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Reconstruction of the medial patellotibial ligament results in favorable clinical outcomes: a systematic review

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Abstract

Purpose The medial patellotibial ligament (MPTL), the medial patellofemoral ligament (MPFL), and the medial patellomeniscal ligament (MPML) support the stability of the patellofemoral joint. The purpose of this systematic review was to report the surgical techniques and clinical outcomes of the repair or reconstruction of the MPTL in isolation or concomitant with the MPFL and/or other procedures.

Methods A systematic review of the literature was conducted. Inclusion criteria were articles in the English language that reported clinical outcomes of the reconstruction of the MPTL in isolation or in combination with the MPFL and/or other procedures. Included articles were then cross-referenced to find additional journal articles not found in the initial search. The methodological quality of the articles was determined using the Coleman Methodology Score.

Results Nineteen articles were included detailing the clinical outcomes of 403 knees. The surgical procedures described included hamstrings tenodesis with or without other major procedures, medial transfer of the medial patellar tendon with or without other major procedures and the reconstruction of the MPTL in association with the MPFL. Overall, good and excellent outcomes were achieved in $>75\%$ of cohorts in most studies and redislocations were $<10\%$, with or without the association of the MPFL. An exception was one study that reported a high failure rate of 82%. Results were consistent across different techniques. The median CMS for the articles was 66 out of 100 (range 30–85).

Conclusion Across different techniques, the outcomes are good with low rates of recurrence, with one article reporting a high rate of recurrence. Quality of the articles is variable, from low to high. Randomized control trials are needed for a better understanding of the indications, surgical techniques, and clinical outcomes. This systematic review suggests that the reconstruction of the MPTL leads to favorable clinical outcomes and supports the role of the procedure as a valid surgical patellar stabilization procedure.

Level of evidence IV: systematic review of level I–IV studies.

Keywords Medial patellotibial ligament · MPTL · Systematic review · Clinical outcomes · Patellar instability · Patellar dislocation · Patellar ligaments · Ligament reconstruction · MTPL reconstruction · Medial patellotibial ligament reconstruction · Surgical treatment patellar instability

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Introduction

Lateral patellar dislocation is a significant cause of knee injuries with associated hemarthrosis, especially in young patients [1]. The medial patellotibial ligament (MPTL), in association with the medial patellofemoral ligament (MPFL) and the medial patellomeniscal ligament (MPML), is responsible for maintaining the stability of the patellofemoral (PF) joint. While the MPFL is the primary stabilizer of the PF joint (contributing ~ 50–60% to medial restriction during early flexion), the function of the MPTL should not be understated [8, 9, 17, 20, 35]. It has been shown that the contribution of the MPTL and MPML in the restriction of lateral patellar translation increases from 26% at full extension to 46% at 90◦ flexion [36]. In addition, the influence of the MPTL and MPML in resisting lateral patellar tilt at 90◦ flexion was 72% [36].

In 1922, Galeazzi [12] described a semitendinosus (ST) patellar tenodesis for treating patellar instability. In 1998, Rillmann et al. [37] described a transfer of the medial portion of the patellar tendon (PT). Both surgical techniques are analogous to a MPTL reconstruction. Many other authors have reported their results with these procedures, in isolation or combined with procedures other than the MPFL (e.g., lateral retinaculum release, tibial tuberosity osteotomy—TTO, Roux–Goldthwait) [3, 23, 26, 29, 31]. With the introduction of the MPFL reconstruction in the early 2000s, the reconstruction of the MPTL has fallen out of favor. More recently, however, combined MPFL and MPTL reconstruction has been reported [5, 10, 11, 13, 18, 39].

The MPTL reconstruction and analogous procedures have been part of the surgical armamentarium for surgical treatment of patella instability for decades [3, 26, 37]; despite this, clinical reported outcomes have remained sparse. The purpose of this systematic review is to report the techniques and clinical outcomes of the reconstruction of the MPTL in isolation and in combination with the MPFL and/or other procedures, in patients with lateral patellofemoral instability. The hypothesis of this review is that reconstruction of the MPTL leads to favorable clinical outcomes with minimal morbidity.

Materials and methods

Literature search

The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) protocol for reporting systematic reviews and meta-analyses [27] was followed. Clinical studies of the reconstruction of the MPTL were identified with the goal of summarizing current evidence and elucidating the effectiveness of these surgical procedures. Two authors (CAB and ELP) independently conducted a broad search of PubMed (NLM), and Medline (OvidSP) employing the predetermined search terms: "MPTL", "medial patellotibial ligament", "medial patellotibial ligament reconstruction", "patellar dislocation reconstruction", "Galeazzi", "semitendinosus tenodesis", "patellar tenodesis", for English-language articles prior to May 20, 2017. All peer-reviewed journal articles that provided any clinical outcomes concerning the reconstruction of the MPTL were included. Exclusion criteria were surgical technique articles, review articles, and clinical studies that did not report any clinical outcomes. Discrepancies were resolved by one senior author (BBH). In addition, the articles' references were reviewed to locate journal articles not identified in the initial search.

Data extraction and analysis

All study data was extracted using a standardized predetermined criterion: study (first author and year), number of knees, follow-up, indications, graft/technique used for the MPTL reconstruction, associated risk factors, associated procedures, and clinical results. To interpret results, the studies were grouped by technique, and further grouped by the association with, or absence of, other major procedures. For this purpose, associated procedures considered major were procedures that significantly changed patellofemoral morphology or alignment, such as tibial tuberosity osteotomy (TTO), Roux–Goldthwait procedure (medial transfer of the lateral half of the patellar tendon), Green's procedure (transfer of the medial head of the quadriceps to the lateral patella with a duplication of the medial patella retinaculum and joint capsule), Insall's proximal realignment (medial advancement of a medial flap created by a medial parapatellar arthrotomy, with lateral retinacular release) and trochleoplasty. In addition, the combined reconstruction of the MPTL with the MPFL was considered a separate group. Redislocation was recorded as a further episode of lateral patellar dislocation. Other stability-related issues such as lateral subluxation, apprehension, medial instability, or subjective instability complaints were recorded separately, as complications.

Quality assessment

The methodological quality of the articles included in this systematic review was assessed by the Coleman Methodology Score (CMS) [7]. Two authors independently applied the CMS (CAB and ELP); and then, a final score was reached by consensus. The CMS is computed by summation

of ten separate criteria (study size, follow-up, number of procedures, type of study, diagnostic certainty, description of surgical technique, rehabilitation and compliance, outcome criteria, outcome assessment, and selection process), leading to a total possible score of 100 [7]. The higher the score, the more probable the study avoids chance and other biases characteristic of poor methodology.

Statistical analysis

Mean and standard deviation (SD) were calculated for each criterion. Differences between the groups (by technique, and with or without associated major procedures) were tested by Student's *T* test (SigmaPlot 13.0), with significance set at $p \leq 0.05$.

Results

Literature search

The articles included in this study were published between the years of 1972 and 2016. No randomized control trial was found in our search, and all articles are case reports or case series. The flowchart of search, exclusion, and inclusion is shown in Fig. 1.

Data extraction

Table 1 shows the results of the data that were extracted.

In the 19 papers, a total of 403 knees were included. Mean follow-up ranged from 5.5 months to 8.1 years. The mean follow-up was less than 2 years: $n = 10$ (2%), 2–5 years: $n = 212$ (53%), 5–10 years: $n = 181$ (45%).

There were five articles that discussed ST tenodesis without other major procedures (130 knees, 32%), four articles that discussed ST tenodesis with other major procedures (45 knees, 11%), three articles that discussed medial transfer of the patellar tendon without other major procedures (103 knees, 26%), two articles that discussed the medial transfer of the patellar tendon with other major procedures (47 knees, 12%), and five articles that discussed MPTL reconstruction associated with MPFL reconstruction (78 knees, 19%, mostly without other major procedures).

Reconstruction of the MPTL was indicated for the treatment of patellar instability; mostly objective instability with recurrent lateral patellar dislocations. Some authors indicate the procedure in the absence of risk factors [5, 10, 34, 39] and others in the presence of anatomic patellar instability risk factors or factors associated with worse outcomes [16,

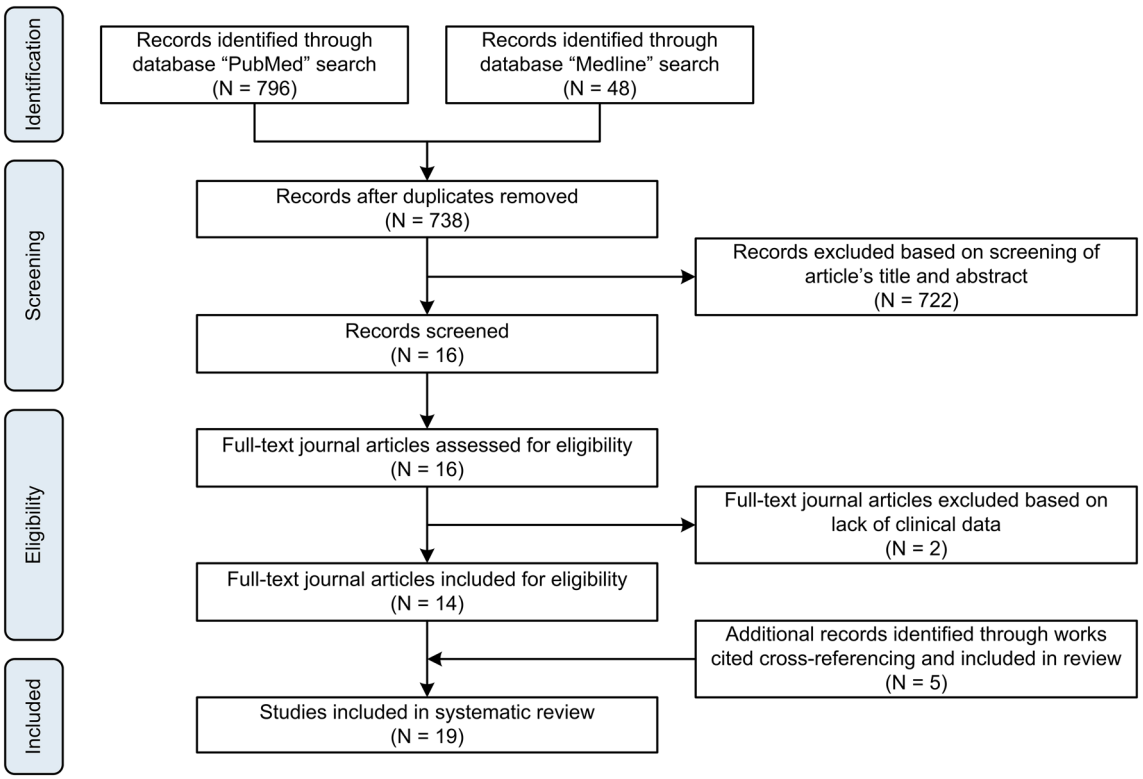

Fig. 1 Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram outlining systematic review algorithm

Table 1 Clinical results of MPTL reconstructions

References	*N*	Follow-up (mean)	Indications	Graft/technique	Associated risk factors	Associated procedures	Results
Semitendinosus tenodesis without other major procedures (*n* = *130*)							
Baker et al. [3]	53	5 years	Recurrent dislocation	ST Tenodesis with patellar tunnel	Trochlear dysplasia: Hypoplastic lateral condyle (17%) Patella alta (18.9%) Lateral quadriceps vector: genu valgum (15.1%) and genu valgum with recurvatum (17%)	Lateral retinaculum release when there was lateral tightness Medial retinaculum plication when arthrotomy was performed	Redislocation: 3.8% Results: 30.2% excellent 50.9% good 9.4% fair and 5.7% poor Decreased range of motion: 5.7% Infection: 3.8% anterior Pain due to chondromalacia: 9.4% Reoperation: 9.4% (excision of saphenous neuroma, 1 loose body) Numbness in saphenous territory: several
Letts et al. [26]	26	3.2 years	Greater than three episodes of patellar dislocation	ST Tenodesis with patellar tunnel	Trochlear dysplasia: nm Patella alta: nm Lateral quadriceps vector: nm Ligamentous laxity (38%)	Lateral retinaculum release in 100% Medial retinaculum plication in 100%	Redislocation: 3.8% Results: 26.9% excellent 50% good and 23.1% poor Lysholm score: mean 68 Anterior pain: 11.5% Medial dislocation: 3.8%
Moyad et al. [30]	1	6 months	Recurrent sensations of instability and subluxation	ST Tenodesis with patellar tunnel	nm	Lateral retinaculum release in 100% Vastus medialis advancement in 100%	Redislocation: none Running with no instability Full range of motion No evidence of patellar subluxation
Aulisa et al. [2]	16	4.5 years	Recurrent dislocation	ST Tenodesis with patellar tunnel	Trochlear dysplasia: sulcus angle: 161° Patella alta (43.8%) Lateral quadriceps vector: mean Q angle 19.4°; mean TTTG 21.5 mm	Lateral retinaculum release in 100% Medial retinaculum plication in 100%	Redislocation: nm Results: 62.5% excellent and 37.5% good Transient saphenous nerve sensory deficit: 25%
Grannatt et al. [14]	34	70 months	Patellofemoral instability despite physical therapy of 6 months	ST Tenodesis with patellar tunnel	nm	Lateral retinaculum release in 100% Medial retinaculum plication in 61.8%	Redislocation: nm Recurrence equivalent: 35% of reoperation due to instability Reoperation rate: 34.3% IKDC < 70 in 41.2% Subjective subluxation and dislocations: 82%

Table 1 (continued)

References	*N*	Follow-up (mean)	Indications	Graft/technique	Associated risk factors	Associated procedures	Results
Results of the semitendinosus tenodesis without other major procedures group: overall, there were 3 (2.3%) redislocations and 15 (11.5%) including the redislocation equivalent from Grannatt et al. Most studies indicated redislocation rates no higher than 8% [2, 3, 26, 30]. Grannatt et al. however, indicated recurrence (objective and subjective patellar instability) rates of 82%, which they believe resulted from the associated risk factors [14]. Overall, there were 23 complications (17.7%). Transient saphenous nerve sensory deficit in 3.1% ($n=4$), decreased range of motion (ROM) in 2.3% ($n=3$), anterior pain 6.2% ($n=8$), infection in 1.5% ($n=2$), medial dislocation in 0.76% ($n=1$), and reoperation in 3.8% ($n=5$)							
Semitendinosus tenodesis with other major procedures ($n=45$)							
Hall et al. [16]	26	43 months	Patellar dislocation (including habitual patellar dislocation) and recurrent subluxation	ST Tenodesis with patellar tunnel	Trochlear dysplasia: nm Patella alta: IS > 1.2 (61.5%) Lateral quadriceps vector: nm	Roux–Goldthwait in 73.1% Vastus medialis advancement in 100%	Redislocation: none Results: 61.5% excellent and good; and 38.5% fair or poor due to chondromalacia Wound problems: 30.8% Worse results associated with ligamentous laxity
Joo et al. [23]	6	54.5 months	Habitual dislocation	ST Tenodesis without patellar tunnel, anchor fixation	Trochlear dysplasia: Dejour classification, B (16.7%) and C (83.3%) Patella alta: IS < 1.2 in 100% Lateral quadriceps vector: nm ps vector: nm Ligamentous laxity in 100%	Lateral retinaculum release in 100% Proximal Insall realignment in 100% Roux–Goldthwait procedure in 100%	Redislocation: none Kujala > 88 in 100% At final follow-up, all patients had grade A trochlear dysplasia with mean sulcus angle 148.2° Skin necrosis: 33.3%
Niedzielski et al. [33]	11	8.1 years	Unilateral habitual dislocation Under 18 years of age A Beighton score of at least 4 points	ST Tenodesis without patellar tunnel	Trochlear dysplasia: sulcus angle 147 (72.7%); Dejour classification, A (72.7%) and C (27.3%) Patellar alta (45.5%) Patella baja (27.3%) Lateral quadriceps vector: nm Patellar tilt increased (72.7%) Ligamentous laxity: Beighton score 4 points in 100%	Lateral retinaculum release in 100% Vastus medialis advancement in 100% Roux–Goldthwait procedure in 100%	Redislocation: 9.1% Normal patellar tracking: 90.9% Lysholm scores: 9.1% excellent, 54.5% good, 18.2% fair and 18.2% poor results Isokinetic tests: decrease in the maximum quadriceps muscle torque values at 60 and 180°/s compared with contralateral side No significant difference in maximal knee flexion values
Kocon et al. [25]	2	39 months	Irreducible or recurrent dislocation with an associated diagnosis of Down's syndrome	ST Tenodesis with patellar tunnel	nm	Lateral retinaculum release in 100% Green's procedure in 100%	Redislocation: none Satisfactory results

Table 1 (continued)

References	*N*	Follow-up (mean)	Indications	Graft/technique	Associated risk factors	Associated procedures	Results
Results of the semitendinosus tenodesis with other major procedures group: two studies reported good or excellent results in approximately 2/3 of cases [16, 33], while one had good results in all [23] and one satisfactory results in all [25]. Overall, there was only one redislocation (2.2%) [33]. Overall, there were 10 complications (22.2%), all of which were wound problems/skin necrosis at the surgical site							
Medial transfer of the medial patellar tendon without other major procedures (*n* = *103*)							
Rillman et al. [37]	36	62.8 months	Persistent objective instability despite intense therapy of at least 6 months	Medial PT Medial transfer with bone plug	Trochlear dysplasia: Dejour classification A (88.9%) and B (11.1%) Patella alta: CD > 1.2 (19.5%) Lateral quadriceps vector: nm	Lateral retinaculum release in 5.6% Vastus medialis advancement in 2.8%	Redislocation: none Results: 19.4% excellent and 77.8% good; Tegner increased from 3.1 to 3.8 Congruence angle changed from + 7.4° to − 14.7° Reoperations related to index surgery: 8.3% Subjective instability complaints: 11.1% Temporary peroneal paralysis: 2.8%
Myers et al. [31]	42	Minimum 2 years	Recurrent dislocation in Skeletally mature patients with Q angle < 25° Skeletally immature patient with any Q-angle value	Medial PT Medial transfer	nm	Lateral retinaculum release in 100% Vastus medialis advancement in 100%	Redislocation: 9.5% Results: 76.2% excellent or good Deep vein thrombosis: 2.4% Open arthrolysis required: 2.4%
Oliva et al. [34]	25	3.8 years	At least 2 radiographically documented episodes of unilateral dislocation Without risk factors: sulcus angle < 145°; IS < 1.2; Q angle < 20°, genu valgum < 7°	Medial PT Medial transfer	Trochlear dysplasia: sulcus angle mean 129° ± 15° Patella alta: mean IS 1.04 ± 0.2 Lateral quadriceps vector: Q-angle mean 14° ± 3.5°	Lateral retinaculum release in 100% Vastus medialis advancement in 100%	Redislocation: 4% (motor vehicle accident) Cincinnati score: 51.7–94.3 Kujala score: 52.4–93.8
Results of the medial transfer of the medial patellar tendon without other major procedures group: there were good and excellent results in > 75% of knees and good improvement in the Kujala score. Overall, there were 5 redislocations (4.85%). Overall, there were 9 complications (8.7%). Functional instability complaints in 3.9% (*n* = 4), deep vein thrombosis (DVT) in 0.97% (*n* = 1), and reoperation (including 2 medial retinaculum incisions for patella baja and 1 arthrolysis) in 3.9% (*n* = 4)							
Medial transfer of the medial patellar tendon with other major procedures (*n* = *47*)							
Marcacci et al. [29]	18	5 years	Objective habitual or chronic instability	Medial PT Medial transfer with bone plug	Trochlear dysplasia: severe (22.2%) Patella alta: IS > 12 (100%) Lateral quadriceps vector: nm	TTO, medialization (Elmslie-Trillat) in 100% Lateral retinaculum release 100% Trochleoplasty in 22.2%	Redislocation: none IKDC score: 83.3% A and B Kujala score: 88.9% excellent

Table 1 (continued)

References	*N*	Follow-up (mean)	Indications	Graft/technique	Associated risk factors	Associated procedures	Results
Zaffagnini et al. [41]	29	6.1 years	Dislocation either traumatic or atraumatic with no resolution of symptoms after at least 3 months of conservative treatment	Medial PT Medial transfer with bone plug	Trochlear dysplasia: Dejour classification A (13.8%), B (41.4%), C (24.1%), and D (20.7%) Patella alta: IS < 12 (48.3%) Lateral quadriceps vector: nm	Lateral retinaculum release in 100% Trochleoplasty in 20.7% Medial facetectomy in 3.4% Lateral facetectomy in 3.4%	Redislocation: 6.9% Kujala score: 41–78.1 IKDC score: 34.7–71 Womac score: 55.9–88 EVD score: 60.8–19.6 Tegner score: 1–4 Progression to arthritis: 3.4%, associated with trauma, valgus alignment and moderate PF arthritis when index surgery, further required TKA Persistent subjective subluxation: 3.4%, required MPFL reconstruction
Results of the medial transfer of the medial patellar tendon with other major procedures group: there was an important clinical improvement in various validated patient reported outcomes (PROs) such as IKDC, Kujala, Womac and Tegner. Overall, there were 2 redislocations (4.2%). Overall, there was 1 complication (2.1%), which was a progression to arthritis							
MPTL and MPFL reconstruction ($n = 78$)							
Drez et al. [10]	15	31.5 months	Recurrent instability after failed non-operative measures Patients with patellar instability and a loose osteochondral fragment following patellar dislocation	ST (6 knees), ST + G (5 knees), and Iliotibial band (3 knees) All as free grafts, one repair	Trochlear dysplasia: nm Patella alta: normal Lateral quadriceps vector: Q angle < 15°	MPFL reconstruction in 100%	Redislocation: none Results: 93% excellent and good Fulkerson score mean: 93 Kujala score mean: 88.6 Congruence angle: 25.3°–5.5° Arthrofibrosis: 6.7% Quadriceps atrophy: 60%
Brown and Ahmad [5]	2	14 months	Dislocation with normal osseous anatomy and mechanical alignment	ST and G Distal insertion maintained. Docking tunnel in the patella	nm	MPFL reconstruction in 100%	Redislocation: none Kujala scores: 43–88 in patient 1; 50–98 in patient 2 Lysholm scores: 38–97 in patient 1; 55–95 in patient 2
Ebied and El-Kholy [11]	25	34 months	At least 1 dislocation or subluxation Persistent symptoms of instability despite 2 weeks of rehabilitation	ST and G Distal insertion maintained. One tunnel in the patella	Trochlear dysplasia: mean sulcus angle 141° Patella alta: nm Lateral quadriceps vector: mean TTTG 15 mm	MPFL reconstruction in 100% Lateral retinaculum release in 68% TTO in 32%	Redislocation: nm Results: 76% excellent, 20% good, and 4% fair IKDC scores: 54–81 Effusion of the knee: 8%

Table 1 (continued)

References	*N*	Follow-up (mean)	Indications	Graft/technique	Associated risk factors	Associated procedures	Results
Sobhy et al. [39]	29	32.2 months	Recurrent dislocation with normal patellofemoral bone morphology and limb alignment with no other ligamentous deficiencies	ST and G Distal insertion maintained. Two tunnels in the patella	no risk factors	MPFL reconstruction in 100%	Redislocation: none Returned to previous level of activity and were satisfied: 96.4% Kujala scores: 36.6–90.6 Lysholm scores: 51.9–89.5 VAS mean 6.3–1.8 Cincinnati scores: 50–88 Congruence angle: 11.93°–6.48° Patellar tilt: 10.9°–2.45° Persistent subjective instability: 6.9%
Hinckel et al. [18]	7	5.5 months	Recurrent patellar dislocation with: Subluxation in extension (lateral and proximal displacement of the patella) Instability in flexion (habitual dislocation or glide in flexion) Hyperextension of the knee with ligament laxity Open growth plate in association with predisposing factors (increased lateral quadriceps vector, patella alta and trochlear dysplasia)	Medial quadriceps for the MPFL and medial patellar tendon for the MPTL	Trochlear dysplasia: modified Dejour classification A (57.1%), B (14.3%), C (14.3%), and D (14.3%) Patella alta: CD > 1.2 (71.4%) Lateral quadriceps vector: TTTG > 20 mm (42.9%)	MPFL reconstruction in 100% Lateral retinaculum release in 42.9% Shortening of the patellar tendon in 14.3% Lengthening of the quadriceps tendon in 14.3%	Redislocation: none Satisfaction 9/10: 71.4% Satisfaction 10/10: 28.6% All would have surgery again Wound dehiscence: 14.3%
Results of the MPTL and MPFL reconstruction group: overall, across studies there was an important clinical improvement in various validated patient reported outcomes (PROs) such as IKDC, Kujala, Womac and Tegner and in subjective satisfaction. Overall, there were no redislocations. However, 1 study reported 6.9% of persistent subjective instability [39]. Overall, there were 15 complications (19.2%). Quadriceps atrophy in 11.5% ($n = 9$), arthrofibrosis in 1.3% ($n = 1$), effusion of the knee in 2.6% ($n = 2$), subjective instability complaints in 2.6% ($n = 2$), and wound deficiencies in 1.3% ($n = 1$)							

N number of knees evaluated, *ST* semitendinosus, *G* gracilis, *PT* patellar tendon, *MPTL* media patellotibial ligament, *MPFL* medial patellofemoral ligament, *nm* not mentioned, *TTTG* tibial tuberosity–trochlear groove distance, *recurrence* further lateral patellar dislocation episode, *TKA* total knee arthroplasty, *IS* Insall-Salvati, *IKDC* International Knee Committee Score, *TTO* tibial tuberosity osteotomy

18, 23, 25, 33]. More specific indications were reported in only one paper by Hinckel el al [18]. These indications were: subluxation in extension, instability in flexion, knee hyperextension with ligamentous laxity, and skeletal immaturity with associated risk factors.

From the MPTL reconstruction without the MPFL, most knees did not undergo other major procedures, 233 knees versus 92 with other major procedures. For MPTL reconstruction, all used autograft tissue: hamstrings (ST or G) (242 knees, 60.3%), medial patellar tendon (157 knees, 39%), or the iliotibial band (3 knees, 0.7%). One repair was described. In the surgical technique utilizing ST/G, the hamstring tibial insertion was preserved in 231 (95%). In the medial patellar tendon transfer techniques, an associated distal bone plug for tibial fixation was harvested in 83 (53%).

Of the 403 knees reported in this review, 328 of the knees reported on redislocation rates as an outcome; of which 11 redislocations were reported (3.4%). Overall, there were 11 redislocations (2.7%). Grannat et al. [14] did not report redislocation separately, but reported reoperation due to instability. These cases were likely severely unstable and were reported in this review as "redislocation equivalent". Redislocation and redislocation equivalent totaled 23 (6%). Although as mentioned it is not clear how many actual redislocations were present in Grannatt et al. [14], the 35% redislocation equivalent reported was much higher than the < 10% reported in all other studies. Redislocation in the MPTL without other major procedures group was 9 (3.8%) and 21 (8.9%), including the redislocation equivalent from Grannatt et al., versus 3 (1.8%) with other major procedures or MPFL. Overall, there were 58 complications (14.4%). Most common complications other than redislocation were wound complications [3, 16, 18, 23], quadriceps atrophy [26], anterior pain [3, 26] and subjective instability complaints [3].

Semitendinosus tenodesis without other major procedures

A modified Galeazzi technique with bone tunnels was performed [2, 3, 14, 26, 30]. A variety of risk factors were present. Lateral retinaculum release and medial retinaculum plication were commonly performed. In addition, Aulisa et al. [2] reported adequate correction of patellar tilt and subluxation, and correction of patellar height without quadriceps contraction; in patients with patella alta, corrections were not maintained during quadriceps contraction.

Semitendinosus tenodesis with other major procedures

These cohorts consisted mostly of patients with risk factors and many highly unstable patients, including habitual dislocation. The major procedures were Roux–Goldthwait procedure, Insall's proximal realignment and Green procedure. All complications were related to wound problems/skin necrosis at the surgical site.

Medial transfer of the medial patellar tendon without other major procedures

Rillmann et al. utilized the medial portion of the patellar tendon with a bone block from the tibial tuberosity, while Myers et al. and Oliva et al. utilized only the patellar tendon. The presence of risk factors was variable or not mentioned. Rillman et al. performed very few associated procedures while Myers et al. and Oliva et al. performed a vastus medialis advancement and lateral retinaculum release in all knees as part of the "3-in-1 procedure".

Medial transfer of the medial patellar tendon with other major procedures

Risk factors were very common in these cohorts, and Marcacci et al. [29] had 100% of patients with patella alta and Zaffagnini et al. [41] > 95% of severe trochlea dysplasia (Types B, C, and D of Dejour). To correct these risk factors, Marcacci et al. performed major procedures in almost all knees (most common, was TTO), while Zaffagnini et al. performed them in approximately 25% of the cases (most common was trochleoplasty).

MPTL and MPFL reconstruction

Most studies used hamstrings autograft preserving the tibial attachment [5, 11, 39], and two had free ends fixed in the tibia [10, 18], one using hamstrings [10] and one using the medial patellar tendon [18]. Three techniques permit tensioning of the MPFL and MPTL to be independent [5, 10, 18] while two did not. Mostly, patients had no risk factors, although Ebied and El-Kholy performed TTO in 32% to correct a large quadriceps vector [11]. In addition, in Hinckel et al. cohort, high-grade dysplasia was present in 43%, patella alta in 71% of patients and large quadriceps vector in 43%. Specific correction to address the risk factor was performed in only 14% (one patient) by shortening of the patellar tendon due to restrictions by open physis in most patients.

Description and details of the surgical techniques are abridged in the Appendix.

Quality assessment

The results of the CMS are systematized in Table 2. There was a large range of CMS values, 30–91, and the mean was 64.1. Many studies had small study sizes, short follow-ups,

Table 2 Results of Coleman Methodology Score

References	Study size	Follow-up	*N* procedures	Type of study	Diagnostic certainty	Description of surgical technique	Rehabilitation and compliance	Outcome criteria	Outcome assessment	Selection process	Total
Baker et al. [3]	7	5	10	0	0	5	10	4	0	13	52
Hall, et al. [16]	4	5	7	0	5	5	10	10	0	13	59
Rillman, et al. [37]	7	5	7	0	5	5	10	10	0	15	64
Myers, et al. [31]	7	5	10	0	0	5	10	10	6	15	68
Letts, et al. [26]	4	5	10	0	0	5	10	10	11	13	68
Drez, et al. [10]	0	5	10	0	5	5	10	10	6	13	67
Marcacci, et al. [29]	0	5	7	0	5	5	10	10	6	15	63
Moyad, et al. [30]	0	0	10	0	5	5	0	0	0	10	30
Joo, et al. [23]	0	5	10	0	5	5	10	10	6	15	66
Brown and Ahmad [5]	0	2	10	0	5	5	0	10	6	0	38
Oliva, et al. [34]	4	5	10	10	5	5	10	10	11	15	85
Aulisa, et al. [2]	0	5	10	0	5	5	10	10	11	15	71
Grannatt, et al. [14]	4	5	7	0	5	5	10	10	6	13	65
Ebied and El-Kholy [11]	4	5	7	0	5	5	10	10	0	15	61
Kocon, et al. [25]	10	5	10	10	5	5	10	10	5	15	85
Sobhy, et al. [39]	10	5	10	10	5	5	10	10	11	15	75
Zaffagnini, et al. [41]	4	5	7	0	5	5	10	10	6	15	67
Niedzielski, et al. [33]	0	5	10	0	5	3	10	10	6	15	64
Hinckel, et al. [18]	0	0	10	10	5	5	10	10	5	15	70
Maximum Score Possible	10	5	10	15	5	5	10	10	15	15	100
Mean ± Standard Deviation	3.42 ± 3.50	4.32 ± 1.67	9.05 ± 1.43	2.11 ± 4.19	4.21 ± 1.87	4.89 ± 0.46	8.95 ± 3.15	9.16 ± 2.61	5.37 ± 3.90	13.42 ± 3.52	64.11 ± 13.24

unclear outcome criteria and assessments, and poor patient selection processes, and were retrospective. Therefore, scores were particular low across studies in the CMS criterion of study size, type of study, and outcome assessment. There was no statistically significant difference between subgroups (Table 3).

Table 3 Results of Coleman Methodology Score comparison between groups

Surgical technique	*N*	Mean CMS ± standard deviation	Range
Tenodesis without other major procedures	5	57.2 ± 16.84	30–71
Tenodesis with other major procedures	4	68.5 ± 11.39	59–85
Medial transfer of the medial patellar tendon without other major procedures	3	72.33 ± 11.15	64–85
Medial transfer of the medial patellar tendon with other major procedures	2	65 ± 2.83	63–67
MPTL and MPFL reconstruction	5	62.2 ± 14.45	38–75

MPFL media patellofemoral ligament, *MPTL* medial patellotibial ligament, *n* number of papers, *CMS* Coleman Methodology Score

Discussion

The most important findings were that a considerable number of articles ($N = 19$) with a substantial number of knees ($N = 403$) reported favorable outcomes with low rates of redislocation associated with the reconstruction of the MPTL. Quality of the articles is variable, from low to high.

The introduction of MPFL reconstruction has resulted in a shift from the reconstruction of the MPTL to the MPFL, due to its favorable biomechanics in resisting lateral translational restraint near extension [8, 9, 17, 35]. However, with a 12% persistence of objective or subjective instability [38] after isolated MPFL reconstruction, interest in the MPTL as an augmentation has grown. Anatomical, histological, and biomechanical studies have shown that the MPTL is a proper ligament, with biomechanical characteristics (load to failure and stiffness) that can be advantageous to the patellofemoral tracking and stability [20, 24, 36]. By providing this additional ligamentous support in carefully selected patients, combined reconstruction of the MPTL and MPFL can potentially improve outcomes relative to isolated MPFL reconstructions [5, 10, 11, 13, 18, 39]. In addition, this combination may reduce surgical morbidity by decreasing the need for additional bony procedures, thereby defining a different surgical threshold for when to add a TTO or a trochleoplasty [21]. This systematic review summarizes the clinical evidence of the MPTL reconstruction in isolation or in combination with other minor or major procedures, and/or the MPFL. Acknowledging the benefits and complications from the MPTL reconstruction may help the surgeon decide if it is worthy to consider the addition of the procedure to current patellar instability algorithms.

Even though no meta-analysis could be made, we conclude that, in general, good clinical outcomes were achieved. This is supported by the low rate of redislocations (mostly < 10%), similar to redislocations reported after isolated MPFL reconstructions surgeries [4, 6, 22, 28, 42]. When analyzing redislocations, it is important to recognize that three studies did not adequately report them [2, 11, 14]. In addition, good and excellent outcomes were achieved in > 75% of cohorts in most studies. In the papers that reported the presence of risk factors or factors associated with worse outcomes, their presence did not seem to negatively affect clinical outcomes. Frequently, patients with risk factors had additional procedures such as trochleoplasty, TTO, Roux–Goldthwait, or MPFL reconstruction [16, 18, 23, 25, 29, 33, 41]. However, in some cohorts, the MPTL reconstruction was in essence isolated and nothing but minor procedures were added [26, 37]. Therefore, the presence of risk factors is seemingly not a contraindication to the procedure. The study from Grannatt et al., which included 34 knees, has worse outcomes than the other studies collectively [14]. Considering the study from Grannatt et al. had far worse outcomes, results and complications should be analyzed with this consideration in mind [14]. Other than redislocations, there were few complications reported. Of these, two of the studies that reported wound complications, in about 30% of the patients each, had a population of habitual dislocations and other major procedures were performed [16, 23]. Therefore, wound problems should be related to extensive exposure and releases. As such, they should be avoided when possible. Other concerning complications that could be associated with the increase in the medial and distal restriction by the MPTL, such as patella baja and arthritis, were rare. The slightly higher rate of complications in the MPTL and MPFL reconstruction could be a result of the combination of procedures, but may also be just a reflect of better reporting characteristic of more recent studies.

In aggregate, this is encouraging information and the authors believe that the MPTL reconstruction can be added to current patellar instability algorithms with low risk of additional morbidity. However, it should not be included as a standard procedure for all patellar instability patients, neither substitute MPFL reconstruction, owing to the fact that many patients do well with isolated MPFL reconstruction [4, 6, 22, 28, 42]. In addition, the addition of a MPTL reconstruction might decrease the need for bony procedures, such as TTO in patients with borderline patella alta/lateralized force vector or trochleoplasty in patients with moderate dysplasia. However, bony procedures will likely continue to have an important role in correcting more severe malalignment and

maltracking. Due to lack of randomized control trial or comparative studies, and scarce study of specific conditions or situations associated with patellar stability that would benefit from the procedure, we are unable to define the ideal indications for MPTL reconstruction from the clinical data reviewed. Nonetheless, the authors believe that the indications suggested by Hinckel et al. [18, 19] (subluxation in extension, instability in flexion, knee hyperextension with ligamentous laxity, and skeletal immaturity with associated risk factors) are supported by some clinical data as well as anatomical and biomechanical studies, and can be used with caution until stronger clinical evidence is available.

In this literature review, many different techniques were found. Nevertheless, they are fundamentally variations in graft choice, harvesting, and fixation. There are two major graft options (hamstrings, ST and/or G; and the medial patellar tendon). The hamstrings can be used as a free graft or the tibial attachment can be maintained. With the medial patellar tendon, the patellar attachment is preserved and the distal portion can be detached as soft tissue only or with a bone plug. It is important to acknowledge that hamstrings insertion (distal to proximal tibial growth plate; 41 ± 6.6 mm distal from the joint line and 6.88 ± 1 mm medial to the patellar tendon [15]) is more distal and more midline than the MPTL insertion (≈ 13 mm distal to joint line and ≈ 12 mm medial to patellar tendon [20, 24]) leading to a non-anatomic reconstruction. In addition, in children, the graft should be fixed on the proximal epiphysis of the tibia, so tension can be maintained during growth; this agrees with MPFL surgical principles of fixation distal to the femoral growth plate [21, 32]. For the patellar tendon, the preserved patellar attachment coincides with the MPTL insertion [20, 21, 24]. When concomitant to the MPFL, techniques that permit independent fixation [5, 10, 18, 39] are advantageous. Since, for the MPFL is better to tension it and secure it between 20° and 45° of flexion, while for the MPTL is better to tension it and secure fixation in greater degrees of flexion (close to 90°) to preserve its biomechanical function [36, 40]. Drilling of patellar tunnels can potentially result in patellar fracture, but that complication was not reported. Even though there are advantages and disadvantages with the different techniques, results were consistent and any of them can be used accordingly to surgeon's preference.

The Coleman score demonstrated that, on average, the studies had moderate quality. In addition, it can be noted that focusing on enlarging samples, utilizing prospective and randomized studies, and employing validated PROs in future studies will improve the most common deficiencies seen. These improvements will aid in determining for which subgroup of patients with patellar instability the MPTL reconstruction should be indicated.

The greatest limitation of this systematic review is the quality of the studies reported. There are no randomized control trials versus non-operative treatment neither comparing different operative treatments or different subgroup of patients. Furthermore, many studies are dated and, therefore, currently used PROs were not often reported. Due to heterogeneity and small size of cohorts, lack of randomized trials, and lack of common PROs among studies, it was not possible to perform a meta-analyzes. The clinical significance of this review is to present the clinical outcomes and complications of the MPTL reconstruction, so that surgeons can appropriately include the procedure in surgical armamentarium of treatment for recurrent patella instability.

Conclusions

Published literature on MPTL reconstruction suggests that it leads to favorable clinical outcomes with minimal morbidity, which supports this as a valid surgical technique for lateral patellar dislocations and that there is a role for MPTL reconstructions in surgical patellar stabilization techniques.

Author contributions CAB certifies that he had no conflicts of interest related to this study. ELP certifies that he had no conflicts of interest related to this study. SLS certifies that he had no conflicts of interest directly related to this study (see declaration of disclosure form for indirect activities outside the submitted work). EAA certifies that she had no conflicts of interest directly related to this study (see declaration of disclosure form for indirect activities outside the submitted work). BBH certifies that she had no conflicts of interest related to this study.

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Compliance with ethical standards

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