Quadriceps Tendon Autograft Medial Patellofemoral Ligament Reconstruction

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Abstract

Purpose Critically evaluate the published literature related to quadriceps tendon (QT) medial patellofemoral ligament (MPFL) reconstruction.

Recent findings Hamstring tendon (HT) MPFL reconstruction techniques have been shown to successfully restore patella stability, but complications including patella fracture are reported. Quadriceps tendon (QT) reconstruction techniques with an intact graft pedicle on the patella side have the advantage that patella bone tunnel drilling and fixation are no longer needed, reducing risk of patella fracture. Several QT MPFL reconstruction techniques, including minimally invasive surgical (MIS) approaches, have been published with promising clinical results and fewer complications than with HT techniques. Parallel laboratory studies have shown macroscopic anatomy and biomechanical properties of QT are more similar to native MPFL than hamstring (HS) HT, suggesting QT may more accurately restore native joint kinematics.

Summary Quadriceps tendon MPFL reconstruction, via both open and MIS techniques, have promising clinical results and offer valuable alternatives to HS grafts for primary and revision MPFL reconstruction in both children and adults.

Keywords Medial patellofemoral ligament · MPFL · Quadriceps tendon · Patella dislocation · Patella instability

Introduction

The medial patellofemoral ligament (MPFL) represents the primary soft tissue restraint to lateral patellar dislocation close to knee extension [1–4, 5•] and rupture of the MPFL has been reported in 95 to 100% of patients with acute patellar dislocation [1–3, 6–8]. Several surgical techniques with promising clinical results have been described to reconstruct the MPFL and restore patellar stability, either as an isolated procedure or

combined with tuberosity transfer, trochleoplasty or osteotomy.

To date, most MPFL reconstruction techniques have used hamstring tendon (HT) grafts [9–13]. The majority of techniques use bone tunnels and/or anchors to secure these free grafts to the patella [9, 13–15]. In a systematic review, Sah et al. reported an overall complication rate of 26.1%, with patella fractures and loss of motion (restricted flexion), among the most common complications [5•, 16].

The first description of partial thickness quadriceps tendon (QT) graft MPFL reconstruction was by Burks and Luker in 1997 [17•]. This was also a *free graft* technique, harvesting a strip of QT with a patella bone block, which was placed into a recessed bony bed in the femoral epicondyle and secured with a screw/washer. The QT end of the graft was secured through a bone tunnel on the patella side.

Steensen et al. in 2005 [18] were the first to describe leaving the quadriceps tendon attached on the patella side. Harvesting a partial thickness quadriceps tendon graft, they extended dissection distally over the anterior patella elevating the thick periosteum. By dissecting further distal laterally than medially, they created a diagonal hinge point, allowing the graft to fold into position medially on an intact periosteal

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pedicle. This has the advantage that fixation is only needed on the femoral side, and patella bone tunnel drilling and fixation devices are no longer necessary.

Surgical Techniques

Following Steensen, et al. [18•], several authors have described variations/modification of QT MPFL reconstruction based on the principle of preserving the quadriceps attachment on the patella side [19•, 20•, 21•, 22•, 23•, 24•, 25•, 26•, 27•, 28•, 29•, 30•, 31•, 32•]. The variations include the following:

- Approach: open (midline or paramedial) or minimally invasive (MIS)
- Graft harvest location: central or medial graft harvest in the QT
- Graft dimensions: width, thickness (depth) and length. The latter of which depends at least in part on the chosen method of femoral fixation.
- Medial graft routing: subcutaneous (Steensen et al. [18•]), sub-retinacular (Goyal and others [19•, 20•, 21•, 22•, 23•, 24•, 30•, 31•, 32•]), or sub-periosteal (Fink et al. [25•, 26•, 27•, 28•])
- Femoral fixation technique: suturing techniques to bone [18•] and soft tissue [29•, 30•], interference screws [21•, 22•, 23•, 25•, 26•, 27•, 28•] and anchors [24•, 31•, 32•].

Open Approach, Central QT Harvesting, Subcutaneous Graft Routing and Trans-osseous Suturing

In the description by Steensen et al. [18•], a 5-cm midline longitudinal incision is made extending proximally from the superior pole of the patella. A partial thickness quadriceps

tendon graft, 10–12 mm wide, is harvested from the central third of the quadriceps tendon. The graft length required is determined by measuring the distance from the superior pole of the patella to the medial epicondyle.

Anatomically, the insertion of the quadriceps femoris into the patella is a common tendon with a tri-laminar arrangement [33•, 34–38]. The superficial fibres originate from rectus femoris, the deepest layer from the vastus intermedius and the intermediate layer from the vastus lateralis and vastus medialis. The laminae fuse with a degree of individual variation over a 13- to 90-mm (mean 44 mm) region proximal to the superior pole of the patella [33•] (Fig. 1). The quadriceps tendon inserts into the patella via an expansion that passes over the anterior aspect of the patella, most commonly comprised solely of fibres from the rectus femoris portion of the tendon [39–41].

A partial thickness graft is harvested by identification of the superficial lamina of the quadriceps tendon (rectus femoris) approximately 2–3 cm proximal to the patella. This layer is separated from the deeper layers and graft dissection is continued sub-periosteally from superior to inferior over the anterior surface of the patella. By continuing dissection further infero-laterally than infero-medially, a diagonal hinge point is created so that when the graft is folded back on itself 180° (the deep surface becoming superficial and vice versa), it rotates 90° medially on an intact periosteal pedicle (Fig. 2). The distance of proximal to distal anterior periosteal dissection can be adjusted to achieve the desired patella attachment (Fig. 3).

In order to fix the graft on the femoral side, a second 2-cm incision is made medially over the most prominent part of the medial epicondyle and the graft passed subcutaneously (over the medial pre-patellar tissue and retinaculum) to this point. A K-wire is inserted at the desired point of femoral fixation and the graft temporarily fixed to test for isometry by moving the knee through a range of motion. The wire is adjusted as necessary and the position retested until a satisfactory point is found.

Fig. 1 Schematic representation of quadriceps tendon anatomy showing the three anatomical layers and the relative size of graft harvested in relation to the total tendon volume

Fig. 2 Harvesting the superficial layer of the quadriceps femoris tendon composed of rectus femoris and continuing sub-periosteal dissection over the anterior aspect of patella more distal laterally than medially to create a diagonal hinge point

Fixation is achieved with no. 0 non-absorbable trans-osseous sutures through paired drill holes arranged in a 1-cm square, creating a 1-cm² footprint for the neo-ligament.

Open Midline Approach, Central QT Harvesting, Sub-retinacular Graft Routing and Interference Screw Fixation

The next author to describe an anatomic QT MPFL reconstruction technique with bony femoral fixation was Goyal in 2013 [19, 20], once again harvesting the central 10–12 mm of the QT superficial lamina, this time via a 7–8-cm longitudinal incision starting at the superior pole of the patella. As per the technique of Steensen et al., dissection of the superficial lamina of the QT is continued sub-periosteally over the anterior aspect of the patella, and the graft is folded medially on the periosteal hinge.

From this point, Goyal describes three modifications of the technique. Firstly, the proximal free end of the graft is tunnelled medially between the capsule and medial retinaculum, rather than subcutaneously. Secondly, Ethibond stay sutures are placed at junction of the medial edge of the patella and the graft to stabilise the graft-patella anatomic attachment

(Fig. 4). Finally, the graft is secured in the distal femur with a bio-interference screw rather than trans-osseous sutures.

Open Medial Approach, Medial QT Harvesting, Sub-retinacular Graft Routing and Interference Screw Fixation (Nelitz et al.) or Anchor Fixation (Vavalle et al.)

Nelitz et al. in 2014 [21, 22] described an open technique, via a 4–5-cm anteromedial skin incision, starting 2–3 cm proximal to the proximal pole of the patella and taking a slightly wider 12–15-mm-wide strip of the superficial lamina of the medial (rather than central) QT, leaving a 3–4-mm strip of tendon intact along the lateral border of vastus medialis obliquus (VMO). The graft is passed medially as per Goyal [19, 20], between the capsule and VMO in the second medial layer and secured in the distal femur with a bio-absorbable screw.

Similar to Nelitz et al., Vavalle et al. [24] in 2016 describe an open technique performed via a 6–7-cm longitudinal incision, taking a slightly narrower, but thicker medial sided QT graft 10–12 mm wide and 5 mm deep, whilst also leaving a 3–4-mm strip of tendon intact along the lateral border of VMO. The graft is routed medially as

Fig. 3 Distance of anterior sub-periosteal dissection determines the location of the hinge point and thus the point of femoral attachment of the reflected graft in a proximal to distal axis

Fig. 4 Stay sutures to stabilise the patella anatomic attachment as described by various authors (see text for details)

per Goyal. Femoral fixation is with a 5.5-mm screw anchor loaded with no. 2 non-absorbable suture.

MIS Technique, Central QT Harvesting, Sub-periosteal Graft Routing and Interference Screw Fixation

Fink et al. in 2014 [25•, 26••, 27•] were the first to describe a MIS technique, using specialised instruments (KARL STORZ, Tuttlingen, Germany) to harvest the graft. The graft is harvested with the knee in 90° flexion via a 2.5–3-cm transverse incision over the superior pole of the patella following Langer's lines. The pre-patellar bursa is incised longitudinally and the quadriceps tendon is carefully exposed.

Fig. 5 Minimally invasive quadriceps tendon graft harvesting via a 3-cm transverse incision at the superior margin of the patella. A double-bladed knife (a) and a tendon separator (b) (KARL STORZ, Germany) are sequentially inserted to determine the graft width and depth, typically 12 mm width and 3 mm depth

A long Langenbeck retractor is introduced and the quadriceps tendon subcutaneously exposed proximal to the patella. A double knife of 10 or 12 mm width is introduced, starting over the middle of the superior patella border and pushed up to a minimum of 8 cm (marked on the instrument) (Fig. 5). Graft thickness is then determined using a 3-mm tendon separator, rather than by identification of the tendon laminae. The separator is pushed proximal to the same mark (min. 8 cm) and the tendon strip is cut subcutaneously using a special tendon cutter (Fig. 6).

Distally, the longitudinal cuts in the quadriceps tendon are continued with a scalpel over the anterior patellar surface in the chosen width (10 or 12 mm) lateral for 2 cm and medial for 1 cm, creating a diagonal axis to reflect and fold the graft. The quadriceps tendon strip is then sub-periosteally elevated from the patella surface.

The proximal 1.5 cm of the medial patellar border are then exposed also sub-periosteally, and a tunnel is created under the anteromedial patella periosteum and pre-patellar tissue, as described by Macuro and Vasselko [42•]. This allows the graft to be passed sub-periosteally over the medial border of the patella, rather than subcutaneously (as per Steensen et al.) [18••], or under the medial retinaculum (as per Goyal and others) [19•, 20••, 21•, 22••, 23•, 24••, 30••, 31••, 32•]. The graft is then passed through a tunnel between the vastus medialis and the joint capsule to a separate 1–2-cm incision over the adductor tubercle. The graft is secured to retinacular tissue on the medial patellar edge by 2.0 absorbable sutures, similarly to Goyal [19•, 20••] (Fig. 4). The desired femoral insertion is determined using fluoroscopic guidance and secured with a cannulated bio-absorbable interference screw.

MIS and Open QT MPFL Reconstruction with Medial QT Harvesting, Sub-retinacular Graft Routing and Suture Anchor Fixation Combined with Patella Tendon Reconstruction of the Medial Patella Tibial Ligament

Hinckel et al. in 2016 describe both open and MIS techniques using an 8-mm-wide partial thickness medial QT graft to

Fig. 6 The tendon strip is cut at a desired length (8–10 cm) using a tendon cutter (Karl STORZ, Tuttlingen, Germany)

reconstruct the MPFL and a 6-mm full-thickness medial patella tendon graft to reconstruct the medial patellotibial ligament (MPTL) as a combined procedure [31•, 32•] (Fig. 7).

The QT graft is either harvested via a 3-cm longitudinal minimally invasive approach, or via an 8–9-cm midline longitudinal open approach. The graft is reflected as per the technique of Steensen et al. and secured with two absorbable stitches (PDS) at the medial periosteal border before being passed under the medial retinaculum as per Goyal and others. Medially, it is fixed at the radiographically chosen femoral insertion point via a separate 1–2-cm incision with a 5-mm suture anchor. The 6-mm full-thickness patella tendon graft MPTL reconstruction is performed via a separate distal 2–3-cm longitudinal incision for MIS technique or by extending an open approach distally, and tibial fixation is with a 3.5-mm suture anchor.

Open Midline Approach, Medial QT Harvesting, Sub-retinacular Graft Routing and Soft Tissue Suturing (Non-anatomical Fixation)

Shortly after Steensen et al., in 2005, Noyes and Albright [29•] published a technique, also based on an intact graft pedicle on the patella side. They harvested an 8 × 70-mm *full-thickness* graft from the medial (rather than central) aspect of the QT. This was left attached at the superomedial border of the patella, passed medially beneath the medial retinaculum and sutured to the medial intermuscular septum.

Due to non-anatomical femoral fixation, this is technically not an MPFL reconstruction, but a medial reinforcement. However, it is the first description of medial, rather than

Fig. 7 Combined QT MPFL and PT MPTL reconstruction. The partial thickness QT MPFL graft is reflected into position as per Steenson et al. The full-thickness patella tendon MPTL graft is rotated into position

central, QT graft harvesting and the first description of soft tissue suturing rather than bony fixation on the femoral side.

Leal-Blanquet et al. in 2017 [30•] described another technique using soft tissue rather than bony fixation on the femoral side. They describe both open (via a midline longitudinal incision) and minimally invasive (via “two small incisions”) harvesting of a 10-mm-wide × 3-mm-deep graft from the medial QT, again leaving an intact 3–4-mm strip of VMO medially. The graft is flipped according to the technique of Steensen et al. and secured on the femoral side by looping around the adductor magnus tendon and suturing the graft back to itself. The authors suggest this technique may be useful in skeletally immature patients, reducing the risk of femoral physeal injury, and also in revisions, avoiding the use of implants, additional tunnels and bone grafting.

Clinical Results

Five authors have published results of isolated anatomical QT MPFL reconstruction in 104 patients with an overall mean

follow-up of 23 months [18•, 20•, 22•, 24•, 26•]. The non-anatomical femoral fixation of Leal-Blanquet et al. [30•] and the combined QT MPFL and PT MPTL procedures of Hinckel et al. [31•] increase the group to 115 patients (Table 1). There were no repeat dislocations, no patella fractures and no implant related complications in any study.

Clinical Scores

The reported mean Kujala score [43] improvement from pre-op to post-op was 49 to 91 for Goyal [20•]; 63 to 89 for Nelitz et al. [22•]; and 36 to 89 for Vavalle et al. [24•]. The mean Lysholm score [44] improvement was 43 to 89 for Vavalle et al. [24•] and 69 to 88 for Fink et al. [26•]. The Tegner scores [45] improved from 4.8 to 5.0 in Fink et al. [26•] and 4 to 5 in Nelitz et al. [22•]. The VAS score improved significantly from 4 (range 1–7) to 1 (range 0–4) in Nelitz et al. [22•].

Satisfaction

Overall, 97% of patients were satisfied or very satisfied. One patient was reported to be unsatisfied and three patients partially satisfied. The unsatisfied patient [26•] and two of the partially satisfied patients [24•] had grade 3–4 chondral damage.

Return to Sport

Vavalle et al., reported on return to sport, with five out of nine patients returning to the pre-injury level (three semi-professional, two recreational), one of nine returning at a lower level (semi-professional to recreational) and three retiring from sport (all recreational) [24•].

Complications

Loss of motion was only reported in one patient who had 10° reduced flexion compared to the other side at 12 months [26•], but did not require intervention. One patient had an infection requiring surgical debridement [31•].

Discussion

QT MPFL reconstruction is successful at restoring patella stability with no redislocations, improvement in knee scores and high levels of patient satisfaction. In contrast to HT grafts, where complication rates of up to 26% are reported [5•, 16], the overall complication rate was 1% for isolated anatomical MPFL reconstruction and 1.7% including the non-anatomical and combined MPFL/MPTL QT variants.

Incision and Approach

In contrast to HT harvesting, which can be performed via a relatively small (1.5–3 cm) more cosmetic incision over the pes anserinus, the most common approaches for QT graft harvesting are 5–8-cm midline or medial parapatellar incisions. Given that many patients undergoing this procedure are young females, the importance of cosmesis should not be overlooked and the incision required for open QT harvesting may have deterred surgeons from using QT in the past. The MIS approach described by Fink et al. [25•, 26•, 27•], harvesting the graft via a 2–3-cm transverse incision following Langer's lines along the superior patella border, potentially offers superior cosmetic results to open QT and HT techniques (Fig. 8).

In cases where a midline incision is required for an associated procedure such as trochleoplasty, QT MPFL reconstruction has the advantage that it can be performed through the same incision. Nelitz [23•] reported results of 26 patients who underwent QT MPFLR in combination with trochleoplasty. No recurrent dislocations occurred, knee scores improved significantly and 95% of patients were satisfied or very satisfied.

Anatomy and Biomechanics

A systematic review of the published articles on MPFL anatomy suggests the native MPFL is a broad flat structure approximately 1 mm thick arising from a broad origin on the femur approximately 9–17 mm in width and is located within a triangle formed by the adductor tubercle, medial femoral epicondyle and gastrocnemius tubercle. It has a similarly broad insertion on the patella (24 ± 5 mm), occupying approximately the upper half of the length of the patella articular surface. Hence, the native MPFL is morphologically more similar to a broad flat QT graft, than a tubular HS graft [46•].

Biomechanically, Herbolt et al. found that the characteristics of a 3-mm-thick by 10-mm-wide QT strip are very similar to the native MPFL (maximum load, yield load and stiffness), whilst Lentschow et al. found that HT constructs are about three times stiffer [47•, 48•]. Therefore, QT grafts may more closely restore native MPFL kinematics and may be more forgiving of variations in position and tension. Stiffer HT grafts may be more sensitive to over-tensioning or malpositioning, which can lead to increased patellofemoral joint stress compression forces, and lead to restricted motion.

Interestingly, embryologically, the MPFL and QT are both formed from the same origin, ventral mesenchyme, whilst the HT originates in the dorsal mesenchyme [19•].

Graft Harvesting

As described above, the quadriceps tendon near its patellar insertion is a tri-laminar structure [33•, 34–41]. Some authors have emphasised that a critical part of the technique is identifying a

Table 1 Summary of clinical results of quadriceps tendon MPFL reconstruction

Authors, year	Approach	Graft harvest TECHNIQUE	Medial graft routing	Femoral fixation	Patients and follow-up	Satisfaction	Outcome	Complications
Steensen [18••]	Open 5-cm midline + med.	Central 1/3, 10–12-mm wide superficial lamina	Subcutaneous	Anatomical Trans-osseous sutures	14 patients 37 months		No redislocations No complications	None
Goyal [19•]	Open 7–8-cm midline + med.	Central, 10–12-mm-wide superficial lamina	Sub-retinacular + non-abs. suture	Anatomical Bio-interference Screw	32 patients 38 months		No redislocations No complications Kujala 49 to 91	None
Fink [25•]	MIS 3-cm transverse + med.	Central, 10–12 mm wide, 3 mm deep, 8 cm long	Sub-periosteal and sub pre-patellar tissue + abs. suture	Anatomical Bio-interference screw	17 patients 12 months	96% satis. 4% dis-sat.	No redislocations No complications Lysholm 69 to 88 Tegner 4, 8 to 5	1 pt. 10° reduced flex 1 pt. unsatisfied (had grade 3A chondromalacia and type 2 trochlear dysplasia)
Vavalle [24••]	Open 6–7-cm midline + med.	Medial (3–4 mm from VMO) 10–12 mm wide, 5 mm deep	Sub-retinacular + non-abs. suture	Anatomical 5.5-mm screw anchor	16 patients (mean age 22 years) 38 months	85% satis. or very satis. 15% part. satis.	No redislocations No complications Kujala 36–89 Lysholm 43–89 Return to sport 5/9 same level, 1/9 semi pro to rec.	2 partially satisfied patients. Both had outer bridge grade 3–4 chondral damage
Nelitz [22••]	Open 4–5-cm med. parapap + med.	Medial (3–4 mm from VMO) 12–15-mm-wide superficial lamina	Sub-retinacular	Anatomical Bio-interference screw	25 adolescents (mean age 13 years) 31 months	94% sat. or very sat. 6% part. sat.	No redislocations No complications Kujala 63 to 89, Tegner 4 to 5, VAS 4 to 1	None
Hinckel [31••]	Open and MIS (3-cm med. long, prox. and 3-cm med long. dist.) + 1–2-cm med.	Medial border QT, 8 mm wide, sup. MPFL-med. border patella, 6 mm wide, FT.	Sub-retinacular + abs. suture MPFL - Angular rotation	Anatomical 5-mm anchor femur, 3.5-mm anchor tibia	7 patients (mean age 15) 5 months	All patients are satisfied	No redislocations, restoration of ROM, normalisation of patella translation and apprehension, restoration of patella tilt 5/7,	1 patient wound infection requiring 2× washout and debridement
Leal-Blanquet [30••]	Open/MIS med. para. + med.	Medial (3–4 mm from VMO) 10 mm wide 3 mm deep	Sub retinacular + abs suture	Non-anatomical Suture around add. magnus	4 patients 10 months	“Excellent”	No pain No instability Full ROM “Improved” Kujala and Lysholm	None

Fig. 8 The MIS technique results in smaller surgical scars, than open techniques for QT harvest. The incision follows Langer's lines, improving the cosmetic results

naturally occurring surgical plane of separation between the superficial and middle laminae. However, fusion of the laminae occurs with a degree of variation and interlamina separation is not always easy to identify. In these cases, Goyal recommends a small vertical nick is made at the lateralmost part of the tendon, around 2 cm proximal to the upper pole of the patella, followed by the use of scissors used to define a plane [20•]. Fink and Vavalle essentially recommend a similar technique as standard practice, choosing the depth of tendon to harvest rather than letting it be determined by the thickness of the superficial lamina [24•, 25•, 26•, 27•, 28•].

Three authors [18•, 19•, 20•, 25•, 26•, 27•, 28•] describe harvesting the central 10–12 mm of the tendon in 63 patients. Four authors describe harvesting the medial portion of the tendon [21•, 22•, 23•, 24•, 29•, 30•, 31•, 32•] in 52 patients, with graft sizes suggested from 8 to 15 mm. As Herbolt et al. have demonstrated a 3-mm-thick $\times$ 10-mm-wide QT strip has similar biomechanical properties to the natural MPFL [46•], a larger graft is rarely required.

The width of the QT at the patella insertion is approximately 44 mm (range, 34 to 54 mm) and the tendon shape is asymmetric, with the maximum length of 89 mm (range, 78 to 100 mm) typically occurring 62% from the medial border of the QT patella insertion [33•]. Given these dimensions, a 12-mm strip harvested 4 mm from the medial border is likely to miss this maximum length unless the tendon is harvested obliquely; hence, the authors suggest central harvesting is optimal.

Donor Site Morbidity

Given the native QT width (44 mm), harvesting a 10–12-mm-wide graft will usually constitute 20–30% of the QT width. QT

thickness increases steadily as aponeurotic layers of the extensor apparatus join, reaching a maximal thickness of 7.9 mm distally (range 6.5 to 9.5 mm) [49•]. Therefore, a 3-mm-deep graft will constitute less than half the depth distally (Fig. 1). Due to proximal tendon narrowing and thinning, the graft constitutes a relatively larger proportion of the volume proximally. However, volumetric MRI studies have shown that a full-thickness 10-mm $\times$ 80-mm graft constitutes 39% by volume [50•]. A 3-mm-deep graft therefore is likely to constitute only around 20% by volume and no donor site problems have been reported in any published studies.

Graft Length

Graft length depends on the chosen femoral insertion point and fixation method as well as location of the graft harvest (central vs medial) and routing method. A review of methods described to determine fixation point is beyond the scope of this article; however, measuring the distance from the graft harvest site to the desired femoral insertion and adding 2–3 cm for length lost in graft folding, routing and fixation are suggested. The native MPFL length is 56 mm (45–74 mm) so a graft of 80–90 mm is usually required [45, 48•].

Graft Routing

Steensen et al. [18•] describe routing the graft subcutaneously. Goyal [20•], Nelitz et al. [21•, 22•, 23•], and Vavalle et al. [24•] pass the graft beneath the medial retinacular structures. Fink et al. [25•, 26•, 27•, 28•] tunnel the graft deep to the patella periosteum and the medial retinaculum. The authors believe the latter technique helps

Fig. 9 AP and axial schematic diagrams of QT graft medial rerouting. If the graft is taken centrally in the tendon, then there is sufficient medial pre-patellar tissue that it is possible to pass the graft under both the anterior pre-patellar tissue and periosteum as described by Fink et al., adding to stability and positioning the neo-attachment of the MPFL in a deeper, more anatomical plane. When the graft is taken more medially, there is insufficient pre-patellar tissue medial to the graft to anchor the graft in this way. This may result in a more superficial positioning of the neo-ligament attachment, which risks altering the patella axis and causing patella tilt

stabilise the graft attachment, provides a broad bed for bone-tendon healing and more closely recreates the native anatomical broad continuous attachment to the patella at the correct anatomical level, positioning the neo-MPFL patella attachment closer to the articular surface than if the graft was reflected more superficially. This ensures an appropriate patella axis is restored and the risk of patella tilt is minimised (Fig. 9). It is worth noting that with medial QT graft harvesting techniques, tunnelling the graft under the anteromedial periosteum and pre-patellar tissue is more difficult as there is less medial tissue than if the tendon is harvested centrally (Fig. 9).

Goyal [19•, 20••], Vavalle et al. [24••], Fink et al. [25•, 26•, 27•], Hinckel et al. [31•, 32•] and Leal-Blanquet et al. [30••] all reinforce the graft attachment with sutures. Goyal [19•, 20••] and Vavalle et al. [24••] use non-absorbable sutures, whereas Fink et al. [25•, 26•, 27•], Hinckel et al., [31•, 32•] and Leal-Blanquet et al. [30••] use absorbable sutures.

Femoral Fixation

Fixation on the femoral side was most commonly with a bio-interference screw (Goyal, Nelitz et al., Fink et al), totalling 74/115 patients (66%), followed by suture anchors (Vavalle et al. and Hinckel et al) in 23/115 patients (20%), trans-osseous suturing (Steensen et al.) in 14/115 patients (12%) and suturing the tendon in a loop to itself around adductor magnus tendon (Leal-Blanquet et al) in 4/115 patients (3%) [18•, 19•, 20•, 21•, 22•, 23•, 24•, 25•, 26•, 27•, 28•, 29•, 30•, 31•, 32•].

The technique of Leal-Blanquet et al. is of interest as it removes the need for tunnels or fixation devices altogether [30••]. This may be useful in skeletally immature patients, reducing the risk of distal femoral physal injury, and revision situations, removing the need for use of implants, additional tunnels and/or bone grafting.

Conclusions

QT MPFL reconstruction has been shown to be a safe technique with high success at preventing recurrent dislocations and fewer complications than HT techniques. QT grafts provide a thin, broad strip of tissue with a continuous anatomic attachment along the superior half of the medial border of the patella that is anatomically and biomechanically more similar to the native MPFL than HT grafts. Maintaining an intact graft pedicle on the patella means that patella bone tunnel drilling or suture anchor placement is not necessary, reducing fracture risk.

Long incisions described for open QT graft harvesting may have deterred surgeons from using this technique; however, MIS QT harvesting techniques offer potentially better cosmetic results than both open QT and HT techniques. On the other hand, the option to harvest QT via a midline incision means that QT MPFL reconstruction combines well with trochleoplasty via the same incision.

Overall, QT is a valuable alternative to common HT grafts for primary MPFL reconstruction in children and adults and is an important revision surgery option.

The senior author's preferred technique is MIS QT reconstruction.

Author's Pearls and Pitfalls

Pearls:

- Careful dissection is necessary to expose the QT (including removal of all the bursal and superficial layers).
- The QT is longest when starting slightly lateral over the centre of the patella.
- The QT can be inspected using the arthroscope before harvesting.
- Be sure you have enough graft length (minimum of 9 cm in an average patient).

Pitfalls:

- The QT strip could peel off the bony surface of the patella.
- To avoid a “peel off”, dissection must be performed carefully. If “peel off” occurs and the graft is amputated from the patella, bone anchors may be used to fix the QT strip to the medial aspect of the patella (free QT graft) or if the graft is long enough, it can be looped through the pre-patellar tissue and sutured on to itself.
- The QT strip could be too short.
- It is important to angle the tendon separator 30° down, in order to avoid “cutting out” anteriorly leading to premature graft amputation. We had one case in our clinical series where the QT strip was cut too short (5 cm). In this case, a second 3-cm strip was harvested and sutured to the primary one. Alternatively, a strip of adductor tendon could have been harvested, left attached to the femur and sutured to the QT graft.
- As the MPFL functions as a checkrein, it is important to avoid overtightening.
- Graft fixation at the desired length should be performed in 30° flexion with just enough tension to align the patella with the lateral trochlea.

Compliance with Ethical Standards

Conflict of Interest Christian Fink is a consultant for Karl Storz, Medacta and Zimmer Biomet and reports royalties from Karl Storz. The other authors have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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