Technical Note

Double-Bundle Quadriceps Tendon Autograft for Reconstruction of the Medial Patellofemoral Complex to Manage Recurrent Patellar Dislocation in Patients With Open Physes

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Abstract: Management of chronic patellar instability in patients with open physis requires special reconstruction techniques to minimize the risks of femoral growth plate injury due to the close proximity of the open physis to the native femoral origin of the medial patellofemoral ligament (MPFL). Children and adolescents have a relatively smaller patella than the adult group, so, there is a higher risk of patellar fracture when tunnels are performed in the patella. It is wise to mimic the normal anatomy of the medial patellofemoral complex (MPFC) by reconstruction of both of the medial quadriceps tendon femoral ligament (MQTFL) and MPFL, so as to restore the normal fan-shaped MPFC, with its wide anterior attachment to both of the patella and quadriceps tendon (QT). This article describes a simple, safe, reproducible, and cost effective technique for surgical management of chronic patellar instability in patients with open physis by reconstruction of the MPFC using a double-bundle QT autograft.

Introduction

Patellar dislocation is a common and debilitating knee problem especially in children and adolescents. An incidence of about 15-50% of recurrent patellar dislocation after the first (primary) dislocation was reported in many studies.[1]

Non operative treatment of chronic patellar instability is ineffective. Surgical intervention is required in such individuals. Patients with open physis suffering chronic patellar instability represent a special entity of patients, as there is a great concern in regard to physeal injury due to the close proximity of the origin of the medial patellofemoral ligament (MPFL) to the distal femoral physis. In addition, there is great variation of the femoral origin of the MPFL during skeletal development. The patellar size also is relatively smaller than the adult patella, making it more vulnerable for complications.

In this article, we describe a simple technique to reconstruct the medial patellofemoral complex (MPFC) in open physis patients suffering manifestations of chronic patellar instability. MPFC is achieved by reconstruction of both of the MPFL and the medial quadriceps tendon-femoral ligament (MQTFL). This technique avoids the risks and complications to the patella (e.g., patellar fractures due to tunnel making in the patella) and to the femoral physis (e.g., physeal growth arrest and deformity), besides, being cost effective (no implants needed), reproducible, safe (no fluoroscopy used), and restorative of the normal anatomy of the MPFC.

Surgical Technique

This article describes a step-by-step reconstruction of the medial patellofemoral complex (MPFC) by using double bundle quadriceps tendon autograft for management of recurrent patellar dislocation in patients with open physis. The quadriceps tendon is divided into two bundles (a larger lateral bundle and a smaller medial bundle). The larger lateral bundle is used for reconstruction of the medial patellofemoral ligament

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Table 1. Showing Tips, Pearls, Pitfalls, and Risks of the Technique

Pearls	Pitfalls and risks
After reconstruction, we have to ensure a lateral patellar translation of 10 mm to avoid overtightening.	Adjust the ligaments tension to avoid medial overconstraint that would cause arthritis and pain.
We have to pass the graft medially between layers 2 and 3 of the medial side of the knee to be extraarticular and deep to the VMO.	If the graft passed superficial to the VMO, we lose the dynamic stabilizing advantage of the action of the VMO.
Ensure a wide retinacular channel for easy graft passage.	Improper identification of the distal attachment of the AM tendon will mislead the femoral attachment of the MPFL.
Use a partial-thickness quadriceps autograft to preserve the postoperative quadriceps muscle function.	
The 2 bundles of the graft are sutured with strong nonabsorbable sutures to the anterior surface of the patella, and to the quadriceps tendon, so as to create a fixed point of anterior fixation of the graft.	
Diagnostic arthroscopy before reconstruction is crucial to evaluate the knee and manage any chondral or meniscal injuries.	
Identify the AM tendon and dissect it until its bony insertion is as close as possible to the anatomic femoral attachment of the MPFL.	
Reinsert the scope after finishing your reconstruction to ensure normal patellar tracking.	
The knee is placed in full extension orthosis.	

AM, adductor magnus; MPFL, medial patellofemoral ligament; VMO, vastus medialis obliquus.

(MPFL), while the smaller medial bundle is used for reconstruction of the medial quadriceps tendon femoral ligament (MQTFL). The aim of this type of reconstruction (two bundles instead of one bundle) is to mimic the normal anatomy of the MPFC (Video 1). Advantages and limitations are summarized in Table 1, and pearls and pitfalls are summarized in Table 2.

Patient Position and Surgical Landmarks

After induction of anesthesia, the patient is placed in the supine position. Landmarks for arthroscopic and surgical work are drawn (Fig 1). The patient is examined under anesthesia. A high-thigh, nonsterile, padded tourniquet is then applied. The patient is then prepared and draped in the usual manner.

Knee Arthroscopy

Routine knee arthroscopy is performed. Any chondral or meniscal pathology is managed. We use 30° arthroscope (Hopkins II; Karl Storz, Tuttlingen, Germany).

Surgical Technique

A 6-8-cm midline surgical incision is made on the anterior aspect of the distal femur, extending from the upper border of the patella upward. The quadriceps tendon is identified after removing the overlying fat. A width of about (1.5 cm) of the required graft is measured and marked with a sterile pen (Fig 2A). Three vertical lines are drawn on the quadriceps tendon with a sterile pen to mark the required 2 bundles of the quadriceps tendon (Fig 2B). A sharp scalpel is used to cut through the medial and lateral vertical lines with a depth of only about 2-3 mm, leaving the central line intact. Then the tendon is released proximally to free the quadriceps tendon graft (Video 1). A scissor is used to cut the freed graft into 2 bundles; a larger lateral bundle (red dot) and a smaller

Table 2. Advantages and Disadvantages of the Technique

Advantages	Disadvantages
Simple	The cosmetic concern in regard to the surgical wounds; however, there are surgical instruments (if available) that can help for harvesting the quadriceps tendon through a smaller incision.
Mimics the normal anatomy of the MPFL and MQTFL.	Does not address underlying patella alta, elevated TT-TG distance, or trochlear dysplasia, so it may lead to potential failure
Safe especially in open physis patients	
Reproducible	
Dynamic femoral fixation is more forgiving than fixed bony fixation.	
No need for fluoroscopy	
No implant	
No tunnels	
No pain at the MFC area (a very unforgiving area in regards to metal fixation, hardware, and tunnels	
Can be used for any age.	
Accurate femoral site fixation as the adductor magnus tendon is used as a landmark	

MFC, medial femoral condyle; MPFL, medial patellofemoral ligament; MQTFL, medial quadriceps tendon femoral ligament; TT-TG distance, tibial tubercle-trochlear grove distance.

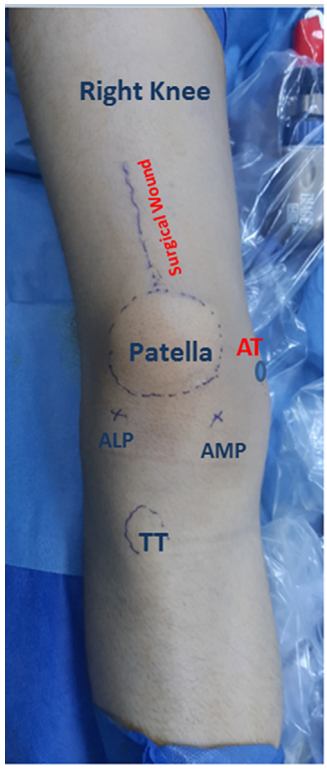

Fig 1. Surgical landmarks. Image of the front of the right knee, while the patient is supine showing landmarks for the arthroscopic portals (ALP), anterolateral portal, anteromedial portal (AMP), tibial tuberosity (TT), the patella, the adductor tubercle (AT), and the surgical wound (dotted line).

medial bundle (yellow dot) (Fig 2C). The lateral bundle is used for reconstruction of the medial patellofemoral ligament (MPFL), while the smaller medial bundle is used for reconstruction of the medial quadriceps tendon femoral ligament (MQTFL).

Focus is then directed to the medial side of the knee. A 2-3-cm skin incision is made centered on the adductor tubercle (Fig 3A). The adductor magnus tendon is identified at its insertion near the adductor tubercle after incising the fascia overlying it (Fig 3B). A sterile pen is used to mark the site of the anatomic attachment of the MPFL on the medial side of the medial femoral condyle (blue dot), just distal and anterior to the adductor tubercle (Fig 3C).

Then, we return to the 2 bundles of the graft. The lateral bundle for reconstruction of the MPFL (red dot) is released more distally over the patella than the medial bundle (yellow dot), and also its lateral side is released more distally than its medial side to make medial reflection of the bundle easier. The medial bundle (yellow dot) is left attached to the quadriceps tendon at its junction to the upper border of the patella (Fig 4A). The distal ends of both bundles are stitched with #2 FiberWire (Arthrex) in a Krackow whipstitch manner. The 2 bundles are reflected medially to evaluate if the length is sufficient or not (Fig 4B). A forceps is used to make a clear passage for the 2 bundles between layer 2 and layer 3 of the medial side of the knee (Fig 4C).

The sutures on each end of the 2 bundles are shuttled medially in between layer 2 and layer 3 of the medial side of the knee (Fig 5A). The lateral bundle of the quadriceps tendon is sutured to the anterior surface of the patella with #2 FiberWire (Arthrex) to make a fixed point of attachment. The medial bundle of the quadriceps tendon is sutured to the quadriceps tendon at its junction to the proximal border of the patella with #2 FiberWire (Arthrex) to make a fixed point of attachment. The lateral bundle is used for reconstruction of the MPFL, while the smaller medial bundle is used for reconstruction of the MQTFL (Fig 5B). The smaller medial bundle (yellow dot) for reconstruction of the MQTFL is sutured medially to the adductor magnus tendon with #2 FiberWire (Arthrex), the knee is taken in full range of motion to determine the position of suturing the medial bundle to the adductor magnus tendon that does not limit the normal knee flexion motion (the knee is in 90° flexion) (Fig 5C). The lateral bundle (red dot) for reconstruction of the MPFL is sutured to the adductor magnus tendon, the periosteum over the medial femoral condyle just distal and anterior to the adductor tubercle (the knee is in 30°-60° flexion). Tension of the ligaments was adjusted, so as to allow a 10-mm manual lateralization of the patella to avoid overconstraint (Fig 5D).

The knee range of motion and patellar stability is checked. An arthroscopic evaluation of the corrected patellar tracking is performed by viewing through the superolateral and superomedial portals while taking the knee in full range of motion. Then the wound is closed in layers (Video 1).

Rehabilitation Protocol

The patients were put in a hinged knee brace for 2 weeks, and isometric quadriceps muscle exercises, and partial weight bearing were then initiated immediately. Full range of motion and normal gait are retained after 3 weeks.

Discussion

The MPFL is the primary static stabilizer to lateral patellar dislocation from 0° to 70° of knee flexion. It contributes to ~50% of the restraint for lateral patellar dislocation.[2-5] The remaining soft tissue contributions to patellar stability are derived from the medial patella-tibial ligament (MPTL) and medial patella-meniscal ligament (MPML), with the combination of these 2 ligaments reported to contribute ~26% to resisting lateral patellar shift in full extension and 46% at 90° of knee flexion.[6] The MPFL is injured in 95-100% of patients after the first patellar dislocation.[7-9]

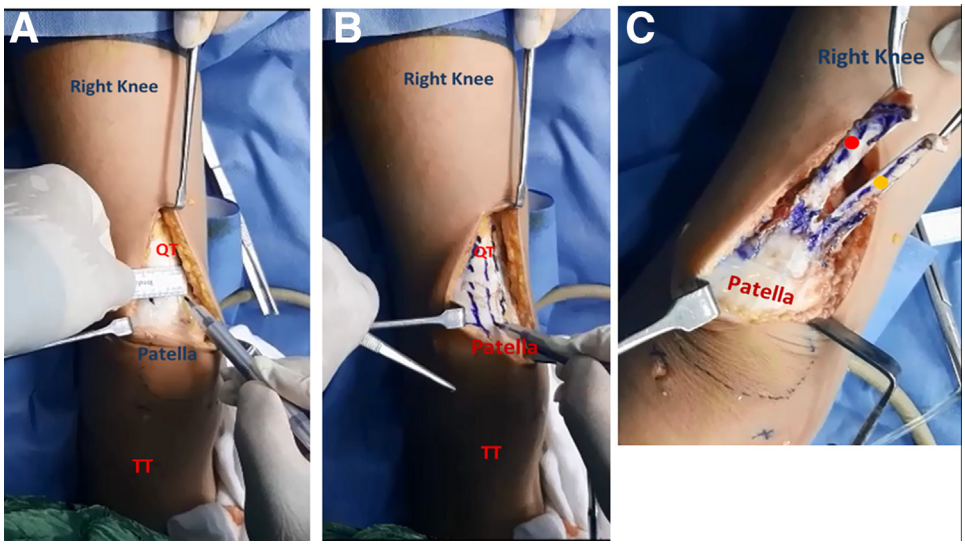

Fig 2. Steps of quadriceps tendon exposure and proximal release. (A) Image of the front of the right knee, while the patient is supine. The quadriceps tendon is shown exposed during measurement of the width of the required graft. (B) Three lines are drawn on the quadriceps tendon for the planned 2 bundles of the quadriceps tendon. (C) Division of the quadriceps tendon into two bundles. The lateral bundle (red dot) for reconstruction of the medial patellofemoral ligament (MPFL), while the smaller medial bundle (yellow dot) for reconstruction of the medial quadriceps tendon (QT) femoral ligament (MQTFL). TT, tibial tuberosity.

The MPFL was first described in a cadaveric dissection study by Warren and Marshall as a condensation of fibers extending from the medial epicondyle to the superomedial patella.[10] Recently, an understanding of the medial patellar soft tissue restraint has evolved with the description of distinct fibers arising from the same femoral origin of the MPFL, however, inserted on the quadriceps tendon rather than the patella. These fibers are termed the medial quadriceps tendon femoral ligament (MQTFL). A new term has emerged—the medial patellofemoral complex (MPFC)—which includes both of the MPFL and the MQTFL.[11-13]

There is a length difference between the MPFL and MQTFL throughout knee range of motion, suggesting a variable anisometry between these 2 structures. This difference in length is attributed to changes in anatomic distances between attachment points throughout knee range of motion.[13,14] Since the anatomy and function of the MQTFL is better known, it is wise to reestablish the normal anatomy and restore the fan-shaped MPFC with its wide anterior attachment to both the patella and quadriceps tendon.[6,15,16]

A precise femoral origin of the MPFC in open physis individuals has not yet achieved, as its site undergoes

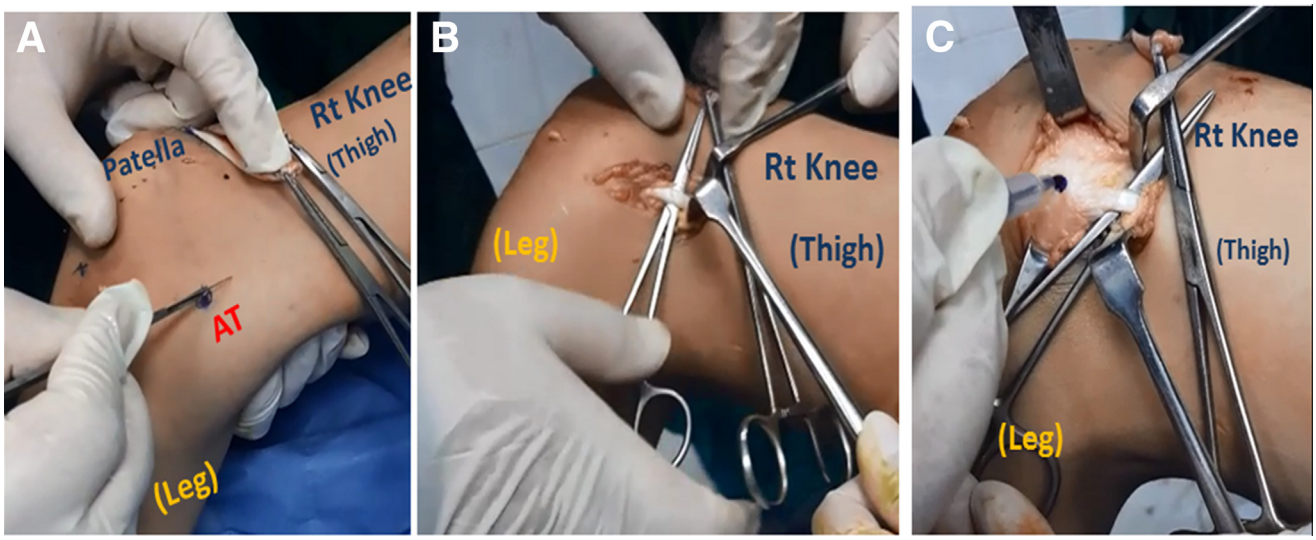

Fig 3. Steps of identification of the adductor magnus tendon. Viewing the right knee from the medial side while the patient is supine. (A) Making a skin incision (about 2-3 cm long) centered over the adductor tubercle. (B) Identification of the adductor magnus tendon at its insertion near the adductor tubercle (an artery forceps is put under the adductor magnus tendon). (C) Marking the anatomical femoral attachment site of the MPFL, which is distal and anterior to the adductor tubercle (blue dot). AT, adductor tubercle; MPFL, medial patellofemoral ligament.

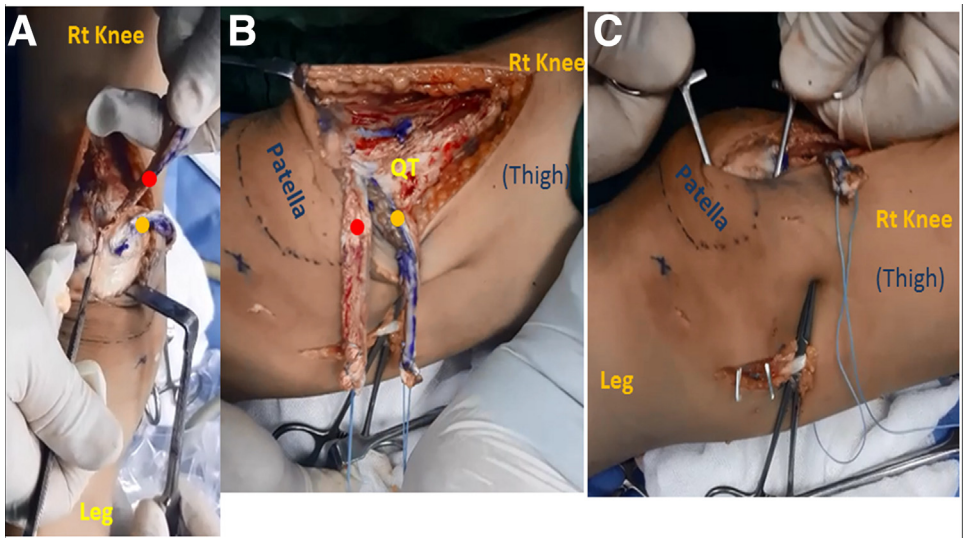

Fig 4. Preparation of the 2 bundles of the quadriceps tendon and creation of a free passage for the 2 bundles. (A)Viewing the right knee from above while the patient is supine. The lateral bundle for reconstruction of the MPFL (red dot) is released more distally over the patella than the medial bundle (yellow dot), and also its lateral side is released more distally than its medial side to make medial reflection of the tendon easier. (B) Viewing the right knee from the medial side while the patient is supine. The two bundles of the quadriceps tendon are sutured with FiberWire #2 and reflected medially. (C) Viewing the right knee from the medial side while the patient is supine. An artery forceps is used to create a clear passage (between layer 2 and layer 3) for the 2 bundles of the quadriceps tendon. Another artery forceps is put under the adductor magnus tendon. MPFL, medial patellofemoral ligament; QT, quadriceps tendon.

great variation during development. The relation of the femoral origin of the MPFC to the physis also has not yet been determined, with studies showing that this origin is 5 mm distal to the physis in 86% of cases with the remaining 14% would have a variable location up to 7.5 mm proximal to the physis. Consequently, because of the variable femoral origin location in skeletal immature patients and its proximity to the growing physis, there is a great challenge in localizing the femoral origin with the high risk of physeal damage if a femoral tunnel is performed.[16-19]

Generally, even in the adult population, localization of the Schottle's point is inaccurate because of the difficulty in obtaining a true lateral view during the surgical procedure by fluoroscopy, resulting in a nonanatomic reconstruction.[20] Using the anatomical landmarks (e.g., the adductor magnus tendon and the adductor tubercle) during the surgical procedure can help so much to fix the graft as close as possible to the anatomic origin, even without fluoroscopy.[16,20,21] Since the femoral origin is very narrow, so it is very critical and non-forgiving. Studies showed that a 5-mm malposition of the femoral origin will result in graft elongation of up to 12 mm during knee flexion extension that would be reflected in increased patellofemoral pressure, resulting in patellofemoral arthritis and pain.[16,21] Dynamic reconstruction is more forgiving and safer, as it is quasi-isometric and avoids overloading the patellofemoral joint.[22]

In the current technique that we have been using for 4 years, we tried to restore the normal patellofemoral stability and mechanics while minimizing the well-documented risks and complications in other techniques for skeletally immature patients with patellar instability.

We used a dynamic femoral fixation so as to avoid overconstraining the patellofemoral joint, and at the same time to avoid any damage to the growing physis of the distal femur, as there are no tunnels performed in the femur.

We used a partial thickness quadriceps tendon as an autograft to reconstruct the MPFL and MQTFL (MPFC), so we could preserve the normal function of the quadriceps tendon without the need for patellar tunnels with its complications, such as patellar fracture.

This technique is cost effective, as it is hardware free, and no implants are needed for the femoral, patellar, or quadriceps tendon fixation. The distal bundle (used for MPFL reconstruction) is sutured with #2 FiberWire to the adductor magnus tendon at its insertion, and to the periosteum just distal and anterior to the adductor tubercle (the anatomic attachment of the native MPFL).

We reestablished the normal fan-shaped anatomy of the MPFC with its wide anterior attachment to the

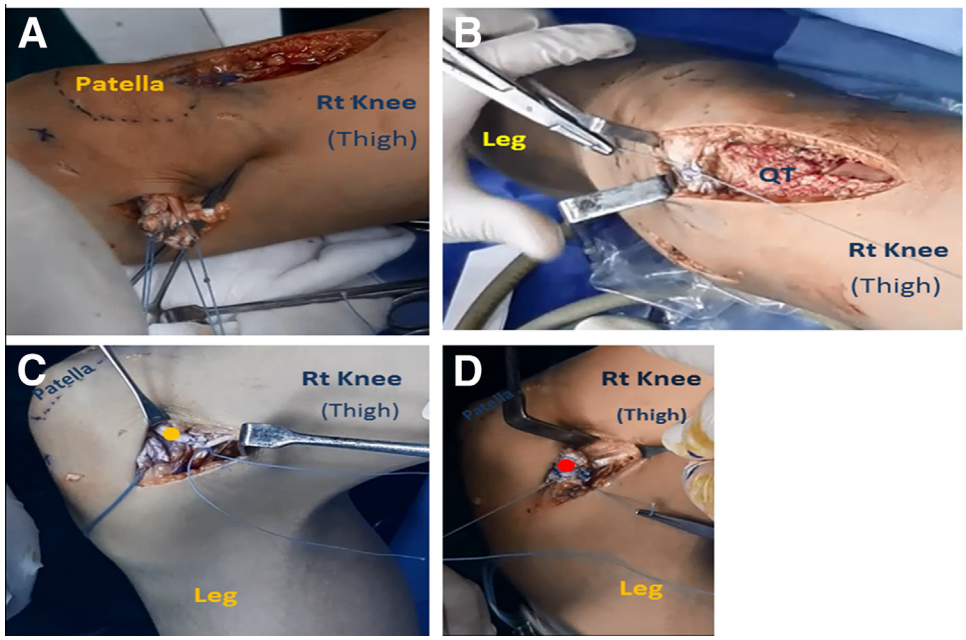

Fig 5. Steps of preparation, medial delivering, and suturing of the 2 bundles of the quadriceps tendon. (A) Viewing the right knee from the medial side while the patient is supine. The two bundles of the quadriceps tendon are passed to the medial side of the knee between layer 2 and layer 3. (B) Viewing the right knee from above, while the patient is supine. The lateral bundle of the quadriceps tendon is sutured to the anterior surface of the patella with #2 FiberWire (Arthrex, Naples, FL) to make a fixed point of attachment. The medial bundle of the quadriceps tendon is sutured to the quadriceps tendon at its junction to the proximal border of the patella with #2 FiberWire (Arthrex) to make a fixed point of attachment. The lateral bundle is used for reconstruction of the medial patellofemoral ligament (MPFL), while the smaller medial bundle is used for reconstruction of the medial quadriceps tendon femoral ligament (MQTFL). (C) Viewing the right knee from the medial side with the patient supine. The smaller medial bundle (yellow dot) for reconstruction of the MQTFL is sutured medially to the adductor magnus tendon after taking the knee in full range of motion to determine the position of fixation that does not limit the knee flexion motion (the knee is in 900° flexion). (D) Viewing the right knee from the medial side with the patient supine. The lateral bundle (red dot) for reconstruction of the MPFL is sutured to the adductor magnus tendon, the periosteum over the medial femoral condyle (just distal and anterior to the adductor tubercle (the knee is in 600 flexion). MPFL, medial patellofemoral ligament; MQTFL, medial quadriceps tendon femoral ligament; QT, quadriceps tendon.

patella and quadriceps tendon. The two bundles are passed in the normal anatomic course of the MPFC between layers 2 and 3 in the medial side of the knee.

Four major factors are associated with recurrence of patellar dislocation. These factors are trochlear dysplasia, patella alta, lateralization of the tibial tuberosity relative to the trochlear groove, which is called the tibial tubercle trochlear groove offset (TT-TG offset), and insufficient medial retinacular tissue.[23] Unfortunately, trochlear dysplasia, patella alta, and lateralized tibial tuberosity (TT-TG $>$ 20 mm) cannot be addressed by bony procedures in patients with open physis, for which the procedure may lead to potential failure.

Other factors to predisposed patellar instability are excessive femoral anteversion, genu valgum, and tibial torsion. If not correctly evaluated and addressed, these factors may result in inferior clinical outcomes after surgical treatment.[24,25]

Generalized joint laxity (GJL) is a soft tissue factor contributing to patellar instability. Patients can be assessed for hyperlaxity by using the Beighton scoring system.[26] Patients with GJL have to be informed that the results of the treatment may be different than for the general population.[27,28]

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