Comparative study between quadriceps tendon sling and semitendinosus graft for medial patellofemoral ligament reconstruction

Ahmed H.T. Waly

Department of Orthopaedic Surgery and Traumatology, Arthroscopy and Sports Injury Unit, Alexandria University, Alexandria, Egypt

Correspondence to Ahmed H.T. Waly, MD, Department of Orthopedicsurgery and Traumatology, Alexandria University, Postal Code 21532, Zezenia, Alexandria, Egypt.
Tel: +00201222186065;
e-mail: drwaly28@gmail.com

Received: 13 November 2021
Revised: 15 December 2021
Accepted: 15 January 2022
Published: 23 September 2022

The Egyptian Orthopaedic Journal 2022, 57:99–108

Background
Acute patellar dislocation is a common knee injury. The main injured structure is the medial patellofemoral ligament (MPFL). This ligament is the main static stabilizer against lateral patellar dislocation. Many surgical techniques have been described for the management of MPFL tear. The gold standard graft used for reconstruction is the hamstring. This study was done to compare the results of quadriceps tendon sling with semitendinosus graft for MPFL reconstruction (MPFLR).
Patients and methods
A prospective comparative study was held on 62 patients in El-Hadra University hospital between March 2018 and November 2019. Patients were divided into two groups. Group A had quadriceps graft and group B had semitendinosus graft for MPFLR. Patients were matched for age, sex, and body mass index. All cases were assessed clinically and functionally over 12 months of follow-up.
Results
There was no statistically significant difference between the 2 groups regarding Lysholm, Tegner, International Knee Documentation Committee, Visual Analog Scale, and Kujala scores. However, there was a statistically significant difference regarding the SCAR score.
Conclusion
Quadriceps tendon sling is a reliable alternative for MPFLR, especially in patients with small patellae or previous anterior cruciate ligament reconstruction.

Keywords:
medial patellofemoral ligament, patellar instability, quadriceps tendon, semitendinosus tendon

Egypt Orthop J 2022, 57:99–108

1110-1148

Introduction

Acute dislocation of the patella is a common injury, especially among adolescents and young adults, with higher rates in females [1]. It can be triggered by traumatic or nontraumatic events, the latter being associated with important anatomical changes in the distal femur and trochlear geometry along with the knee extensor mechanism. Patella alta, genu valgum, abnormal bony morphology, and vastus medialis muscle hypoplasia may predispose to instability. Patients with 'first-time' patellar dislocation most often are prescribed a conservative treatment approach. On the contrary, recurrent instability occurs in up to 44% of patients possessing traumatic patellar dislocation, with operative intervention reserved for cases where nonoperative treatment has failed [2].

The medial patellofemoral ligament (MPFL) has been identified as a pivotal structure for patella stability. It is the main static stabilizer during a knee flexion arc of 0 through 30 degrees of flexion, providing up to 60% of the total medial restraining force. Rupture of the MPFL often occurs with lateral patella dislocations. Frequent dislocations and recurrent instability demand MPFL reconstruction (MPFLR), a surgery in which a new grafted medial patellofemoral ligament is created to steady the knee and restore stability. MPFLR for the persistently unstable patient population is often performed alone or in association with other bone realignment procedures to restore stability. Most MPFLRs have satisfying results with very low rate of redislocation [3–7].

Several soft-tissue graft options are reported for medial patellofemoral ligament reconstruction. Despite satisfactory clinical results, hamstring autograft use has been reported to have a cumulative complication rate of 12.5%, including persistent postoperative patellar instability, postoperative knee stiffness, and patellar fracture [5].

Recently, the use of the quadriceps tendon in primary and revision knee cruciate ligament surgery has found renewed research and clinical interest and is being met with such enthusiasm that an International Quadriceps Tendon Interest Group has been formulated to further the understanding and application of this graft option in sports medicine [8].

Yet, there is no consensus on the best graft option for MPFLR [9]. MPFLR using a superficial 'swingdown' quadriceps tendon autograft may have some advantages over current hamstring techniques, akin to recent evidence in cruciate ligament surgery, including but not limited to biomechanical advantages and reduced risk profiles. A 'swing-down' graft refers to a pedicled graft, attached at the patella and freed proximally. Studies have shown that quadriceps tendon MPFLR has promising clinical results and offers valuable alternatives to hamstring tendon grafts for primary and revision MPFLR [2,10–12].

Recently, numerous studies have investigated the feasibility of the pedicled strip of quadriceps tendon autograft as a MPFLR [13]. The story started in 1997 when Burks *et al.* [14] described a novel MPFLR technique using a free quadriceps tendon autograft with a bone block. However, the bone block violated the bone structure of the patella, reducing stability and increasing the chances of fracture.

Eight years later, Steensen *et al.* [15] first described a pedicled strip of quadriceps tendon as a graft source. Their technique involved using only the proximal ventral lamina of the quadriceps tendon, whereas distally the tendon remained attached to its anatomic insertion on the upper pole of the patella, thus avoiding drilling or tunneling through the patella. Vavalle *et al.* [16] described their technique as turning the graft 90 degrees medially and then suturing it to the medial retinaculum, thus restoring the isometric patellar site of the MPFL. They then sutured the distal margin of the vastus medialis to the graft, enhancing the stability of graft and patella.

This prospective study was done to compare the results of MPFLR in patients with recurrent dislocation of the patella, using pedicled strip of quadriceps tendon versus the gold standard semitendinosus hamstring autograft.

Patients and methods

This is a prospective comparative study on 62 patients with recurrent patellar dislocation. Patients were admitted to El-Hadra University Hospital between March 2018 and November 2019. All cases were followed up for a maximum of one year postoperatively. Only cases with traumatic recurrent patellar dislocation were included in the study.

The exclusion criteria were as follows:

(1) First-time dislocations.
(2) TT-TG distance > 20 mm.
(3) Patella alta with CDI more than 1.3.
(4) Genu valgum with HKA more than 5 degrees of valgus.
(5) Trochlear dysplasia (Dejour [17] B–D).
(6) Avulsed MPFL from patellar or femoral sides.

Patients were classified randomly into 2 groups. The first group (Group A) was treated with MPFLR using quadriceps tendon strip (n=32). The other group (Group B) was treated using semitendinosus autograft (n=30). Both groups were matched for age, sex, and times of dislocations.

Patients were assessed preoperatively using frontal and lateral X-ray films and MRI films. A clinical evaluation was done using range of motion (ROM) and apprehension test. Functional evaluation was done using the Kujala score [18], Lysholm score [19], Tegner score [19], Visual Analog Scale score for pain [20], and International Knee Documentation Committee score [21] preoperatively and postoperatively at 6 and 12 months. At the end of follow-up, the SCAR (Scar Cosmesis Assessment and Rating) [22] scale was used to assess patient satisfaction for postoperative scar.

Statistical evaluation was done using SPSS version 25 (IBM SPSS Statistics for Windows, Version 25, Armonk, NY: IBM Corp). The P-value was set at 0.05. Independent t-test was used to compare between the two groups, as the data were parametric and normally distributed. χ^2 test was used for qualitative data. The study was approved by the local ethical committee of Alexandria University faculty of medicine. An informed consent was taken from every patient subjected to the study.

Surgical technique

All patients were operated supine under general anesthesia with a high thigh tourniquet. A side support was used, and patients were positioned to allow free knee motion between 0° and 120°. The knee was draped to allow fluoroscopy during the procedure (Fig. 1).

First, knee arthroscopy was done to deal with any intra-articular pathologies and to assess patellofemoral tracking and patellar engagement.

First group (Group A): quadriceps tendon pedicled strip technique

In 90° of knee flexion, an 8-cm transverse skin incision was placed over the quadriceps tendon and superomedial border of the patella. The prepatellar bursa was incised longitudinally and the quadriceps tendon was then carefully exposed. A long Langenbeck retractor was introduced, and the quadriceps tendon was subcutaneously exposed proximal to the patella (Figs 2 and 3).

Figure 1

Patient positioning with side and foot support to allow 90 flexion.

Figure 2

Incision over medial side of quadriceps tendon.

A no. 11 knife blade was used to strip the medial third of the quadriceps tendon. Only superficial layer is stripped from the tendon. The blade was introduced starting over the middle of the superior patella border and pushed up to a minimum of 8 cm. The thickness of the graft should be not less than 3 mm, and the length should not be less than 10 mm. Another cut was done over the medial border of the tendon. A tissue forceps was then pushed through the plane of the separation from proximal to distal (Figs 4 and 5).

The graft was left attached distally, and the free proximal end was anchored with a resorbable suture whip stitch.

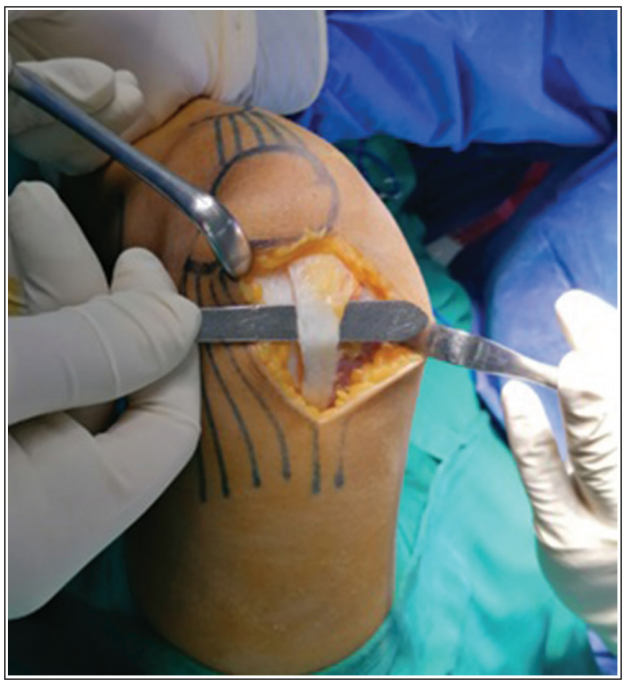
Figure 3

Exposed quadriceps tendon.

Figure 4

Stripping the superficial layer of quadriceps tendon.

Figure 5



Separation of layers of quadriceps tendon.

Figure 6

Cutting of quadriceps tendon proximally.

Distally, the longitudinal cuts were continued with a surgical knife toward the patella and over the patellar periosteum in the chosen width (10 or 12 mm), lateral for 2 cm and medial for 1 cm, on the anterior surface of the patella (Fig. 6).

The quadriceps tendon strip was then subperiosteally elevated from the surface of the patella. The proximal

Figure 7

Ensure adequate length of the quadriceps tendon before proximal detachment.

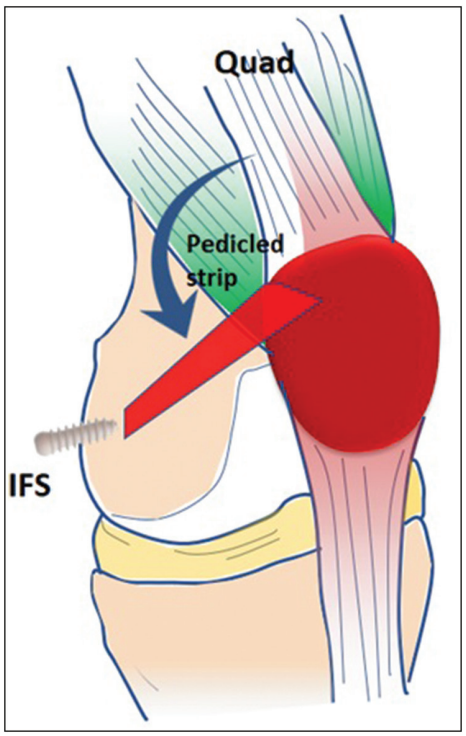
Figure 8

A ripstop stitch at the medial border of the patella to prevent graft detachment.

1.5 cm of the medial patellar border was exposed. From the medial patellar border, the prepatellar tissue was elevated laterally creating a tunnel reaching the medial edge of the graft. This was performed with a periosteal elevator. (Fig. 7)

At the distal end of the tendon, ripstop sutures were done to prevent graft stripping from anterior surface of the patella (Figs 8 and 9).

Figure 9



An illustration showing the superficial sling take down of the quadriceps tendon.

The second group (Group B): semitendinosus autograft

The semitendinosus graft was harvested in the usual manner. The graft is then prepared and whip stitched to tabularize the graft. A medial patellar incision was done to expose the medial border of the patella. Two parallel patellar tunnels were done under fluoroscopic guidance using anterior cruciate ligament guides. A 4.5-mm cannulated drill bit was used to widen the tunnels for later graft passage.

Two shuttle sutures were used to shuttle the graft in a C-shaped fashion inside the 2 patellar tunnels. The graft was then passed between the second and third layers of the medial retinaculum down to the insertion point of the femur (Figs 10–14).

In both techniques

A vertical medial incision was made between medial epicondyle and adductor tubercle. Under fluoroscopic guidance, a 2.4-mm anterior cruciate ligament guide pin was drilled into the insertion of the MPFL at the Schottle point [23]. It was directed anterolaterally to exit the femur on the lateral cortex well proximal to the lateral epicondyle. The pin was overreamed to thickness of the graft (about 7 mm) to a depth of 30 mm. Then, a surgical clamp was introduced between the second and third layers of medial retinaculum from medial to lateral to shuttle the graft. The graft was then introduced into the tunnel using a loop

Figure 10

An incision over medial border of the patella.

Figure 11

Drilling the patellar tunnels under fluoroscopic control.

suture. This loop was used to pull the graft toward the femoral insertion. The knee was cycled five times with moderate tension on the graft. Fixation was performed with 8 × 28 mm bioabsorbable interference screw at 30° of knee flexion with the lateral patellar border flush with the lateral border of the trochlear groove keeping low tension on the graft to allow two-quadrant lateral translation of the patella in full extension (Figs 15–20).

Postoperative treatment

A knee brace with ROM 0–90° was used for 6 weeks during postoperative rehabilitation. The patients were mobilized with 20-kg partial weight bearing for 3 weeks. Full weight bearing was started thereafter. Passive ROM exercises to a maximum of 30 degrees were initiated immediately postoperatively till the second week. The range was increased to 60 degrees in the second 2 weeks, and then, 90 degrees till 6 weeks. Stationary cycling was started 6 weeks postoperatively.

Figure 12

Two parallel patellar tunnels at the superior part of the patella.

Figure 13

Passing the graft in a C-shaped manner into patellar tunnels.

Full return to pivoting sports and daily work was allowed between 4 and 5 months after the operation.

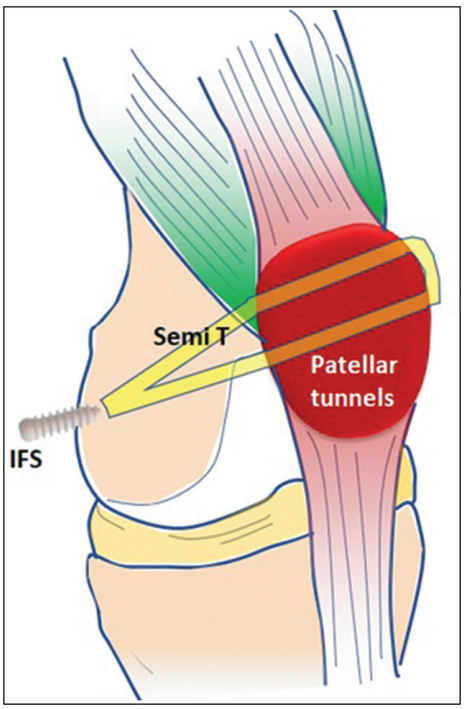
Results

The study included 62 patients who were admitted to El Hadra University Hospital with recurrent patellar dislocation. Group A was subjected to MPFLR using quadriceps tendon strip (n=32). Their mean age was 21.5 ± 3.9 years. Group B was subjected to MPFLR using the semitendinosus graft (n=30). Their mean age was 23.3 ± 6.4 years. The difference between the 2 groups was statistically insignificant, denoting adequate matching of the groups. Patients' demographic data are included in Table 1.

Regarding ROM, there was no statistically significant difference between both groups (P>0.05). Regarding the improvement of clinical patient scores, there was no statistically significant difference in both groups in all scores except in the SCAR score at the end of the follow-up. This confirms our hypothesis that the quadriceps pedicled strip can reach nearly the same results of semitendinosus graft for medial patellofemoral ligament reconstruction (Table 2, Fig. 21).

Regarding complications, one case of group A had QT stripped out from patellar anterior surface. The graft was sutures to medial border of the patella with nonabsorbable sutures, and the patient had positive apprehension for 6 m then improved. There were no postoperative complications in group B. At final FU, all cases had negative apprehension with no redislocations.

Figure 14



An illustration showing the semitendinosus technique.

Figure 15

Making a tunnel from femoral to patellar insertion points between the second and third layers of medial retinaculum.

Figure 16

A curved clamp is used to shuttle the graft from lateral to medial.

Figure 17

Graft shuttled to femoral insertion point.

Discussion

Anatomically, the MPFL is a flat band-like structure. The gross morphological appearance of such a quadriceps tendon strip more closely resembles the natural MPFL than a hamstring construct. A human cadaveric study investigated the biomechanical characteristics of a 3-mm thick and 10-mm wide

Figure 18

Under fluoroscopic guidance, the Schottle point is chosen and drilled.

Figure 19

A 4.2 guide pin is drilled from the shuttle point and directed lateral and proximal.

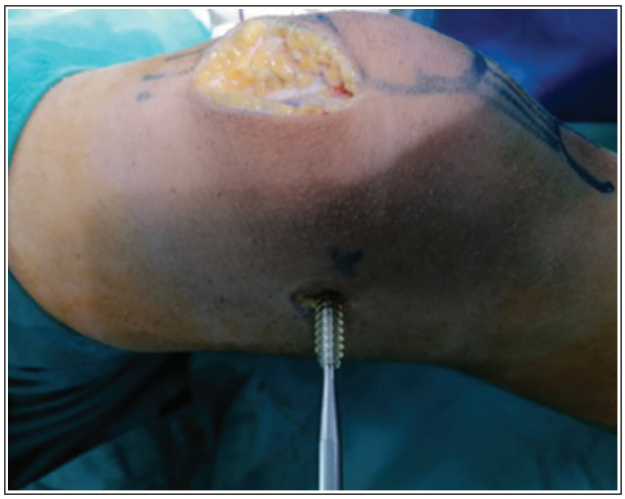
quadriceps tendon strip and found that they were similar to the natural MPFL [24].

Several studies showed the biomechanical advantage of the quadriceps tendon graft as a substitute for the native medial patellofemoral ligament. The native MPFL is a structurally thin fascial band with a load to failure strength of 208 N and stiffness of 12 N/mm. Reconstructed MPFL ligaments with quadriceps tendon grafts were shown to have a load to failure of 205 N and a stiffness of 33.6 N/mm. The average width of the native MPFL halfway along its total length is

10.5 mm. Therefore, a quadriceps graft width of 10–12 mm is appropriate to achieve anatomic similarity to the native MPFL. These numbers may suggest that the quadriceps tendon remains a good anatomic match to the native MPFL [16,24,25].

Complications of hamstring tendon MPFLR were reported in the literature in the form of patellar fractures, persistent patellar instability, and flexion deficits. Furthermore, hamstring strength has been shown to decrease (3–27%) after semitendinosus or gracilis autograft harvest [26–29].

Figure 20



The graft is then fixed using a bioabsorbable interference screw.

The quadriceps tendon has a trilaminar structure with the anterior layer formed by the rectus femoris, the intermediate layer formed by the vastus medialis and vastus lateralis, and the deep layer by the tendon of the vastus intermedius. The superficial slip is composed of the anterior lamina of the quadriceps tendon and is also a purely aponeurotic tendon matching the anatomic profile of the MPFL [30].

The main advantages of quadriceps as a graft for MPFLR are avoiding drilling or tunneling of the patella, which violates its integrity, with an increased risk of complications, such as secondary fracture. This is of particular importance in children with smaller patellae who are more prone to bone-related complications. Other potential advantages of the pedicled strip of quadriceps tendon autograft are simplicity of the surgical procedure, the anatomic patellar attachment of the native MPFL is close to the preserved insertion of the graft on the patella, thus facilitating isometry, and avoiding inadequate graft placement or fixation failure. All these advantages of the pedicled strip of quadriceps tendon

Table 1 Patients' demographic data

	Group A QT (32)	Group B SemiT (30)	Test of significance	*P* value
Age (years)	21.5 ± 3.9	23.3 ± 6.4	*t*=0.09	0.96
Sex				
Male	1	2	χ^2=0.516	0.472
Female	31	28		
Side affected				
Rt	14	12	χ^2=0.045	0.832
Lt	18	18		
BMI	22.6 ± 3.9	24.1 ± 2.5	*t*=0.93	0.32
TT-TG	26.7 ± 3.1	22.1 ± 4.8	*t*=0.49	0.62
Patellar tilt angle	12.3 ± 2.0	14.3 ± 2.9	*t*=1.55	0.12
Trochlear dysplasia	3 Dejour A	1 Dejour A	*t*=1.91	0.32
Caton–Deschamps index (CDI)	1.1 ± 0.9	1.3 ± 0.8	*t*=1.45	0.22
Hyperlaxity				
Knee hyperextension >10 deg	17	20	*t*=2.3	0.11
Operative time (min)	46 ± 12.8	52 ± 11.3	*t*=1.32	0.19

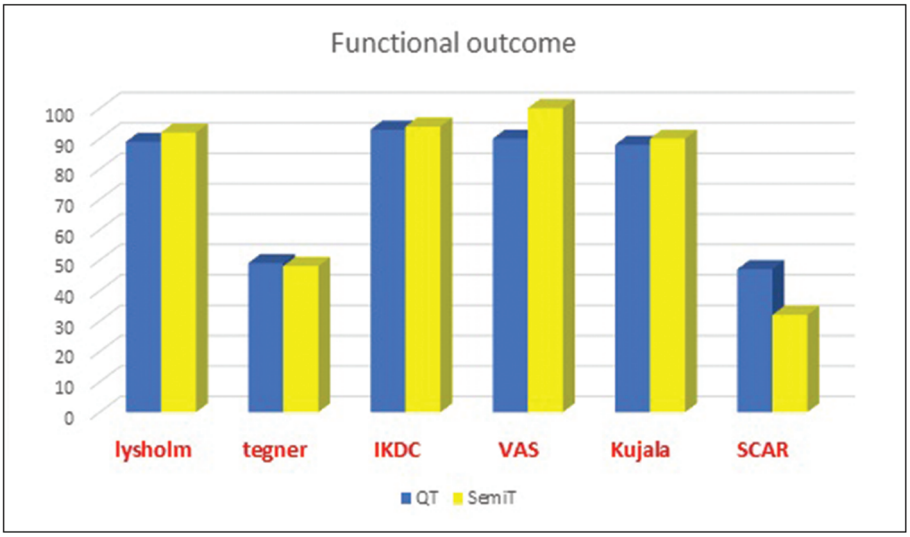
t: independent *t* test, χ^2: Chi-square test. BMI, body mass index.

Table 2 Patients' clinical improvement

	Group A QT (32)	Group B Semi T (30)	Test of significance	*P* value
Lysholm score	89.4 ± 2.3	92.1 ± 3.4	*t*=0.3	0.78
Tegner score	4.9 ± 2.1	4.8 ± 1.9	*t*=0.4	0.99
IKDC score	93.2 ± 3.1	94.7 ± 4.4	*t*=1.30	0.19
VAS scale	0.9 ± 1.2	1.0 ± 0.9	*t*=1.55	0.12
Kujala score	88.4 ± 4.4	90.3 ± 2.9	*t*=1.92	0.09
SCAR score	4.7 ± 0.9	3.2 ± 1.3	*t*=2.28	0.02*

t: independent *t* test, χ^2: Chi-square test. IKDC, International Knee Documentation Committee; SCAR, Scar Cosmesis Assessment and Rating; VAS, Visual Analog Scale. **P* significant if less than 0.05.

Figure 21



Improvement of functional outcomes.

autograft may promote superior outcomes compared with other traditional techniques, such as those involving the use of gracilis or semitendinosus autografts [31–36].

The quadriceps tendon can either be harvested as a full or partial-thickness graft, with or without a patellar bone plug, or may be left attached distally. Additionally, the graft is compatible with any and all fixation devices. Leaving the graft attached to the patella further reduces the complication profile by mitigating complications associated with drilling patellar bone tunnels. There have been several documented cases of iatrogenic patellar fractures that occurred because of drilling bone tunnels, which accounts for 2.4% of complications associated with MPFLR. Donor site morbidity as a complication was not mentioned as a complication with quadriceps tendon autograft [37–39].

Several studies had reported good to excellent clinical outcomes after quadriceps pedicled strip use for MPFLR. Peter *et al.* [40] used quadriceps tendon for MPFLR in patients with recurrent dislocation with the exclusion of patients with patella alta or elevated TT-TG and included 8 patients with trochlear dysplasia type A. At the final follow-up, no complications were detected. Goyal *et al.* [12] used quadriceps tendon in 32 cases with recurrent patellar dislocation. No complications were detected at 38 months of follow-up. Fink *et al.* [11] and Lenschow *et al.* [41] performed a similar procedure in patients without signs of elevated TT-TG. After 2 years of follow-up, they reported a positive apprehension test in 11%; however, no further complications were detected. Calapodopulos *et al.* [42] performed the same surgical procedures in patients without patella alta, trochlear dysplasia, or elevated TT-TG. At 30 months of follow-up, one patient presented a positive apprehension test; otherwise, no other complications were detected. Nelitz *et al.* [35] additionally fixed the quad tendon it to the adductor magnus tendon. The study population of this study was pediatric patients with mixed pathoanatomic risk factors. However, no complications were found after a minimum of 2 years of follow-up. All the patients returned to the same preoperative level of sport, whereas a third progressed to a higher level.

Migliorini *et al.* [13] performed a systematic review on the quadriceps tendon strip for MPFLR. They reported that the use of pedicled strip of quadriceps tendon as graft for MPFLR may be encouraged in patients with recurrent patellar instability, and it seems to be feasible and reliable, with very low rates of complications within approximately 28 months of follow-up.

Olotu *et al.* [2] performed a recent systematic review on quadriceps tendon sling down procedure. They found that the quadriceps tendon produced improved clinical outcomes with low rates of recurrent postoperative patellar dislocation. They concluded that the quadriceps tendon remains a suitable alternative for MPFLR and should remain part of the arsenal of knee ligament surgeons. Furthermore, the studies included in this systematic review had an overall complication rate of 4.9% compared with an overall complication rate of 12.5% reported for MPFLR with hamstring tendon autografts.

Conclusion

MPFLR for recurrent patellar instability using a pedicled swing down quadriceps tendon strip autograft is a safe procedure with improved clinical outcomes comparable to the gold standard semitendinosus graft.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. Clin Orthop Relat Res 2007; 455:93–101.

2 Olotu O, Siddiqui A, Peterson D. The superficial 'swing-down' quadriceps tendon autograft is a viable option for medial patellofemoral ligament reconstruction: a systematic review. Arthroscopy 2021; 37:3187–3197.

3 Drez JrD, Edwards TB, Williams CS. Results of medial patellofemoral ligament reconstruction in the treatment of patellar dislocation. Arthroscopy 2001; 17:298–306.

4 Patel NK, Vaswani R, Kay J, Musahl V, Lesniak BP. Knee flexion angle during graft fixation for medial patellofemoral ligament reconstruction: a systematic review of outcomes and complications. Arthroscopy 2019; 35:1893–1904.

5 Grantham WJ, Aman ZS, Brady AW, Rosenberg SI, Turnbull TL, Storaci HW, *et al*. Medial patellotibial ligament reconstruction improves patella tracking when combined with medial patellofemoral reconstruction: an in vitro kinematic study. Arthroscopy 2020; 36:2501–2509.

6 Shamrock AG, Day MA, Duchman KR, Glass N, Westermann RW. Medial patellofemoral ligament reconstruction in skeletally immature patients: a systematic review and meta-analysis. Orthop J Sports Med 2019; 7:2325967119855023.

7 Singhal R, Rogers S, Charalambous C. Double-bundle medial patellofemoral ligament reconstruction with hamstring tendon autograft and mediolateral patellar tunnel fixation: a meta-analysis of outcomes and complications. Bone Joint J 2013; 95:900–905.

8 Sheean A, Musahl V, Slone H, Xerogeanes J, Milinkovic D, Fink C, *et al*. International Quadriceps Tendon Interest Group: Quadriceps tendon autograft for arthroscopic knee ligament reconstruction: use it now, use it often. Br J Sports Med 2018; 52:698–701.

9 McNeilan RJ, Everhart JS, Mescher PK, Abouljoud M, Magnussen RA, Flanigan DC. Graft choice in isolated medial patellofemoral ligament reconstruction: a systematic review with meta-analysis of rates of recurrent instability and patient-reported outcomes for autograft, allograft, and synthetic options. Arthroscopy 2018; 34:1340–1354.

10 Rhatomy S, Soekarno NR, Setyawan R, Primasara S, Gaol IL, Budipharama NC. Minimal invasive MPFL reconstruction using quadriceps tendon graft with lateral release: 2 years follow up. Int J Surg Open 2019; 17:20–26.

11 Fink C, Veselko M, Herbort M, Hoser C. MPFL reconstruction using a quadriceps tendon graft: part 2: operative technique and short term clinical results. Knee 2014; 21:1175–1179.

12 Goyal D. Medial patellofemoral ligament reconstruction: the superficial quad technique. Am J Sports Med 2013; 41:1022–1029.

13 Migliorini F, Trivellas A, Eschweiler J, Betsch M, Tingart M, Maffulli N. Pedicled strip of quadriceps tendon graft for primary medial patellofemoral ligament reconstruction in recurrent patellofemoral instability: a systematic review. Arthroscopy 2021; 37:1992–1999.

14 Burks RT, Luker MG. Medial patellofemoral ligament reconstruction. Tech Orthop 1997; 12:185–191.

15 Steensen RN, Dopirak RM, Maurus PB. A simple technique for reconstruction of the medial patellofemoral ligament using a quadriceps tendon graft. Arthroscopy 2005; 21:365–370.

16 Vavalle G, Capozzi M. Isolated reconstruction of the medial patellofemoral ligament with autologous quadriceps tendon. J Orthop Traumatol 2016; 17:155–162.

17 Dejour H, Walch G, Neyret P, Adeleine P. Dysplasia of the femoral trochlea. Rev Chir Orthop Reparatrice Appar Mot 1990; 76:45–54.

18 Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. Arthroscopy 1993; 9:159–163.

19 Lysholm J, Tegner Y. Knee injury rating scales. Acta Orthop 2007; 78:445–453.

20 Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: visual analog scale for pain (VAS pain), numeric rating scale for pain (NRS pain), McGill pain questionnaire (MPQ), short-form McGill pain questionnaire (SF-MPQ), chronic pain grade scale (cpgs), short form-36 bodily pain scale (SF-36 BPS), and measure of intermittent and constant osteoarthritis pain (ICOAP). Arthritis Care Research 2011; 63(S11):S240–S252.

21 Crawford K, Briggs KK, Rodkey WG, Steadman JR. Reliability, validity, and responsiveness of the IKDC score for meniscus injuries of the knee. Arthroscopy 2007; 23:839–844.

22 Roh M. The SCAR (SCAR Cosmesis assessment and rating) scale: new evaluation method for postoperative scars. Br J Dermatol 2016; 175:1151–1152.

23 Schöttle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. Am J Sports Med 2007; 35:801–804.

24 Herbort M, Hoser C, Domnick C, Raschke MJ, Lenschow S, Weimann A, *et al*. MPFL reconstruction using a quadriceps tendon graft: part 1: biomechanical properties of quadriceps tendon MPFL reconstruction in comparison to the Intact MPFL. A human cadaveric study. Knee 2014; 21:1169–1174.

25 Tuxøe J, Teir M, Winge S, Nielsen P. The medial patellofemoral ligament: a dissection study. Knee Surg Sports Traumatol Arthrosc 2002; 10:138–140.

26 Parikh SN, Nathan ST, Wall EJ, Eismann EA. Complications of medial patellofemoral ligament reconstruction in young patients. Am J Sports Med 2013; 41:1030–1038.

27 Dhinsa BS, Bhamra JS, James C, Dunnet W, Zahn H. Patella fracture after medial patellofemoral ligament reconstruction using suture anchors. Knee 2013; 20:605–608.

28 Parikh SN, Wall EJ. Patellar fracture after medial patellofemoral ligament surgery: a report of five cases. JBJS 2011; 93:e97.

29 Shah JN, Howard JS, Flanigan DC, Brophy RH, Carey JL, Lattermann C. A systematic review of complications and failures associated with medial patellofemoral ligament reconstruction for recurrent patellar dislocation. Am J Sports Med 2012; 40:1916–1923.

30 Andrikoula S, Tokis A, Vasiliadis HS, Georgoulis A. The extensor mechanism of the knee joint: an anatomical study. Knee Surg Sports Traumatol Arthrosc 2006; 14:214–220.

31 Christiansen SE, Jacobsen BW, Lund B, Lind M. Reconstruction of the medial patellofemoral ligament with gracilis tendon autograft in transverse patellar drill holes. Arthroscopy 2008; 24:82–87.

32 Smith TO, Walker J, Russell N. Outcomes of medial patellofemoral ligament reconstruction for patellar instability: a systematic review. Knee Surg Sports Traumatol Arthrosc 2007; 15:1301–1314.

33 Thaunat M, Erasmus PJ. Recurrent patellar dislocation after medial patellofemoral ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2008; 16:40–43.

34 Schüttler KF, Hoeger A, Heyse T, Figiel J, Timmesfeld N, Stein T, *et al*. Femoral tunnel widening is associated with tunnel malposition but not with clinical failure after medial patellofemoral ligament reconstruction with a free gracilis tendon graft. Arch Orthop Trauma Surg 2018; 138:979–984.

35 Nelitz M, Dreyhaupt J, Williams SRM. Anatomic reconstruction of the medial patellofemoral ligament in children and adolescents using a pedicled quadriceps tendon graft shows favourable results at a minimum of 2-year follow-up. Knee Surg Sports Traumatol Arthrosc 2018; 26:1210–1215.

36 Migliorini F, Rath B, Tingart M, Meisen N, Eschweiler J. Surgical management for recurrent patellar dislocations in skeletally immature patients. Eur J Orthop Surg Traumatol 2019; 29:1815–1822.

37 Kanakamedala AC, Obioha OA, Arakgi ME, Schmidt PB, Lesniak BP, Musahl V. No difference between full thickness and partial thickness quadriceps tendon autografts in anterior cruciate ligament reconstruction: a systematic review. Knee Surg Sports Traumatol Arthrosc 2019; 27:105–116.

38 Crum RJ, Kanakamedala AC, Obioha OA, Lesniak BP, Musahl V. Aperture and suspensory fixation equally efficacious for quadriceps tendon graft fixation in primary ACL reconstruction: a systematic review. J Knee Surg 2020; 33:704–721.

39 Weinberger JM, Fabricant PD, Taylor SA, Mei JY, Jones KJ. Influence of graft source and configuration on revision rate and patient-reported outcomes after MPFL reconstruction: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc 2017; 25:2511–2519.

40 Peter G, Hoser C, Runer A, Abermann E, Wierer G, Fink C. Medial patellofemoral ligament (MPFL) reconstruction using quadriceps tendon autograft provides good clinical, functional and patient-reported outcome measurements (PROM): a 2-year prospective study. Knee Surg Sports Traumatol Arthrosc 2019; 27:2426–2432.

41 Lenschow S, Herbort M, Fink C. Rekonstruktion eines medialen patellofemoralen ligaments mit quadrizepssehnenstreifen. Oper Orthop Traumatol 2015; 27:474–483.

42 Calapodopulos CJ, Nogueira MC, Eustáquio JMJ, Rodrigues OA. Reconstrução do ligamento patelofemoral medial com enxerto autólogo do tendão quadricipital no tratamento da luxação recidivante da patela. Rev Bras Ortop 2016; 51:187–193.