoral ligament reconstruction. J Knee Surg. 2002;15:185-189.
45. Sillanpää PJ, Mäenpää HM. First-time patellar dislocation treatment options. Sports Med Arthrosc Rev. 2012;20:128-135.
46. Shah JN, Howard JS, Flanigan DC. Systematic review of MPFL reconstruction outcomes. Am J Sports Med. 2012;40:1916-1923.
47. Nelitz M, Williams SR, Dornacher D. Complications after MPFL reconstruction. Am J Sports Med. 2014;42:1919-1925.
48. Lind M, Enderlein D, Nielsen T, et al. Clinical outcome after MPFL reconstruction. Knee Surg Sports Traumatol Arthrosc.

2016;24:666-671.
49. Bitar AC, Demange MK, D'Elia CO, et al. Reconstruction of MPFL using quadriceps tendon graft. Knee Surg Sports Traumatol Arthrosc. 2012;20:1593-1597.
50. Steensen RN, Dopirak RM, Maurus PB. Quadriceps tendon autograft for MPFL reconstruction. Arthroscopy. 2005;21(7):859-865.
51. Fink C, Veselko M, Herbort M, et al. Reconstruction of the MPFL using quadriceps tendon. Knee Surg Sports Traumatol Arthrosc. 2014;22:2459-2465.
52. Ahmad R, Brown GD, Stein BE. Adductor magnus tendon for MPFL reconstruction. Orthopedics. 2009;32(3).
53. Weinberger JM, Fabricant PD, Taylor SA, et al. Allograft versus autograft MPFL reconstruction. Orthop J Sports Med. 2017;5(8).
54. Stephen JM, Kaider D, Lumpaopong P, et al. Patellar tracking after MPFL reconstruction. Am J Sports Med. 2014;42:1666-1672.
55. Fink C, Veselko M. Reconstruction of MPFL using quadriceps tendon graft. Arthroscopy. 2013;29(1):123-129.
56. Herbort M, Michel P, Raschke MJ. Quadriceps tendon autograft MPFL reconstruction. Arch Orthop Trauma Surg. 2013;133:147-152.
57. Nelitz M, Dreyhaupt J, Williams SRM. Combined MPFL reconstruction techniques. Am J Sports Med. 2013;41:58-63.
58. Ntagiopoulos PG, Dejour D. Midterm results of MPFL reconstruction using quadriceps tendon. Knee Surg Sports Traumatol Arthrosc. 2013;21:2188-2193.
59. Schottle PB, Hensler D, Imhoff AB. Anatomical reconstruction of the MPFL. Oper Orthop Traumatol. 2010;22:501-515.
60. Steensen RN, Bentley JC, Trinh TQ, Backes JR. Quadriceps tendon graft technique for MPFL reconstruction. Arthrosc Tech. 2015;4:e325-e329.
61. Nelitz M, Lippacher S, Dreyhaupt J. Anatomical MPFL reconstruction outcomes. Am J Sports Med. 2013;41:58-63.
62. Gomes JE. Reconstruction of MPFL using semitendinosus tendon. Arthroscopy. 2008;24:864-869.
63. Lind M, Jakobsen BW. MPFL reconstruction with semitendinosus graft. Arthroscopy. 2008;24:881-887.
64. Gonçalves MBJ, Carvalho LH, Soares LFM, et al. MPFL reconstruction using semitendinosus tendon graft. Rev Bras Ortop. 2015;46:160-164.
65. Steiner TM, Torga-Spak R. MPFL reconstruction using semitendinosus autograft. Am J Sports Med. 2006;34:1254-1261.
66. Christiansen SE, Jakobsen BW. Reconstruction of MPFL with hamstring autograft. Arthroscopy. 2008;24:881-887.
67. Shah JN, Howard JS. Complications of MPFL reconstruction. Am J Sports Med. 2012;40:1916-1923.
68. Nelitz M, Williams SRM. Failure analysis of MPFL reconstruction. Am J Sports Med. 2014;42:1919-1925.
69. Mountney J, Senavongse W, Amis AA. Tensile strength of the MPFL. J Bone Joint Surg Br. 2005;87:36-40.
70. Amis AA, Firer P. Biomechanics of the medial patellofemoral ligament. Knee. 2003;10:215-220.
71. Stephen JM, Lumpaopong P. MPFL biomechanics and reconstruction. Am J Sports Med. 2012;40:1871-1877.
72. Bitar AC, Demange MK. Quadriceps tendon graft for MPFL reconstruction outcomes. Knee Surg Sports Traumatol Arthrosc. 2012;20:1593-1597.
73. Schöttle PB. Radiographic landmarks for MPFL reconstruction. Am J Sports Med. 2007;35:801-804.
74. Stephen JM, Kader D. Length change patterns of MPFL grafts. Knee Surg Sports Traumatol Arthrosc. 2013;21:318-323.
75. LaPrade RF, Ly TV. Anatomy and biomechanics of the MPFL. Am J Sports Med. 2007;35:1655-1662.
76. Schneider DK, Grawe B, Magnussen RA, et al. Outcomes after MPFL reconstruction. Am J Sports Med. 2016;44:2993-3005.
77. Migliorini F, Rath B, Colarossi G, et al. MPFL reconstruction systematic review. Arch Orthop Trauma Surg. 2020;140:565-580.
78. Fink C, Veselko M. Quadriceps tendon MPFL reconstruction outcomes. Knee Surg Sports Traumatol Arthrosc. 2014;22:2459-2465.
79. Ntagiopoulos PG, Dejour D. Midterm results of quadriceps tendon MPFL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2013;21:2188-2193.
80. Lind M, Jakobsen BW. Clinical outcome after semitendinosus MPFL reconstruction. Arthroscopy. 2008;24:881-887.
81. Deie M, Ochi M. Reconstruction of MPFL using hamstring tendon. J Bone Joint Surg Br. 2003;85:887-890.
82. Shah JN, Howard JS. Complications and failures associated with MPFL reconstruction. Am J Sports Med. 2012;40:1916-1923.
83. Nelitz M, Williams SRM. Analysis of failures after MPFL reconstruction. Am J Sports Med. 2014;42:1919-1925.
84. Schneider DK, Grawe B. Return-to-sport after MPFL reconstruction. Am J Sports Med. 2016;44:2993-3005.
85. Sappey-Marinier E, Sonnery-Cottet B, Ohl X, et al. Return to sport after MPFL reconstruction. Orthop Traumatol Surg Res. 2019;105:789-795.