Isolated medial patellofemoral ligament reconstruction for recurrent patellofemoral instability: analysis of outcomes and risk factors

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Abstract

Background: The medial patellofemoral ligament (MPFL) is always damaged after patellar dislocation. In selected patients, MPFL reconstruction is necessary to restore a correct patellar tracking. Despite the large number of different techniques reported to reconstruct the MPFL, there is no consensus concerning the optimal procedure, and debates is still ongoing. The present study analysed the results after isolated MPFL reconstruction in patients with patellofemoral instability. Furthermore, a subgroup analysis of patients presenting pathoanatomical risk factors was made.

Methods: In November 2020, the main electronic databases were accessed. All articles reporting the results of primary isolated MPFL reconstruction for recurrent patellofemoral instability were considered for inclusion. Only articles reporting a minimum 12-month follow-up were eligible.

Results: Data from a total of 1777 knees were collected. The mean age of the patients involved was 22.8 ± 3.4 years. The mean follow-up was 40.7 ± 25.8 months. Overall, the range of motion (+ 27.74; P < 0.0001) and all the other scores of interests improved at last follow-up: Kujala (+ 12.76; P = 0.0003), Lysholm (+ 15.69; P < 0.0001), Tegner score (+ 2.86; P = 0.006). Seventy-three of 1780 patients (4.1%) showed a positive apprehension test. Thirty of 1765 patients (1.7%) experienced re-dislocations, while 56 of 1778 patients (3.2%) showed persisting joint instability. Twenty-five of 1786 patients (1.4%) underwent revision surgeries.

Conclusion: Isolated MPFL reconstruction for recurrent patellofemoral instability provides reliable surgical outcomes. Patients with pathoanatomical predisposing factors reported worse surgical outcomes.

Keywords: Patellofemoral instability, MPFL reconstruction, Risk factors

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Introduction
Recurrent patellofemoral instability is common, accounting for approximately one-third of all knee injuries in sports medicine [1, 2]. Patients suffering from recurrent patellofemoral instability frequently present underlying pathoanatomical abnormalities which predispose them to patellar dislocation [3, 4]. These alterations incorporate bony conformation abnormalities including trochlear dysplasia [5], lower limb mal-alignment syndromes such as tibial extra-rotation [6] and soft tissue abnormalities such as patella alta [7]. Most patients present with a combination of two or more concomitant pathoanatomical risk factors [8, 9]. Given its multifactorial aetiology, the management of recurrent patellofemoral instability can be challenging [10–12]. In non-surgical treatment, most patients experience recurrent patella dislocations, pain and instability in the affected knee [13, 14], leading to a lower level of activity and reduced quality of daily living [15]. Hence, surgical reconstruction of the medial patellofemoral ligament (MPFL) represents a feasible option in those patients [9, 16, 17]. MPFL reconstruction shows an appreciable improvement in quality of life and recreational participation [18, 19]. As a result of the highly promising outcomes recorded, an isolated MPFL reconstruction can be performed even in patients presenting with low- to moderate-grade pathoanatomical alteration, avoiding bony interventions [20–22]. The number of different procedures described to reconstruct the MPFL in these patients is increasing exponentially, and assessment of these options has become a point of considerable research interest [23, 24]. However, there has been no consensus concerning results, and debates are still ongoing [25–27].

Thus, we conducted a systematic review of the literature to analyse results after isolated MPFL reconstruction in patients with recurrent patellofemoral instability. Furthermore, we performed subgroup analyses of patients presenting pathoanatomical risk factors. The focus of the present systematic review was on clinical scores and examinations, rate of revision surgeries, re-dislocations and persistent joint instability. We hypothesised that this procedure provides reliable surgical outcomes and that patients with predisposing risk factors are more prone to complications.

Materials and methods
Search strategy
A comprehensive review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) [28]. To guide the search, a preliminary protocol was defined:

- Outcomes: clinical scores, physical examination, complications;
- Timing: > 24 months follow-up.

Literature search
Two independent reviewers (**;**) performed the search separately. The following electronic databases were accessed: PubMed, Medline, Embase and Google Scholar. In November 2020, the following terms were used in combination: knee, patellofemoral, dislocation, recurrent, instability, medial patellofemoral ligament, MPFL, tear, rupture, surgery, reconstruction, TT-TG, trochlear, dysplasia, patella alta, apprehension test, Kujala, Lysholm, Tegner, re-dislocation, failure, reoperation, revision, subluxation. If title and abstract matched the topic, the full-text was accessed. Furthermore, a cross reference of bibliographies was performed to improve the studies for inclusion. Disagreements between the authors were debated and solved by a third author (**).

Eligibility criteria
All the articles treating primary isolated MPFL reconstruction for recurrent patellofemoral instability were considered for inclusion. According to the authors’ capabilities, articles published in English, French, German, Italian or Spanish were considered. Articles with level of evidence I to IV, according to the Oxford Centre of Evidence Based Medicine [28], were considered. Technical articles, comments, letters, editorials, protocols, guidelines and review articles were excluded. Biomechanical, animal and cadaveric studies were also excluded. Studies on MPFL reconstruction after total knee arthroplasty were excluded, as were articles reporting surgical outcomes regarding combined interventions were also rejected. Articles reporting MPFL rupture with direct suture, ligament plastic or medial retinaculum reefing were excluded. Articles treating MPFL reconstruction in a revision setting were also excluded, along with those treating acute injuries. Only articles reporting a minimum of 12-month follow-up were included. Only articles that reported quantitative data concerning the outcomes of interest were included. Missing data pertinent to these parameters warranted exclusion from this systematic review. The same investigators screened the articles for inclusion. A cross-reference research of the selected articles was performed to identify any article omitted from the initial search.

Outcomes of interest
Two investigators (**;**) extracted the following data independently: patient demographics (author and year, number of procedures, mean age at time of surgery); mean follow-up duration; type of study. Patients clinical status has been evaluated through the analysis of three
scores: the Kujala Anterior Knee Pain Scale [29], the Lysholm Knee Scoring Scale [30] and the Tegner Scale [31]. Range of motion (ROM) was also analysed. Postoperative complications were recorded for each publication: apprehension test, revision surgeries, re-dislocations and persistent joint instability. The latter was defined as recurrence and/or subjective sensation of subluxation or instability [32]. Furthermore, the presence of abnormal tibial tuberosity-trochlea groove distance (TT-TG) of patellar height and trochlear dysplasia was recorded.

Methodological quality assessment
For the methodological quality assessment, we used the PEDro score. Two authors independently (**;**) performed the score calculation. The PEDro score analyses each included article under several items: allocation, presence of randomisation or blinding methods, clear inclusion and exclusion criteria, duration of follow-up and type of analysis. The final score ranks from 0 (poor quality) to 10 (excellent quality). Values > 6 points are considered as acceptable.

Statistical analysis
The statistical analysis was performed through the software IBM SPSS. For continuous variables, the weighted mean differences and the standard deviation (SD) between groups were adopted. For binary variables, the odd ratio (OR) effect measure was used. The confidence interval was set at 95% in all the comparisons. Values of \( P < 0.05 \) were considered statistically significant.

Results

Literature search
The literature search and cross-referencing resulted in a total of 1413 references, of which 411 were rejected because of duplications. Of these, another 930 were rejected or deviations from the eligibility criteria, leaving 77 publications for review. After reading the remaining full-text articles, another 17 articles were excluded, given insufficient details and/or uncertain diagnoses or outcome measures. Finally, 55 articles were included in the present analysis (Fig. 1).

Methodological quality assessment
The PEDro score evidenced several limitations. First, only 7% (4/55) of article were randomised studies. None of the included studies used any blinding. Strength points were the number of prospective studies and the length of follow-up provided by most studies. In total, the PEDro score resulted in 6.38 ± 1.0 points, attesting to the quality of this systematic review. The results of the PEDro score assigned to each study are shown in Table 1.

Demographic data
Data from a total of 1777 knees were collected. The mean age of the patients was 22.8 ± 3.4 years. The mean follow-up was 40.7 ± 25.8 months. Twenty-three of 55 articles (42%) reported data of patients with imaging evidence of trochlear dysplasia, 7 of 55 (13%) with elevated TT-TG and 15 of 55 (27%) with patella alta. Further, 33.8% (606 of 1795) of procedures were performed using a single bundle patellar graft insertion, while 66.2% though a double bundle. Patellar fixation was achieved through a bone tunnel in 44.5% (837 of 1884) of procedures, suture anchors in 30.8% (581 of 1884), soft tissue procedures 10.9% (205 of 1884), suture 23.6% (69 of 1884), Endobutton 3.2% (60 of 1884), quadriceps tendon pedicle 2.9% (55 of 1884), staple 2.4% (46 of 1884) and patellar tendon pedicle 1.6% (31 of 1884). Femoral fixation was achieved through interference screw 83.6% (1492 of 1874), anchors 4.5% (80 of 1874), staple 9.2% (70 of 1874), soft tissue procedures 2.9% (52 of 1874), bone plug 1.7% (31 of 1874), adductor pedicle 1.7% (30 of 1874) and Endobutton 1.6% (29 of 1874). Semitendinosus was used in 37.0% (699 of 1884) of procedures, gracilis 30.5% (574 of 1884), synthetic 6.7% (127 of 1884), quadriceps 2.9% (55 of 1884), patellar 31% (1.6 of 1884) and adductor magnus 30% (1.6 of 1884). The demographic data of studies included are shown in Table 1.

Clinical findings
Overall, the ROM (+ 27.74; \( P < 0.0001 \)) and all the other scores of interests improved at the last follow-up: Kujala (+ 12.76; \( P = 0.0003 \)), Lysholm (+ 15.69; \( P < 0.0001 \)), Tegner score (+ 2.86; \( P = 0.006 \)). These results are shown in detail in Table 2.

Complications
Seventy-three of 1780 patients (4.1%) showed a positive apprehension test. Thirty of 1765 patients (1.7%) experienced re-dislocations, while 56 of 1778 patients (3.2%) showed persisting joint instability. Twenty-five of 1786 patients (1.4%) underwent further revision surgeries.

Subgroup analyses
The presence of pathoanatomical risk factors do not influence the Kujala, Lysholm and Tegner scores, as did the rate of positiveness to the apprehension test (Table 3). Studies treating patients within the normal range of TT-TG distance reported a lower rate of revision surgeries (OR: 0.09; 95% CI: 0.0302 to 0.2943; \( P < 0.0001 \)), re-dislocations (OR: 0.2; 95% CI: 0.0754 to 0.3669; \( P < 0.0001 \)) and persistent joint instability (OR: 0.3; 95% CI: 0.1660 to 0.5886; \( P = 0.0003 \)) compared to those treating patients with an increased TT-TG. Studies treating patients with patella height within the normal range reported a lower rate of revision surgeries (OR: 0.8; 95% CI: 0.1495 to 1.6667; \( P = 0.04 \)), re-dislocations (OR: 0.2; 95% CI: 0.0514 to 0.6044; \( P = 0.006 \)) and persistent joint instability (OR: 0.2; 95% CI: 0.0929 to 0.4825; \( P = 0.0002 \)) compared to
those treating patients with signs of patella alta. Studies treating patients with trochlear morphology within the normal anatomic range reported a lower rate of revision surgeries (OR: 0.2; 95% CI: 0.0536 to 0.6541; \( P = 0.009 \)), re-dislocations (OR: 0.2; 95% CI: 0.0503 to 0.4216; \( P = 0.0004 \)) and persistent joint instability (OR: 0.2; 95% CI: 0.0832 to 0.3860; \( P < 0.0001 \)) compared to those treating patients with of trochlear dysplasia. These results are shown in detail in Table 4.

Discussion

The present study assessed the outcome of isolated MPFL reconstruction in selected patients with patellar instability. Isolated MPFL reconstruction for recurrent patellofemoral instability provided very good outcomes, as witnessed by the Kujala, Lysholm and Tegner scores. Patients with patella alta, trochlear dysplasia and those with elevated of TT-TG distance showed an increased rate of revision surgeries, re-dislocations and persistent joint instability compared to those without the presence of pathoanatomical risk factors. Patients with elevated TT-TG distance are more prone to revision surgery.

The MPFL is the most important static restraint to the lateral displacement of the patella during the first 30° of flexion [76]. After the first patellar dislocation, the MPFL is always damaged [77, 78] and a ligament reconstruction is often required [12, 79]. Patients without imaging evidence of pathoanatomical risk factors are suitable for isolated MPFL reconstruction [80–83]. Patellar instability is a multifactorial condition [20, 84, 85]. Twenty-six percent of the patients had two, about 17% three and 15% four concomitant risk factors [86]. Other imaging studies detected similar observations [8, 9]. Thus, proper treatment consists of adequate analysis of the associated pathoanatomical risk factors prior to MPFL reconstruction [87]. The question worth discussing remains whether
### Table 1: Demographics of studies included and related PEDro score. (N/R: not reported; Semit: semitendinosus; Ham: hamstring; Synth: synthetic; Add: adductor; Quad: quadriceps)

| Author, year | Study design | Mean follow-up | PEDro score | Knees (n) | Mean age | Trochlear dysplasia | Patella Alta | Elevated TT-TG | Patellar bundle | Patellar fixation | Femoral fixation | Graft source |
|--------------|--------------|----------------|--------------|-----------|----------|---------------------|-------------|----------------|-----------------|----------------|----------------|--------------|
| Amin et al. 2015 [33] | Retrospective | 24 | 6 | 8 | 22.0 | N/R | N/R | N/R | Single | Bone tunnel | Interference screw | Semit |
| Astur et al. 2015 [34] | Randomised | 60 | 8 | 30 | 31.1 | No | No | No | Single | Single Endobutton | Interference screw | Gracilis |
| Ballal et al. 2018 [35] | Prospective | 12 | 7 | 20 | 24.4 | Yes | No | No | N/R | Suture anchor | Interference screw | Semit |
| Bondi Pinheiro et al. 2018 [36] | Retrospective | 31 | 7 | 16 | 27.1 | No | No | No | Single | Anchor | Interference screw | Semit |
| Btar et al. 2011 [36] | Randomised | 24 | 8 | 21 | N/R | N/R | N/R | N/R | Single | Patellar tendon pedicle | Interference screw | Patellar |
| Btar et al. 2015 [37] | Retrospective | 19 | 7 | 56 | 23.0 | N/R | N/R | N/R | Double | Anchor | Interference screw | Gracilis |
| Calapodopulos et al. 2016 [38] | Prospective | 30 | 5 | 22 | 23.1 | Yes | No | No | Single | Quad tendon pedicle | Anchor | Quad |
| Christiansen et al. 2008 [39] | Prospective | 22 | 6 | 32 | 22.0 | N/R | N/R | N/R | Double | Bone tunnel | Interference screw | Gracilis |
| Csintalan et al. 2014 [40] | Retrospective | 51 | 5 | 56 | 24.3 | Yes | Yes | N/R | Double | Bone tunnel | Interference screw | Semit |
| Deie et al. 2011 [41] | Retrospective | 39 | 5 | 31 | 22.2 | Yes | No | No | Double | Soft tissue | Bone plug | Semit |
| Feller et al. 2014 [42] | Retrospective | 42 | 5 | 26 | 24.4 | No | No | No | Double | Bone tunnel | Interference screw | Hamstring |
| Fink et al. 2014 [42] | Prospective | 12 | 7 | 17 | 21.5 | Yes | N/R | N/R | Double | Quad tendon pedicle | Interference screw | Quad |
| Gomes et al. 1992 [43] | Retrospective | 39 | 5 | 30 | 28.0 | N/R | N/R | N/R | Single | Bone tunnel | Interference screw | Synth |
| Gomes et al. 2004 [44] | Prospective | 60 | 6 | 16 | 26.7 | Yes | Yes | No | Single | Bone tunnel | Soft tissue | Semit |
| Gomes et al. 2008 [45] | Prospective | 53 | 7 | 12 | 19.3 | N/R | Yes | N/R | Single | Bone tunnel | Soft tissue | Semit |
| Goncaives et al. 2011 [46] | Prospective | 26 | 6 | 22 | 28.6 | No | No | No | Double | Bone tunnel | Interference screw | Semit |
| Han et al. 2011 [47] | Retrospective | 68 | 6 | 59 | 24.3 | No | Yes | No | Single | Bone tunnel | Interference screw | Semit |
| Hiemstra et al. 2017 [48] | Retrospective | 24 | 5 | 155 | 25.4 | Yes | Yes | Yes | Single | Suture anchor | Interference screw | Patellar |
| Hinterwimmer et al. 2013 [49] | Retrospective | 16 | 6 | 19 | 23.0 | Yes | N/R | N/R | Double | Bone tunnel | Interference screw | Gracilis |
| Kang et al. 2013 [50] | Randomised | 24 | 8 | 82 | 28.8 | No | No | No | Double | Soft tissue | Interference screw | Semit |
| Kim et al. 2015 [51] | Retrospective | 19 | 6 | 9 | 24.6 | Yes | No | No | Mixed | Soft tissue | Suture anchor | Gracilis |
| Kita et al. 2015 [52] | Prospective | 39 | 7 | 44 | 25.4 | Yes | Yes | Yes | Double | Bone tunnel | Interference screw | Semit |
| Krishna Kumar et al. 2014 [53] | Prospective | 25 | 7 | 30 | 18.0 | No | N/R | N/R | Double | Endobutton | Interference screw | Gracilis |
| Li et al. 2014 [54] | Prospective | 79 | 7 | 65 | 29.4 | Yes | N/R | N/R | Double | Soft tissue | Interference screw | Tibialis Ant |
| Lind et al. 2016 [55] | Prospective | 39 | 8 | 24 | 12.5 | Yes | N/R | Yes | Double | Bone tunnel | Soft tissue | Gracilis |
| Author, year | Study design | Mean follow-up | PEDro score | Knees (n) | Mean age | Trochlear dysplasia | Patella Alta | Elevated TT-TG | Patellar bundle | Patellar fixation | Femoral fixation | Graft source |
|-------------|-------------|---------------|-------------|-----------|----------|---------------------|--------------|----------------|----------------|----------------|----------------|--------------|
| Lin et al. 2015 [56] | Retrospective | 35 | 5 | 18 | N/R | Yes | No | Double | Bone tunnel | Interference screw | Semit |
| Lippacher et al. 2014 [57] | Retrospective | 25 | 7 | 68 | 18.3 | Yes | Yes | No | Double | Bone tunnel | Interference screw | Gracilis |
| Ma et al. 2013 [58] | Randomised | 40 | 8 | 32 | 28.4 | No | N/R | Yes | Double | Anchor | Interference screw | Semit |
| Matsushita et al. 2014 [26] | Retrospective | 44 | 6 | 21 | 22.1 | N/R | No | Yes | Double | Anchor | Interference screw | Semit |
| Nomura et al. 2000 [59] | Prospective | 71 | 7 | 27 | 21.0 | No | Yes | No | Single | Bone tunnel | Interference screw | Synth |
| Nomura et al. 2007 [60] | Retrospective | 143 | 5 | 24 | 22.5 | Yes | Yes | No | Single | Bone tunnel | Interference screw | Synth |
| Panni et al. 2011 [61] | Retrospective | 33 | 5 | 48 | 25.0 | No | No | No | Double | Bone tunnel | Interference screw or anchor | Semit |
| Raghuveer et al. 2012 [62] | Prospective | 42 | 7 | 15 | 29.2 | No | No | No | Single | Bone tunnel | Interference screw or anchor | Semit |
| Ronga et al. 2009 [63] | Prospective | 37 | 5 | 37 | 28.0 | No | No | No | Double | Bone tunnel | Interference screw or anchor | Hamstring |
| Sadigursky et al. 2016 [64] | Prospective | 12 | 7 | 31 | 29.4 | Yes | Yes | No | Double | Anchor | Interference screw | Semit |
| Sillanpaa et al. 2008 [65] | Retrospective | 121 | 6 | 18 | 20.2 | Yes | Yes | Yes | Single | Soft tissue | Adductor pedicle | Add Magnus |
| Slenker et al. 2013 [66] | Retrospective | 21 | 6 | 35 | 20.6 | N/R | N/R | N/R | Single | Bone tunnel | Interference screw | Hamstring |
| Smith et al. 2014 [67] | Retrospective | 12 | 6 | 21 | 23.0 | No | N/R | N/R | Double | Bone tunnel | Interference screw | Hamstring |
| Suganuma et al. 2016 [68] | Retrospective | 52 | 6 | 18 | 20.7 | No | No | No | Double | Spike staple | Spike staple | Synth |
| Thaunat et al. 2007 [69] | Retrospective | 28 | 5 | 23 | 22.0 | Yes | Yes | No | Double | Bone tunnel | Suture anchor | Gracilis |
| Vaiville et al. 2016 [70] | Retrospective | 38 | 5 | 16 | 22.0 | Yes | No | No | Single | Quad tendon pedicle | Suture anchor | Quad |
| Wagner et al. 2013 [22] | Prospective | 12 | 6 | 50 | 19.0 | Yes | Yes | Yes | N/R | Suture anchor | Interference screw | Gracilis |
| Wang et al. 2010 [71] | Retrospective | 42 | 7 | 28 | 29.0 | Yes | No | No | Single | Suture | Interference screw | Semit |
| Wang et al. 2016 [72] | Retrospective | 38 | 6 | 26 | 26.3 | Yes | No | No | Single | Suture | Interference screw | Semit |
| Wantabe et al. 2017 [73] | Retrospective | 52 | 7 | 29 | 19.0 | N/R | N/R | N/R | Double | Suture anchor | Interference screw | Gracilis |
| Wrotoski et al. 2013 [74] | Prospective | 43 | 7 | 10 | 27.2 | No | No | No | Double | Suture anchor | Endobutton | Hamstring |
| Zhang et al. 2019 [75] | Prospective | 96 | 7 | 60 | 21.0 | No | No | No | N/R | Patellar tendon pedicle | Suture anchor | Patellar |
isolated MPFL reconstruction alone or combined with other procedures are needed to restore optimal biomech-
anics and patellar tracking [20]. Regarding preoperative
planning of such procedures, no clear or detailed rec-
ommendations have been established. Each patient
must be evaluated individually and the decision to
combine reconstruction of the MPFL with another
procedure still depends on the clinical judgement of
the treating orthopaedic surgeon.

Patients presenting with high-grade of pathoanatomical
risk factors are likely suitable for combined interventions.
Combining different interventions aiming to stabilise the
tensor mechanism most probably prevents further
complications such as soft tissue damage or long-term
degenerative joint disease such as osteoarthritis, while also
improving quality of life and activity level [84, 88]. In the
present study, the outcomes of studies reporting the
results of MPFL reconstruction in patients presenting
pathoanatomical risk factors were also compared.

Analysing data from studies reporting MPFL recon-
struction in patients with low-grade trochlear dysplasia
showed no evidence of a statistically significant associ-
ation with clinical scores or clinical examination, but
nevertheless represent an increased risk to incur revision
surgeries, re-dislocations and persistent joint instability.
The most common intervention to restore roughly
correct patellar tracking are an opening wedge osteot-
omy according to Albee [89] and the sulcus deepening
trochleoplasty [90]. These procedures are associated with
controversial outcomes, and performing opening wedge
osteotomies must be considered with caution [91, 92].
Evidence concerning sulcus-deepening trochleoplasty is
limited [93–95]. Wagner et al. [22] found worse results
with isolated MPFL reconstruction in patients with severe
trochlear dysplasia. Steiner et al. [96] performed
an isolated MPFL reconstruction in patients with low- to
severe-grade of trochlear dysplasia, and reported no dis-
location at a minimum of 24-month follow-up. Recently,
Kohn et al. [97] analysed the outcomes of isolated MPFL
reconstruction in patients with high-grade trochlear
dysplasia. The degree of trochlear dysplasia which might
require an isolated MPFL reconstruction only remains
unclear [97].

Studies including patients with a low grade of
increased TT-TG and patella alta showed no difference
in the clinical scores and clinical examination, but a
moderate risk of subsequent re-dislocations and persist-
ent joint instability. Interestingly, the analysis of the rate
of revision surgeries was high in the elevated TT-TG but
low in the patella alta group. These data require further
investigations.

To evaluate patella alta, the most common indexes are
the Caton-Deschamps [98] and/or the Install-Salvati

| Table 2 Analyses of the endpoint: clinical scores |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Endpoint**    | **Pre-operative** | **Post-operative** | **Improvement** | **P** |
| Kujala          | 75.54 ± 9.7 (67.3 to 81.8) | 88.30 ± 5.9 (97.7 to 71) | 12.76 | 0.0003 |
| Lysholm         | 74.41 ± 9.6 (59.1 to 80.4) | 90.10 ± 4.0 (96.4 to 79.7) | 15.69 | > 0.0001 |
| Tegner          | 2.43 ± 2.2 (1.1 to 3.9) | 5.29 ± 1.0 (7.82 to 4) | 2.96 | 0.006 |
| Rom             | 105.31 ± 25.3 (94.6 to 118.1) | 133.05 ± 9.0 (141.3 to 125.9) | 27.74 | > 0.0001 |

| Table 3 Subgroup analyses of the endpoint: clinical scores |
|-----------------|-----------------|-----------------|-----------------|
| **Endpoint**    | **Normal range** | **Abnormal range** | **P** |
| Physiological TT-TG | 87.95 ± 5.9 | 85.32 ± 8.4 | 0.2 |
| Kujala          | 88.59 ± 3.9 | 86.92 ± 4.1 | 0.3 |
| Lysholm         | 5.58 ± 1.1 | 4.50 ± 0.7 | 0.1 |
| Tegner          | 88.36 ± 5.8 | 88.12 ± 5.7 | 0.9 |
| Physiological patellar height | 88.87 ± 3.6 | 85.67 ± 8.4 | 0.4 |
| Kujala          | 5.82 ± 1.3 | 4.88 ± 1.1 | 0.3 |
| Lysholm         | 91.64 ± 4.0 | 88.38 ± 3.9 | 0.2 |
| Tegner          | 4.83 ± 1.1 | 5.51 ± 1.0 | 0.2 |

| Table 4 Subgroup analyses of the endpoint: complications |
|-----------------|-----------------|-----------------|-----------------|
| **Endpoint**    | **Odd Ratio** | **95% CI** | **P** |
| Physiological TT-TG | 0.9 | 0.6874 to 1.0002 | 0.8 |
| Apprehension    | 0.3 | 0.1660 to 0.5886 | 0.0003 |
| Joint instability | 0.2 | 0.0754 to 0.3669 | < 0.0001 |
| Re-dislocations | 0.09 | 0.0302 to 0.2943 | < 0.0001 |
| Revision surgeries | 0.8 | 0.7465 to 1.0432 | 0.9 |
| Physiological patellar height | 0.2 | 0.0929 to 0.4825 | 0.0002 |
| Apprehension    | 0.2 | 0.0514 to 0.6044 | 0.006 |
| Joint instability | 0.8 | 0.1495 to 1.6667 | 0.04 |
| Re-dislocations | 0.2 | 0.0536 to 0.6541 | 0.009 |
| Revision surgeries | 0.9 | 0.5230 to 1.1039 | 0.8 |

Studies including patients with a low grade of
increased TT-TG and patella alta showed no difference
in the clinical scores and clinical examination, but a
moderate risk of subsequent re-dislocations and persist-
ent joint instability. Interestingly, the analysis of the rate
of revision surgeries was high in the elevated TT-TG but
low in the patella alta group. These data require further
investigations.
ratio [99], while a suitable method to rate the trochlear dysplasia is the classification of Dejour et al. [100]. The TT-TG distance is used to investigate the tibial extra-rotation over the femoral axis [21]. These pathoanatomical risk factors with related rating index were not quantitatively evaluated by most of the included studies. Most of studies referred to low- to severe-grade of alteration, without proper data quantification. Therefore, these pathoanatomical risk factors could not be analysed in a quantitative fashion. This represents an important limitation of this study. The poor quality of most of the articles included constitutes another notable limitation. Lack of high-quality comparative trials is prevalent, therefore significantly reducing the overall evidence and opportunity to conduct a high-quality review. Surgical protocols for MPFL reconstruction and post-operative rehabilitation were not considered in the present investigation. The latter were heterogeneous throughout all the included studies. This therefore represents a potential source of bias. Indeed, approach, procedures and grafts were heterogeneous, as were the rehabilitation protocols. Given these limitations, data from the present study must be interpreted with caution. Points of strength of this systematic review are the comprehensive nature of the literature search along with the strict eligibility criteria. The methodological assessment resulted in a good quality assessment, and the baseline of samples was comparable, representing another strength point. Most studies reporting data from patients with additional previous surgeries did not clarify the nature of the interventions. Therefore, further considerations were not possible. Future studies should be aimed to clarify the role of other important risk factors, such as genu valgum, patellar dysplasia and femoral anteversion.

Conclusion
Isolated MPFL reconstruction for recurrent patellofemoral instability provides reliable surgical outcomes. Patients with low-grade patella alta, trochlear dysplasia and those with slight elevated of TT-TG distance showed an increased rate of revision surgeries, re-dislocations and persistent joint instability compared to those in whom pathoanatomical risk factors are not present.

Abbreviations
MPFL: Medial patellofemoral ligament; ROM: Range of motion; TT-TG: Tibial tuberosity-trochlea groove distance; SD: Standard deviation; OR: Odd ratio; N/R: Not reported; Semit: Semitendinosus; Ham: Hamstring; Synth: Synthetic; Add: Adductor; Quad: Quadriceps

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Authors’ contributions
FM: literature search, data extraction, methodological quality assessment, statistical analysis manuscript draft; FO: supervision; GDM: supervision and approval; AT: manuscript draft; editing; JE: supervision and approval; MT: supervision and approval; NF: literature search, data extraction, methodological quality assessment, statistical, manuscript draft, final approval. All authors read and approved the final manuscript.

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This article does not contain any studies with human participants or animals performed by any of the authors.

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Competing interests
The authors declare that they have no competing interest.

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