# Does Tibial Tuberosity Osteotomy Improve Outcomes When Combined With Medial Patellofemoral Ligament Reconstruction in the Presence of Increased Tibial Tuberosity–Trochlear Groove Distance?

## A Systematic Review and Meta-analysis

Borna Guevel,*† MA, MB BChir, MRCS, MPH, Abdoulie Njai,*† MD, MPH, Aly Raboff,† MD, MPH, Andrew Hillman,† MD, MPH, Michael Barton,† MD, MPH, and Mininder S. Kocher,*‡§ MD, MPH
*Investigation performed at Boston Children's Hospital, Boston, Massachusetts, USA*

**Background:** There has been recent debate regarding the optimal surgical management strategy for recurrent patellofemoral instability in the presence of an increased tibial tuberosity–trochlear groove (TT-TG) distance. In particular, performing a combined tibial tuberosity osteotomy (TTO) and medial patellofemoral ligament reconstruction (MPFLR) for patients with a TT-TG >20 mm has been questioned, with the hypothesis that an isolated MPFLR (iMPFLR) would be just as effective.

**Purpose:** To pool and compare outcomes after MPFLR + TTO versus iMPFLR in patients with a TT-TG >20 mm.

**Study Design:** Systematic review; Level of evidence, 4.

**Methods:** PubMed-MEDLINE, Embase, Web of Science, and Cochrane Central were searched, and a systematic review was performed. Included were studies that reported postoperative redislocation rates and/or functional outcome scores for patients with recurrent patellar instability and a TT-TG >20 mm who underwent either MPFLR + TTO or iMPFLR and had minimum 2-year follow-up data. Methodologic quality was assessed using the modified Coleman Methodology Score (mCMS). A proportional meta-analysis comparing redislocation, subjective instability, and total complication rates was performed, and mean postoperative functional outcome scores were pooled using a random-effects model with a restricted maximum likelihood estimator.

**Results:** In total, 1548 studies were screened, from which 13 were included for analysis. Of the 386 included patients (406 knees), 276 underwent MPFLR + TTO and 110 underwent iMPFLR. The mean mCMS was 61.3 ± 10.5 (range, 48-77). The pooled postoperative redislocation rate was 1.22% (95% CI, 0.22%-7%), with no significant difference between the study groups ($P$ = .9995). The pooled complication rate was 10.17% (95% CI, 6.2%-16.3%) with no difference between groups ($P$ = .9275), although the MPFLR + TTO group had higher heterogeneity in complication rates ($I^2$ = 79.4%) compared with iMPFLR ($I^2$ = 0%). There was no group difference in the pooled postoperative Lysholm scores ($P$ = .5177), but patients who underwent iMPFLR had significantly higher postoperative Kujala scores compared with those who underwent MPFLR + TTO ($P$ = .0283).

**Conclusion:** Even in the presence of previously indicative anatomic factors (TT-TG >20 mm), TTO combined with MPFLR does not seem to confer additional benefit compared with iMPFLR. This finding could be advantageous in minimizing the burden of additional surgery with its associated risks. The study findings should, however, be interpreted with caution given the heterogeneity of the studies.

**Keywords:** knee; MPFL; patellofemoral instability; TT-TG; TTO; meta-analysis

The Orthopaedic Journal of Sports Medicine, 11(12), 23259671231195905
DOI: 10.1177/23259671231195905

Patellar dislocation is common, accounting for 3% of all knee injuries,[9] and is most prevalent among a young, active population.[10] It can have a substantial impact on quality of life[20] and is a significant risk factor for long-term patellofemoral arthritis.[31] The established initial treatment for first-time patellar dislocation without chondral injury is nonoperative management,[28,39] but recurrence rates of 15% to 44% have been reported.[13,46] Patients with recurrent dislocation have up to a 50% chance of further dislocations[9] and often require surgery.[23]

There are a variety of surgical treatment options available, including isolated lateral release,[42] tibial tuberosity osteotomy (TTO),[11] and trochleoplasty,[5] but the most common and successful procedure has been medial patellofemoral ligament reconstruction (MPFLR).[32] Radiologic parameters are often relied on to help guide which surgical strategy to take,[45] and the tibial tubercle–trochlear groove distance (TT-TG) is a well-known proxy measure to describe patellofemoral alignment.[24] Biomechanical studies have shown that in the presence of a TT-TG of ≥20 mm, the medial patellofemoral ligament (MPFL) isometry is significantly altered, which could lead to increased graft tension and potential failure.[30] Clinical studies have shown that the probability of patellofemoral dislocation significantly increases in any patient with a TT-TG >20 mm,[6,36] and biomechanical studies have suggested that MPFLR with a TTO (MPFLR + TTO) could be advantageous in this scenario.[40]

Despite the predominant consensus that a patient with recurrent patellar dislocation and a TT-TG >20 mm requires an MPFLR + TTO,[18] recent evidence has shown that an isolated MPFLR (iMPFLR) will produce similar outcomes, with low rates of redislocation and without the additional morbidity associated with TTO.[8,15] A previous systematic review investigated outcomes of iMPFLR versus MPFLR + TTO in patients with a TT-TG >15 mm,[38] but the number of studies investigating this question in patients with a TT-TG >20 mm remains sparse, with small sample sizes.

The aim of this systematic review was therefore to pool and compare the complication rates and functional outcome scores of iMPFLR versus MPFLR + TTO, specifically in patients with a TT-TG distance >20 mm. Our hypothesis was that the postoperative redislocation and subjective instability rates between patients would be similar, with no difference in postoperative functional outcome scores between the treatment types.

## METHODS

### Study Design and Search Strategy

The systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) in March 2022. It was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Databases searched included PubMed-MEDLINE, Embase, Web of Science, and Cochrane Central from database inception to February 23, 2022. A search strategy for each database was conducted and is reported in Appendix Table A1.

### Study Selection

The results from the search strategy in each database were uploaded into the Covidence software platform (Covidence, Inc), and any duplicates were removed by Covidence and reviewed by first author. Titles, abstracts, and full texts were screened twice by 4 independent reviewers (B.G., A.N., A.R., and M.B.). Any discrepancies were resolved by discussion among authors, including the senior author (M.S.K.). The inclusion criteria were studies that reported results of patients with the following: (1) recurrent patellar dislocation, (2) TT-TG distance >20 mm, (3) surgical management with either MPFLR + TTO or iMPFLR, (4) mean follow-up >2 years, and (5) postoperative redislocation rate and/or functional outcome scores. If the overall study cohort had a mean TT-TG of <20 mm but the authors had reported separate postoperative redislocation rates and/or functional outcomes for patients with a TT-TG >20 mm (the cohort of interest for the current review), then those specific patients were included. Case reports, letters, technique papers, cadaveric/animal studies, revision surgery, studies not in English, unpublished studies or abstracts, studies presenting other types of patellofemoral instability surgery, and studies with <5 eligible patients were excluded. No restrictions were placed on patient age.

### Quality Assessment

The level of evidence of the included studies was assessed according to the guidelines of the Centre for Evidence-based Medicine. Methodological assessment was conducted using the modified Coleman Methodology Score (mCMS),[4]

§Address correspondence to Mininder S. Kocher, MD, MPH, Boston Children's Hospital, 300 Longwood Avenue, Boston, MA 02115, USA (email: Mininder.Kocher@childrens.harvard.edu).

*Boston Children's Hospital, Boston, Massachusetts, USA.

†Harvard T.H. Chan School of Public Health, Harvard University, Boston, Massachusetts, USA.

‡Harvard Medical School, Boston, Massachusetts, USA.

Final revision submitted May 1, 2023; accepted May 19, 2023.

One or more of the authors has declared the following potential conflict of interest or source of funding: M.S.K. has received education payments from Kairos Surgical and royalties from OrthoPediatrics. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

in which 10 criteria are used to evaluate study quality, each graded on a scale from 0 to 10 points: study size, mean follow-up, surgical technique, type of study, diagnostic certainty, description of surgical procedure given, description of postoperative rehabilitation, outcome criteria, procedure for assessing outcomes, and description of subject selection process. As some of the included studies had individual patients with a TT-TG <20 mm, these criteria were applied only to the patients with a TT-TG >20 mm to provide a more accurate assessment of our study question. A score of 85 to 100 is considered high quality (ie, void of confounding factors and bias), 70 to 84 is considered good, 55 to 69 is considered fair, and <55 is considered a poor-quality study. Two independent reviewers (B.G. and A.H.) determined the mCMS for each study. Both reviewers have MD and MPH qualifications and were trained in quality assessment. Any discrepancies were discussed with the senior author (M.S.K.) until a consensus was reached.

### Data Extraction

Two authors (A.N. and A.R.) performed the data extraction from the eligible studies into a predefined Microsoft Excel spreadsheet; extracted data were also manually cross-referenced by the first author. Discrepancies were resolved through discussion and consensus. Sample size (overall and cohort of interest [patients with TT-TG distance >20 mm]), body mass index, age, mean follow-up, TT-TG distance, and other radiologic parameters (Caton-Deschamps index, congruence angle, Insall-Salvati ratio, and patellar tilt angle) were recorded when available. Functional outcome scores for the cohort of interest were recorded and included pre- and postoperative Kujala, Lysholm, and Tegner scores; International Knee Documentation Committee score; and Knee injury and Osteoarthritis Outcome Score (KOOS). All complications, including postoperative redislocations and/or postoperative subjective instability, were recorded.

### Data Analysis

Pooled redislocation, subjective instability, and complication proportions were calculated using a generalized linear mixed-effects model and logit-transformed proportions. Further subgroup analysis of studies using iMPFLR versus MPFLR + TTO was conducted with a $Q$ test using a random-effects model with a Knapp-Hartung adjustment and assuming different $\tau^1$ estimates across subgroups. A random-effects model with restricted likelihood estimator was used to pool raw mean postoperative Kujala and Lysholm scores. Analysis was conducted in R (R Foundation for Statistical Computing) using the *Metafor/Meta* package.

## RESULTS

### Characteristics of the Included Studies

Our initial search yielded 1176 studies from PubMed, 766 from Embase, 1022 from Web of Science and 26 from Cochrane Central, and 1443 duplicate studies were removed, leaving 1547 titles and abstracts, of which 1423 were deemed irrelevant. Our inclusion and exclusion criteria were then applied to 124 full texts, which led to our final group of 13 studies[‖] (Figure 1).

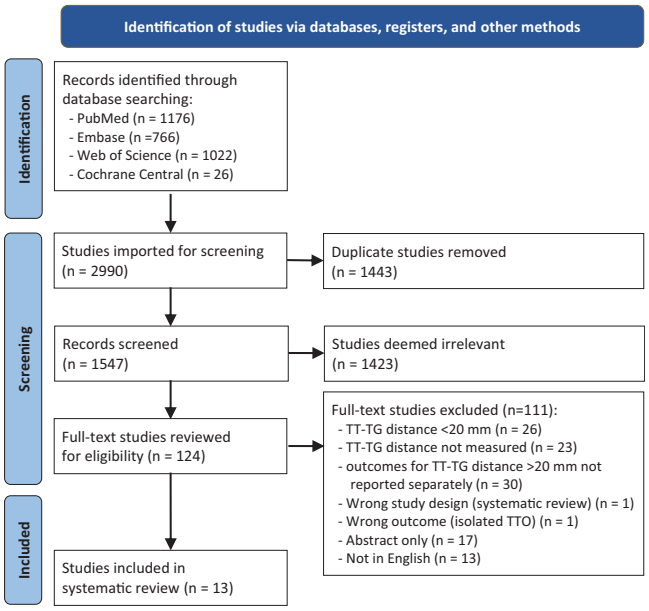


**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of study exclusion and inclusion. TTO, tibial tuberosity osteotomy; TT-TG, tibial tuberosity-trochlear groove.

One study was published in 2022,[17] 5 studies were published in 2021,[12,15,27,41,48] 3 studies were published in 2020,[2,37,47] 2 studies were published in 2019,[8,26] 1 in 2017,[22] and 1 in 2014[21]; 7 studies were judged to be of level 3 evidence,[2,12,15,21,27,37,47] and 6 studies had level 4 evidence.[8,17,22,26,41,48] The mean age of the overall cohort in the 13 studies was 24.1 years, and the mean follow-up was 3.8 years. Within the included studies, 386 patients (406 knees) had a TT-TG >20 mm; of these patients, 276 had undergone MPFLR + TTO, and 110 had undergone iMPFLR. Individual study characteristics are summarized in Table 1.

### Quality Assessment

The mean mCMS was 61.3 ± 10.5, indicating an overall quality assessment of "fair" for the included studies. There were 4 studies rated as good, 5 studies as fair, and 4 studies as poor (Table 2).

### Characteristics of Individual Studies

*Indications.* All studies had outcome scores for patients with a TT-TG >20 mm. All studies included patients with recurrent patellofemoral instability; 8 studies[8,12,15,17,26,37,41,48]

[‖]References 2, 8, 12, 15, 17, 21, 22, 26, 27, 37, 41, 47, 48.

TABLE 1
Characteristics of the Included Studies[a]

| Lead Author (Year) | LOE | Surgical Procedure | TTO Type (Distalization, Medialization, or Both) | MPFL Graft Type | Age, y | Follow-up, mo | No. of Patients (Knees) With TT-TG >20 mm | TT-TG Distance for Cohort of Interest, mm[b] |
|---|---|---|---|---|---|---|---|---|
| Matsushita (2014)[21] | 3 | MPFLR | —[c] | ST auto | 22.1 | 44.0 (12-86) | 19 (21) of 34 (39) | 22.7 ± 2.6 |
| Matsushita (2017)[22] | 4 | MPFLR | — | ST auto | 26.1 ± 7.0 | 63.6 ± 44 | 8 (8) of 46 (54) | 20.2 ± 4.4 |
| Erickson (2019)[8] | 4 | MPFLR | — | ST auto or allo | 19.4 (11-34) | 26.0 | 14 of 72 patients | ≥20 |
| Neri (2019)[26] | 4 | MPFLR + TTO | Both | Gracilis auto | 23.5 (16-39) | 75.6 (49.2-123.6) | 42 (44) of 126 (133) | ≥20 |
| Sisák (2020)[37] | 3 | MPFLR + TTO | Both | Gracilis auto | 21.0 (15-40) | 28.0 (12-44) | 9 of 10 patients | ≥20 |
| Blanke (2020)[2] | 3 | MPFLR | — | Gracilis auto | 26.0 | 24.0 (24-36) | 5 of 52 patients | ≥20 |
| Lee (2022)[17] | 4 | MPFLR | — | ST auto or TA allo | 25.0 (14-51) | 41.1 (24-60) | 12 of 21 knees | ≥20 |
| Zhang (2020)[47] | 3 | MPFLR + TTO | Both | ST auto | 20.5 ± 5.5 | 28.0 (24-32) | 66 (70) of 66 (70) | ≥20 |
| Hadley (2021)[12] | 3 | MPFLR + TTO | Medialization | ST auto | 25 (18-41) | 44.0 (28-92) | 23 (25) of 23 (25) | ≥20 |
| Kim (2021)[15] | 3 | MPFLR; MPFLR + TTO | Medialization | ST and TA auto and allo | 20.7 ± 6.3; 23.3 ± 9.1 | 28.2 ± 13.6; 22.6 ± 10.8 | 18 of 36 patients; 27 of 45 patients | 20 ≥ TT-TG ≤ 25 |
| Pakuts (2021)[27] | 3 | MPFLR + TTO | Both | Gracilis auto | 22.8 (10-42) | 30.4 (12-72) | 11 of 34 patients | 23.2 ± 1.3 |
| Su (2021)[41] | 4 | MPFLR + TTO | Medialization | HT auto | 19.2 ± 6.1 | 61.3 ± 15.4 | 98 (108) of 98 (108) | 22 ± 3.0 |
| Zhao (2021)[48] | 4 | MPFLR | — | ST auto | 19.0 (13-45) | 70.7 (36-108) | 34 of 237 patients | ≥20 |

[a]Data for age, follow-up, and TT-TG distance are presented as mean, mean ± SD, or mean (range). allo, allograft; auto, autograft; HT, hamstring tendon; LOE, level of evidence; MPFL, medial patellofemoral ligament; MPFLR, medial patellofemoral ligament reconstruction; ST, semitendinosus; TA, tibialis anterior; TT-TG, tibial tuberosity–trochlear groove; TTO, tibial tubercle osteotomy.
[b]"Included patients" were those with a TT-TG distance >20 mm; if no mean TT-TG distance was provided for this cohort, a value ≥20 mm was added.
[c]Dash indicates tibial tubercle osteotomy (TTO) was not performed.

specified the number of patellar dislocations required for inclusion. Of these, 3 studies[17,26,41] required >1 dislocation for inclusion, 4 studies[15,37,44,48] required >2 episodes of dislocation, and 1 study[8] required >3 episodes of dislocation. Ten studies[¶] did not exclude patients based on their level of trochlear dysplasia or patellar height. Kim et al[15] excluded patients with a Caton-Deschamps index >1.2, Neri et al[26] only included patients with grade A trochlear dysplasia, and in the study by Sisák et al,[37] patients with a TT-TG >20 mm had normal patellar height (Insall-Salvati ratio <1.2) and grade A or B trochlear dysplasia.

*Surgical Technique.* All included studies used a hamstring (semitendinosus or gracilis) tendon autograft for at least part of their MPFLR strategy. Ten studies[#] used hamstring tendon autograft as their sole graft of choice, 4 studies[2,26,27,37] used gracilis, 5 studies[12,21,22,47,48] used semitendinosus and 1 study[41] used either (Table 1). Kim et al[15] used predominantly semitendinosus or tibialis anterior allograft rather than autograft for their MPFLR, Lee et al[17] used either semitendinosus autograft or tibialis anterior allograft interchangeably, and Erickson et al[8] had 59 semitendinosus autograft patients and 13 semitendinosus allograft patients.

When specified, all included studies used double-bundle graft with 2 drill holes in the patella secured with either suture anchors or tendon sling. Fixation at the MPFL insertion site in the medial femoral condyle was performed with an interference screw or suspensory fixation. Six studies[2,15,26,27,47,48] specified locating the femoral tunnel using the technique described by Schöttle et al.[33]

Hadley et al[12] medialized the tibial tubercle to a TT-TG of <13 mm in all patients, angling the osteotomy 30° in the horizontal plane and fixing the osteotomy with two to three 4.5-mm cortical screws. Zhang et al[47] performed an Elmslie-Trillat medialization osteotomy TTO to 10 to 12 mm. For Kim et al,[15] the TT-TG after TTO was <10 mm and fixed with 2 or 3 fully threaded cannulated or cortical screws.

Six studies[2,12,15,21,22,41] mentioned performing a concomitant lateral release, but only Hadley et al[12] performed a lateral release in all patients. Kim et al[15] performed a lateral release in 14 patients in whom it was deemed necessary. Matsushita et al[22] in their 2017 study performed a lateral release if patellar tilt was >15° in their 2014 study,[21] a lateral release was performed on 22 knees showing strong patellar tilt and lateral soft tissue tightness. Su et al[41] performed a lateral release if the patella moved one-fourth of the patellar width medially, and Blanke et al[2] performed a lateral release if there was a need to recenter the patella before graft fixation.

*Postoperative Rehabilitation.* Postoperative rehabilitation programs were reported in 7 studies.[2,8,12,15,37,41,48] Blanke et al[2] advised partial weightbearing for 2 weeks, Hadley et al[12] and Zhao et al[48] extended this to 6 weeks before full weightbearing, while Erickson et al[8] and Kim et al[15] advised full weightbearing as tolerated immediately. Only Sisák et al[37] advised nonweightbearing for a period of 6 weeks. Where it was specified, studies recommended a return to sport at 6 months. All studies advised the use of a hinged knee brace postoperatively for a period of 6 to 8 weeks with a gradual increase in knee range of motion.

## Functional Outcome Scores

There was no difference in the pooled postoperative Lysholm scores, but iMPFLR patients had significantly

[¶]References 2, 8, 12, 17, 21, 22, 27, 41, 47, 48.
[#]References 2, 12, 21, 22, 26, 27, 37, 41, 47, 48.

TABLE 2
Quality Assessment of Included Studies[a]

| | mCMS Criteria | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead Author (Year) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Score | Quality |
| Matsushita (2014)[21] | 4 | 5 | 10 | 0 | 5 | 5 | 0 | 8 | 5 | 10 | 52 | Poor |
| Matsushita (2017)[22] | 0 | 5 | 10 | 0 | 5 | 5 | 0 | 8 | 8 | 5 | 46 | Poor |
| Erickson (2019)[8] | 0 | 5 | 10 | 10 | 5 | 5 | 5 | 10 | 8 | 15 | 73 | Good |
| Neri (2019)[26] | 7 | 5 | 7 | 0 | 5 | 5 | 0 | 10 | 8 | 15 | 62 | Fair |
| Sisák (2020)[37] | 0 | 5 | 10 | 0 | 5 | 5 | 10 | 8 | 8 | 5 | 56 | Fair |
| Blanke (2020)[2] | 0 | 5 | 10 | 0 | 5 | 3 | 5 | 8 | 8 | 5 | 49 | Poor |
| Lee (2022)[17] | 4 | 5 | 10 | 0 | 5 | 5 | 0 | 10 | 12 | 5 | 56 | Fair |
| Zhang (2020)[47] | 10 | 5 | 10 | 0 | 5 | 3 | 0 | 8 | 8 | 15 | 64 | Fair |
| Hadley (2021)[12] | 4 | 5 | 10 | 0 | 5 | 5 | 10 | 10 | 8 | 10 | 67 | Fair |
| Kim (2021)[15] | 7 | 5 | 7 | 0 | 5 | 5 | 10 | 10 | 12 | 15 | 76 | Good |
| Pakuts (2021)[27] | 0 | 5 | 7 | 0 | 5 | 5 | 0 | 10 | 8 | 10 | 50 | Poor |
| Su (2021)[41] | 10 | 5 | 10 | 0 | 5 | 5 | 10 | 8 | 8 | 15 | 76 | Good |
| Zhao (2021)[48] | 4 | 5 | 10 | 0 | 5 | 5 | 10 | 8 | 8 | 15 | 70 | Good |

[a]mCMS criteria: (1) study size, (2) mean follow-up, (3) type of surgical technique, (4) type of study, (5) diagnostic certainty, (6) description of surgical procedure given, (7) description of postoperative rehabilitation, (8) outcome criteria, (9) procedure for assessing outcomes, and (10) description of subject selection process. mCMS, modified Coleman Methodology Score.

higher postoperative Kujala scores (91.45; 95% CI, 84.52-98.38) compared with MPFLR + TTO patients (85.54; 95% CI, 77.15-93.94) ($P$ = .0283). Kim et al[15] found no significant difference in KOOS values in any of the 5 tested modalities between iMPFLR and MPFLR + TTO groups for those with a TT-TG of 20 to 25 mm, in addition to no difference between Tegner activity score, knee range of motion, Kujala score, or functional instability at >2-year follow-up. The functional outcomes scores for patients with a TT-TG >20 mm in each included study are summarized in Table 3.

## Imaging Data

Table 4 summarizes the radiographic markers of patellar instability in the included studies for patients with a TT-TG distance >20 mm. Eleven studies[**] measured patellar height and/or trochlear dysplasia, all of which used the Dejour classification to measure trochlear dysplasia. Most studies used the Caton-Deschamps index,[††] with the exception of Sisák et al[37] and Matsushita et al,[22] who used the Insall-Salvati ratio. TT-TG was measured using magnetic resonance imaging[2,8,12,17,37] or computed tomography[15,21,22,26,27,41,47,48] axial superimposed images. The studies used variations of the technique used by Matsushita et al,[22] who employed Photoshop software (Adobe, Inc) to superimpose an image of a line going through the deepest point of the trochlear groove to an image of a line though the center of the tibial tuberosity perpendicular to the posterior condylar line and measured the distance between the 2. Zhang et al[47] marked the center of the tibial tubercle as the center of the patellar tendon insertion.

**References 2, 8, 15, 17, 22, 26, 27, 37, 41, 47, 48.
††References 2, 8, 15, 17, 26, 27, 41, 47, 48.

## Complications

There were zero postoperative redislocations noted for iMPFLR in those patients with a TT-TG >20 mm, compared with 7 (2%) postoperative redislocations in the MPFLR + TTO group ($P$ = .9995). The pooled postoperative redislocation rate was 1.22% (95% CI, 0.22%-7%). The pooled subjective instability rate for the MPFLR + TTO group was 5.79% (95% CI, 1.72%-17.72%) compared with 4.14% (95% CI, 0.08%-69.01%) for the iMPFLR group, with no significant difference between the 2 ($P$ = .7895).

The pooled complication rate was 10.17% (95% CI, 6.2%-16.3%), with no difference between groups ($P$ = .9275), although the MPFLR + TTO group had higher heterogeneity in complication rates ($I^2$ = 79.4%) compared with iMPFLR ($I^2$ = 0%). The postoperative complications, including comments on whether these complications applied to the cohort of interest (TT-TG distance >20 mm), are summarized in Appendix Table A2. In addition to the postoperative redislocation and instability rates mentioned, knee stiffness and removal of hardware were common complications.

## DISCUSSION

In patients with a TT-TG >20 mm, iMPFLR seems to confer similar outcomes to MPFLR + TTO, with no difference in postoperative redislocation or subjective instability rate and similar postoperative functional outcome scores, confirming our hypothesis. This finding, while tempered by a lack of control of other anatomic factors (eg, trochlear dysplasia, malalignment) and the heterogeneity of the studies synthesized, adds to the growing body of evidence that an iMPFLR may be all that is required in the surgical treatment of patellar instability in the presence of an increased TT-TG distance.

TABLE 3
Functional Outcome Scores of Included Studies for Patients With TT-TG >20 mm[a]

| Lead Author (Year) | Surgical Procedure | Preoperative | Postoperative | Difference |
|---|---|---|---|---|
| | | Lysholm | | |
| Matsushita (2014)[21] | MPFLR | 79.5 ± 12.6 | 94.7 ± 8.5 | 15.2 ± 15.2 |
| Blanke (2020)[2] | MPFLR | 40.2 ± 15 | 75 ± 24.6 | 34.8 ± 28.8 |
| Lee (2022)[17] | MPFLR | — | 49.24 ± 10.93 | — |
| Zhang (2020)[47] | MPFLR + TTO | 53 ± 7 | 84 ± 9 | 31 ± 11.4 |
| Hadley (2021)[12] | MPFLR + TTO | — | 76.72 ± 18.9 | — |
| | | KOOS | | |
| Matsushita (2017)[22] | MPFLR | Pain: 90.4 ± 16.4<br>Sx: 82.3 ± 11.3<br>ADL: 94.6 ± 7.6<br>Sports/Rec: 84.4± 18.0<br>QoL: 53.3 ± 37.3 | Pain: 84.4 ± 13.9<br>Sx: 70.5 ± 21.9<br>ADL: 92.9 ± 8.4<br>Sports/Rec: 78.1 ± 23.9<br>QoL: 68.8 ± 22.8 | Pain: –6 ± 21.5<br>Sx: –11.3 ± 24.6<br>ADL: –1.7 ± 11.3<br>Sports/Rec: –6.3 ± 29.9<br>QoL: 15.5 ± 43.7 |
| Kim (2021)[15] | MPFLR; MPFLR + TTO | MPFLR<br>• Pain: 55.8 ± 19.6<br>• Sx: 59.5 ± 9.1<br>• ADL: 65.7 ± 14.8<br>• Sports/Rec: 45.0 ± 15.0<br>• QoL: 47.1 ± 11.7<br><br>MPFLR + TTO<br>• Pain: 55.2 ±15.5<br>• Sx: 59.5 ± 8.9<br>• ADL: 70.2 ± 12.4<br>• Sports/Rec: 48.8 ± 19.8<br>• QoL: 46.4 ± 12.8 | MPFLR<br>• Pain: 88.5 ± 6.7<br>• Sx: 88.1 ± 5.9<br>• ADL: 84.4 ± 9.2<br>• Sports/Rec: 76.4 ± 13.6<br>• QoL: 77.3 ± 9.2<br><br>MPFLR + TTO<br>• Pain: 86.8 ± 12.2<br>• Sx: 85.9 ± 13.0<br>• ADL: 90.9 ± 8.5<br>• Sports/Rec: 73.8 ± 18.7<br>• QoL: 76.4 ± 15.3 | MPFLR<br>• Pain: 32.7 ± 20.7<br>• Sx: 28.6 ± 10.9<br>• ADL: 18.7 ± 17.4<br>• Sports/Rec: 31.4 ± 20.3<br>• QoL: 30.2 ± 14.9<br><br>MPFLR + TTO<br>• Pain: 31.6 ± 19.7<br>• Sx: 26.4 ± 15.8<br>• ADL: 20.7 ± 15.0<br>• Sports/Rec: 25 ± 27.2<br>• QoL: 30 ± 20.0 |
| | | IKDC | | |
| Lee (2022)[17] | MPFLR | — | 52.12 ± 18.31 | — |
| Zhang (2020)[47] | MPFLR + TTO | 49 ± 6 | 82 ± 7 | 33 ± 9.2 |
| Su (2021)[41] | MPFLR + TTO | — | 72.7 ± 12.1 | — |
| Zhao (2021)[48] | MPFLR | — | — | 31.65 ± 4.63 |
| | | Tegner | | |
| Matsushita (2017)[22] | MPFLR | 67.8 ± 25.7 | 79 ± 11 | 11.2 ± 28.0 |
| Blanke (2020)[2] | MPFLR | 3.2 ± 1.9 | 4.6 ± 2.5 | 1.4 ± 3.1 |
| Zhang (2020)[47] | MPFLR + TTO | — | 5 ± 2.1 | — |
| Kim (2021)[15] | MPFLR; MPFLR + TTO | MPFLR: 3.7 ± 2.5;<br>MPFLR + TTO: 3.9 ± 1.7 | MPFLR: 4.5 ± 1.7;<br>MPFLR + TTO: 4.6 ± 1.4 | MPFLR: 0.8 ± 3.0;<br>MPFLR + TTO: 0.7 ± 2.2 |
| Su (2021)[41] | MPFLR + TTO | — | 5.3 ± 1.3 | — |
| | | Kujala | | |
| Matsushita (2014)[21] | MPFLR | 75.5 ± 18.5 | 92.3 ± 11.7 | 16.8 ± 21.9 |
| Sisák (2020)[37] | MPFLR + TTO | 48.9 | 88.6 | 39.7 |
| Zhang (2020)[47] | MPFLR + TTO | 56 ± 7 | 80.3 ± 9 | 24.3 ± 11.4 |
| Hadley (2021)[12] | MPFLR + TTO | — | 81.56 ± 14.7 | — |
| Kim (2021)[15] | MPFLR; MPFLR + TTO | MPFLR: 59.5 ± 14.8;<br>MPFLR + TTO: 59.0 ± 14.1 | MPFLR: 91.1 ± 7.3;<br>MPFLR + TTO: 89.3 ± 8.7 | MPFLR: 31.6 ± 16.5;<br>MPFLR + TTO: 30.3 ± 16.6 |
| Su (2021)[41] | MPFLR + TTO | — | 90.5 ± 15.5 | — |

[a]Data are presented as mean or mean ± SD. Dashes indicates data not available. Erickson et al (2019)[9] and Neri et al (2019)[27] did not have functional outcome scores for the cohort of interest. ADL, activity in daily living subscale; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; MPFLR, medial patellofemoral ligament reconstruction; QoL, knee-related quality of life subscale; Sports/Rec, function in sport and recreation subscale; Sx, symptoms subscale; TTO, tibial tubercle osteotomy; TT-TG, tibial tuberosity-trochlear groove.

TABLE 4
Imaging Data for Patients With a TT-TG >20 mm in Included Studies[a]

| Lead Author (Year) | Surgical Procedure | Preoperative | Postoperative |
|---|---|---|---|
| | | Caton-Deschamps Index | |
| Neri (2019)[26] | MPFLR + TTO(m); MPFLR + TTO(m-d) | 1.25 ± 0.09; 1.44 ± 0.02 | 1.10 ± 0.06; 1.09 ± 0.07 |
| Blanke (2020)[2] | MPFLR | 1.2 ± 0.20 | — |
| Lee (2022)[17] | MPFLR | — | 0.08 ± 0.07 |
| Su (2021)[41] | MPFLR + TTO | 1.2 ± 0.22 | — |
| | | Congruence Angle, deg | |
| Matsushita (2014)[21] | MPFLR | 18.7 ± 22.0 | 2.9 ± 16.7 |
| Matsushita (2017)[22] | MPFLR | 19.2 ± 29 | –7 ± 16.7 |
| Lee (2022)[17] | MPFLR | — | 20°: 10.04 ± 3.05<br>40°: 1.24 ± 1.46<br>60°: 0.76 ± 1.55 |
| | | Patellar Tilt Angle, deg | |
| Neri (2019)[26] | MPFLR + TTO(m); MPFLR + TTO(m-d) | 31 ± 11; 31 ± 14 | 17 ± 4; 14 ± 4 |
| Lee (2022)[17] | MPFLR | — | 52.12 ± 18.31 |
| | | Insall-Salvati Ratio | |
| Matsushita (2017)[22] | MPFLR | 1.1 ± 0.3 | 1 ± 0.2 |

[a]Data are presented as mean ± SD. Dashes indicates data not available. Erickson et al (2019),[8] Hadley et al (2021),[12] Kim et al (2021),[15] Pakuts et al (2021),[27] Sisák et al (2020),[37] Zhang et al (2020),[47] and Zhao et al (2021)[48] did not have imaging data for the cohort of interest. MPFLR, medial patellofemoral ligament reconstruction; MPFLR + TTO(m), medial patellofemoral ligament reconstruction with tibial tubercle osteotomy medialization; MPFLR + TTO(m-d), medial patellofemoral ligament reconstruction with tibial tubercle osteotomy medialization and distalization; TTO, tibial tubercle osteotomy; TT-TG, tibial tuberosity-trochlear groove.

In previous systematic reviews investigating this question, Song et al[38] assimilated 9 studies and found that in patients with a TT-TG >15 mm, outcomes were similar between iMPFLR and MPFLR + TTO with no increase in postoperative redislocation noted in the iMPFLR group. Burnham et al[3] noted that functional improvement was similar in both iMPFLR and MPFLR + TTO, although they included studies where iMPFLR was performed in patients without an increased TT-TG. Historically, a TT-TG >20 mm has been deemed truly pathologic,[6] and while no true consensus has been reached, often combined MPFLR + TTO procedures are recommended primarily for those with a TT-TG >20 mm.[12,19,26,35,47] Our review therefore directly addresses this area of uncertainty by only including either studies with a mean TT-TG >20 mm and/or studies with outcomes for patients with a TT-TG >20 mm who have undergone iMPFLR or MPFLR + TTO.

Our pooled redislocation rate was low for both iMPFLR and MPFLR + TTO, a finding supported by the literature.[43] In a matched population-based analysis, Sanders et al[31] found that patients with a patellar dislocation or recurrent patellar instability had a significantly higher risk of developing patellofemoral arthritis compared with control, highlighting the importance of patellofemoral stability. Yet if, as noted in our review, the rate of patellar instability is similar between iMPFLR and MPFLR + TTO, it becomes more difficult to clinically justify the additional surgical insult associated with a TTO. In addition to increased surgical time and a more restrictive postoperative rehabilitation program, TTO offers its own unique complications such as nonunion of the osteotomy and removal of metalwork.[1] While our study noted a similar overall complication rate between the 2 procedures, a systematic review of the complication rate of TTO noted that hardware removal was required in 36.7% of patients.[29] Mikashima et al[25] randomized patients with recurrent patellar instability to have either a TTO or a MPFLR + TTO and found that in the TTO group, there was an apprehension rate of 30% at 2 years, whereas in the MPFLR + TTO group, the rate was zero, suggesting MPFLR is the primary surgical factor in maintaining patella stability when comparing the 2 procedures.

Findings from our review indicated similar postoperative functional outcome scores between the 2 procedures, which is corroborated in other studies.[7] While the postoperative Kujala and Lysholm scores were high for both groups, iMPFLR patients had higher postoperative Kujala scores than those with MPFLR + TTO. This finding has to

be tempered by that fact that only 2 of 13 studies reported Kujala scores for patients with a TT-TG >20 mm and that clearly the postoperative score is dependent on the preoperative functional state of the patients in question. Nevertheless, there have been studies to show the superior functional benefit of the iMPFLR. Krych et al[16] noted that in young athletes with patellar instability undergoing either iMPFLR or MPFLR + TTO, the MPFLR + TTO group had a significantly slower return-to-sport rate and had weaker 6-month isokinetic testing. This may be related to the quicker surgical recovery and lower surgical trauma associated with an iMPFLR.

### Limitations

The main limitations of our review were the heterogeneity of the studies assimilated and the lack of studies directly designed to answer whether MPFLR + TTO is superior to iMPFLR in those with a TT-TG >20 mm. This was reflected in our low overall mCMS, and the results should be interpreted with caution. While some studies controlled for other factors associated with patellar instability such as trochlear dysplasia and patella alta, others did not, and this would also influence the results. There are also other similar radiographic measurements, such as tibial tubercle–posterior cruciate ligament distance[34] or tibial tubercle–midepicondyle distance,[14] which we did not explore. Our review reflected medium-term follow-up with a mean of 3.8 years, but long-term follow-up of 5 to 10 years was lacking and would be important in determining the longevity of the low postoperative instability and redislocation rates associated with the procedures.

## CONCLUSION

This review adds to the increasing body of evidence that an iMPFLR may be all that is required to treat patellar instability, without the need for a TTO, even in the presence of an increased TT-TG. A randomized prospective long-term study comparing iMPFLR to MPFLR + TTO in those with a TT-TG >20 mm would be of great benefit in confirming this finding.

## ACKNOWLEDGMENT

The authors thank Paul Bain, librarian at the Countway Library, Harvard University, for his invaluable help in creating our literature review.

## REFERENCES

1. Ahmad R, Calciu M, Jayasekera N, Schranz P, Mandalia V. Combined medial patellofemoral ligament reconstruction and tibial tubercle transfer results at a follow-up of 2 years. *J Knee Surg*. 2017;30(1):42-46.
2. Blanke F, Watermann K, Haenle M, et al. Isolated medial patellofemoral ligament reconstruction can be an effective procedure in patellofemoral instability with risk factors. *J Knee Surg*. 2020;33(10):992-997.
3. Burnham JM, Howard JS, Hayes CB, Lattermann C. Medial patellofemoral ligament reconstruction with concomitant tibial tubercle transfer: a systematic review of outcomes and complications. *Arthroscopy*. 2016;32(6):1185-1195.
4. Coleman BD, Khan KM, Maffulli N, Cook JL, Wark JD. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. *Scand J Med Sci Sports*. 2000;10(1):2-11.
5. Dejour DH, Deroche É. Trochleoplasty: indications in patellar dislocation with high-grade dysplasia. Surgical technique. *Orthop Traumatol Surg Res*. 2022;108(suppl 1):103160.
6. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc*. 1994;2(1):19-26.
7. Enderlein D, Nielsen T, Christiansen SE, Faunø P, Lind M. Clinical outcome after reconstruction of the medial patellofemoral ligament in patients with recurrent patella instability. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(10):2458-2464.
8. Erickson BJ, Nguyen J, Gasik K, et al. Isolated medial patellofemoral ligament reconstruction for patellar instability regardless of tibial tubercle-trochlear groove distance and patellar height: outcomes at 1 and 2 years. *Am J Sports Med*. 2019;47(6):1331-1337.
9. Fithian DC, Paxton EW, Stone ML, et al. Epidemiology and natural history of acute patellar dislocation. *Am J Sports Med*. 2004;32(5):1114-1121.
10. Gravesen KS, Kallemose T, Blønd L, Troelsen A, Barfod KW. High incidence of acute and recurrent patellar dislocations: a retrospective nationwide epidemiological study involving 24.154 primary dislocations. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(4):1204-1209.
11. Grawe B, Stein BE. Tibial tubercle osteotomy: indication and techniques. *J Knee Surg*. 2015;28(4):279-284.
12. Hadley CJ, Tucker BS, Lombardi NJ, et al. Combined MPFL reconstruction and tibial tubercle osteotomy for patellar instability: a retrospective review of 23 patients. *J Orthop*. 2021;28:49-52.
13. Hawkins RJ, Bell RH, Anisette G. Acute patellar dislocations. The natural history. *Am J Sports Med*. 1986;14(2):117-120.
14. Iseki T, Nakayama H, Daimon T, et al. Tibial tubercle-midepicondyle distance can be a better index to predict the outcome of medial patellofemoral ligament reconstruction than tibial tubercle-trochlear groove distance. *Arthrosc Sports Med Rehabil*. 2020;2(6):e697-e704.
15. Kim JM, Sim JA, Yang H, et al. Clinical comparison of medial patellofemoral ligament reconstruction with or without tibial tuberosity transfer for recurrent patellar instability. *Am J Sports Med*. 2021;49(12):3335-3343.
16. Krych AJ, O'Malley MP, Johnson NR, et al. Functional testing and return to sport following stabilization surgery for recurrent lateral patellar instability in competitive athletes. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(3):711-718.
17. Lee JI, Jaffar MSA, Choi HG, Kim TW, Lee YS. Effect of isolated medial patellofemoral ligament reconstruction in patellofemoral instability regardless of predisposing factors. *J Knee Surg*. 2022;35(3):299-307.
18. Liu JN, Steinhaus ME, Kalbian IL, et al. Patellar instability management: a survey of the International Patellofemoral Study Group. *Am J Sports Med*. 2018;46(13):3299-3306.
19. Longo UG, Berton A, Salvatore G, et al. Medial patellofemoral ligament reconstruction combined with bony procedures for patellar instability: current indications, outcomes, and complications. *Arthroscopy*. 2016;32(7):1421-1427.
20. Magnussen RA, Verlage M, Stock E, et al. Primary patellar dislocations without surgical stabilization or recurrence: how well are these patients really doing? *Knee Surg Sports Traumatol Arthrosc*. 2017;25(8):2352-2356.

21. Matsushita T, Kuroda R, Oka S, et al. Clinical outcomes of medial patellofemoral ligament reconstruction in patients with an increased tibial tuberosity-trochlear groove distance. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(10):2438-2444.
22. Matsushita T, Oka S, Araki D, et al. Patient-based outcomes after medial patellofemoral ligament reconstruction. *Int Orthop*. 2017; 41(6):1147-1153.
23. Mehta VM, Inoue M, Nomura E, Fithian DC. An algorithm guiding the evaluation and treatment of acute primary patellar dislocations. *Sports Med Arthrosc Rev*. 2007;15(2):78-81.
24. Middleton KK, Gruber S, Shubin Stein BE. Why and where to move the tibial tubercle: indications and techniques for tibial tubercle osteotomy. *Sports Med Arthrosc Rev*. 2019;27(4):154-160.
25. Mikashima Y, Kimura M, Kobayashi Y, Asagumo H, Tomatsu T. Medial patellofemoral ligament reconstruction for recurrent patellar instability. *Acta Orthop Belg*. 2004;70(6):545-550.
26. Neri T, Parker DA, Beach A, et al. Medial patellofemoral ligament reconstruction with or without tibial tubercle transfer is an effective treatment for patellofemoral instability. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(3):805-813.
27. Pakuts A ML, Riquoir C, Schadenberg A. Reconstruction of the medial patellofemoral ligament with patellar transosseous sutures: cross-sectional study with 34 patients. *Rev Chil Ortop Traumatol*. 2021;62(2):e104-e112.
28. Palmu S, Kallio PE, Donell ST, Helenius I, Nietosvaara Y. Acute patellar dislocation in children and adolescents: a randomized clinical trial. *J Bone Joint Surg Am*. 2008;90(3):463-470.
29. Payne J, Rimmke N, Schmitt LC, Flanigan DC, Magnussen RA. The incidence of complications of tibial tubercle osteotomy: a systematic review. *Arthroscopy*. 2015;31(9):1819-1825.
30. Redler LH, Meyers KN, Brady JM, et al. Anisometry of medial patellofemoral ligament reconstruction in the setting of increased tibial tubercle-trochlear groove distance and patella alta. *Arthroscopy*. 2018;34(2):502-510.
31. Sanders TL, Pareek A, Johnson NR, et al. Patellofemoral arthritis after lateral patellar dislocation: a matched population-based analysis. *Am J Sports Med*. 2017;45(5):1012-1017.
32. Schneider DK, Grawe B, Magnussen RA, et al. Outcomes after isolated medial patellofemoral ligament reconstruction for the treatment of recurrent lateral patellar dislocations: a systematic review and meta-analysis. *Am J Sports Med*. 2016;44(11):2993-3005.
33. 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(5):801-804.
34. Seitlinger G, Scheurecker G, Högler R, et al. Tibial tubercle-posterior cruciate ligament distance: a new measurement to define the position of the tibial tubercle in patients with patellar dislocation. *Am J Sports Med*. 2012;40(5):1119-1125.
35. Servien E, Verdonk PC, Neyret P. Tibial tuberosity transfer for episodic patellar dislocation. *Sports Med Arthrosc Rev*. 2007;15(2):61-67.
36. Sherman SL, Erickson BJ, Cvetanovich GL, et al. Tibial tuberosity osteotomy: indications, techniques, and outcomes. *Am J Sports Med*. 2014;42(8):2006-2017.
37. Sisák K, Gombár C, Friebert G, Koós Z. Modern treatment of recurrent patellofemoral instability—combined medial patellofemoral ligament reconstruction and tibial tubercle transfer. *Acta Chir Orthop Traumatol Cech*. 2020;87(6):396-403.
38. Song YF, Wang HJ, Yan X, et al. Tibial tubercle osteotomy may not provide additional benefit in treating patellar dislocation with increased tibial tuberosity-trochlear groove distance: a systematic review. *Arthroscopy*. 2021;37(5):1670-1679.e1671.
39. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. *Clin Orthop Relat Res*. 2007;455:93-101.
40. Stephen JM, Dodds AL, Lumpaopong P, et al. The ability of medial patellofemoral ligament reconstruction to correct patellar kinematics and contact mechanics in the presence of a lateralized tibial tubercle. *Am J Sports Med*. 2015;43(9):2198-2207.
41. Su P, Liu X, Jian N, Li J, Fu W. Clinical outcomes and predictive factors for failure with MPFL reconstruction combined with tibial tubercle osteotomy and lateral retinacular release for recurrent patellar instability. *BMC Musculoskelet Disord*. 2021;22(1):632.
42. Tan SHS, Chua CXK, Doshi C, et al. The outcomes of isolated lateral release in patellofemoral instability: a systematic review and meta-analysis. *J Knee Surg*. 2020;33(10):958-965.
43. Tscholl PM, Wanivenhaus F, Centmaier-Molnar V, Camenzind RS, Fucentese SF. Clinical and radiological results after one hundred fifteen MPFL reconstructions with or without tibial tubercle transfer in patients with recurrent patellar dislocation-a mean follow-up of 5.4 years. *Int Orthop*. 2020;44(2):301-308.
44. Wang J, Zhang X, Li S, et al. Plating system design determines mechanical environment in long bone mid-shaft fractures: a finite element analysis. *J Invest Surg*. 2020;33(8):699-708.
45. White AE, Otlans PT, Horan DP, et al. Radiologic measurements in the assessment of patellar instability: a systematic review and meta-analysis. *Orthop J Sports Med*. 2021;9(5):2325967121993179.
46. Wolfe S, Varacallo M, Thomas JD, Carroll JJ, Kahwaji CI. *Patellar Instability*. StatPearls Publishing LLC; 2022.
47. Zhang Z, Zhang H, Song G, et al. Increased femoral anteversion is associated with inferior clinical outcomes after MPFL reconstruction and combined tibial tubercle osteotomy for the treatment of recurrent patellar instability. *Knee Surg Sports Traumatol Arthrosc*. 2020; 28(7):2261-2269.
48. Zhao Z, Wang Y, Li J, et al. Clinical outcomes and prognostic factors in patients with recurrent patellar lateral dislocation treated with isolated medial patellofemoral ligament reconstruction: a retrospective single-center analysis. *Orthop J Sports Med*. 2021;9(4):2325967 121995803.

# APPENDIX

## APPENDIX TABLE A1
Search Strategy[a]

| PubMed (MeSH terms) |
|---|
| ("Osteotomy"[mesh] OR tibial tubercle osteotom*[tiab] OR tibial tuberosity osteotom*[tiab] OR tto[tiab] OR Fulkerson[tiab] OR Elmslie[tiab] OR Elmslie-trillat[tiab] OR tibial tubercle transfer[tiab] OR tibial tuberosity transfer[tiab] OR (("Patellar Dislocation/surgery"[mesh] OR "Patellofemoral Joint/surgery"[mesh]) AND ("Ligaments, Articular"[mesh] OR "Patellar Ligament"[mesh])) OR medial patellofemoral ligament reconstruction[tiab] OR mpfl[tiab]) |
| AND |
| (("Joint Instability"[mesh] AND "Patellofemoral Joint"[mesh]) OR "Patellar Dislocation"[mesh] OR patellofemoral instabilit*[tiab] OR patellofemoral joint instabilit*[tiab] OR patellar dislocation[tiab] OR patellar instabilit*[tiab]) |
| Initial search: 1176 results |
| |
| Embase |
| (1) 'patellofemoral instability'/exp OR ('joint instability'/exp AND 'patellofemoral joint'/exp) OR 'patella dislocation'/exp ((patellofemoral OR patella*) NEAR/3 (instabil* OR dislocat*)):ab,kw,ti |
| (2) 'tibial tubercle osteotomy'/exp OR 'medial patellofemoral ligament reconstruction'/exp OR 'tibia osteotomy'/exp OR (('patellofemoral joint'/exp OR 'patella dislocation'/exp) AND 'ligament surgery'/exp) OR (tibia* NEAR/3 (osteotom* OR transfer*)):ab,kw,ti OR (tto OR Fulkerson OR Elmslie OR 'Elmslie-trillat' OR 'medial patellofemoral ligament reconstruction' OR mpfl): ab,kw,ti |
| (3) 1 AND 2 |
| Initial search: 766 results |
| |
| Web of Science |
| [Tubercle OR tuberosity OR Fulkerson OR Elmslie OR Elmslie-trillat OR TTO OR Tibial Tuberosity Osteotomy OR Tibial Tubercle Osteotomy OR Tibial Tubercle Transfer OR Tibial Tuberosity Transfer] AND [Medial patellofemoral ligament reconstruction OR MPFL] |
| Initial search: 1022 results |
| |
| Cochrane Central |
| (1) Tubercle; (2) Tuberosity; (3) Fulkerson; (4) Elmslie; (5) Elmslie-Trilliat; (6) TTO; (7) Tibial Tuberosity Osteotomy; (8) Tibial Tubercle Transfer; (9) Tibial Tuberosity Transfer |
| (10) 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 |
| (11) Medial Patellofemoral Ligament |
| (12) MPFL |
| (13) 11 OR 12 |
| (14) 10 AND 13 |
| Initial search: 26 results |

[a]MeSH, Medical Subject Heading; MPFL, medial patellofemoral ligament; TTO, tibial tubercle osteotomy.

APPENDIX TABLE A2
Postoperative Complications[a]

| Lead Author (Year) | Subjective Instability/ Redislocations/ Infections | Total Reoperations | Total Complications | Comments[b] |
|---|---|---|---|---|
| Matsushita (2014)[21] | 4/0/— | 0 | — | • Apprehension sign remained in 4 knees in 3 patients with increased TT-TG distance and in 1 knee in the control group.<br>• No other complications were reported. |
| Matsushita (2017)[22] | 3/0/— | 0 | — | • Apprehension remained in 3 knees but not specified if in the cohort of interest.<br>• Total complications were not reported. |
| Erickson (2019)[8] | 1/2/— | 0 | 6 | • There was 1 postoperative redislocation and 1 subluxation with decreased TT-TG distance group (not cohort of interest).<br>• There was 1 medial collateral ligament sprain, 1 deep venous thrombosis, and 2 cases of reaction to skin glue; it is unknown if these occurred in the cohort of interest. |
| Neri (2019)[26] | —/4/— | 19 | 33 | • MPFLR + TTO(m): 1 patient had a recurrent patellar dislocation due to high-energy posttraumatic event with subsequent reconstruction.<br>• One patient who underwent TTO(m) reported tibial fracture requiring iterative osteosynthesis.<br>• Ten patients with TTO had anterior knee pain that required hardware removal.<br>• TTO(m): 3 patients with stiffness in flexion, 2 with amyotrophic quadriceps at 12 mo postoperatively.<br>• TTO(m-d): 1 patient with stiffness in flexion, 1 with amyotrophic quadriceps at 12 mo postoperatively.<br>• The remaining 7 reoperations and 14 total complications occurred in the iMPFLR group (not the cohort of interest). |
| Sisák (2020)[37] | 0/0/— | 0 | — | None of the patients had further episodes of subluxation or dislocation. |
| Blanke (2020)[2] | 6/1/— | 1 | — | • Two of 5 patients with a TT-TG distance >20 mm reported subjective instability.<br>• There was 1 case of postoperative dislocation and 1 case of reoperation, but TT-TG group was not specified.<br>• Total complications were not reported. |
| Lee (2022)[17] | 0/0/0 | 0 | 0 | There were no surgery-related complications or cases of redislocation or limitation in range of motion. |
| Zhang (2020)[47] | 2/0/— | — | | • Although no redislocation occurred, 2 knees demonstrated postoperative MPFLR failure.<br>• Twelve patients had inwardly pointing patella, 20 with patellar cartilage damage aggravation, 16 with trochlear cartilage damage aggravation.<br>• Neither reoperations nor total complications were reported. |
| Hadley (2021)[12] | 0/1/0 | 9 | 10 | • Additional complications included 2 patients with wound complications requiring repeat surgery and 1 patient with stiffness requiring MUA.<br>• Six patients underwent subsequent surgical procedures to the affected knee for removal of symptomatic hardware. |

*(continued)*

APPENDIX TABLE A2
(continued)

| Lead Author (Year) | Subjective Instability/ Redislocations/ Infections | Total Reoperations | Total Complications | Comments[b] |
|---|---|---|---|---|
| Kim (2021)[15] | MPFLR: 2/0/0; MPFLR + TTO: 2/1/0 | MPFLR: 0; MPFLR + TTO: 0 | MPFLR: 4; MPFLR + TTO: 7 | • Within the cohort of interest (20 mm ≤ TT-TG distance ≤ 25 mm), there was 1 case of instability in the iMPFLR group, and the other was in the TT-TG distance <20-mm group. There were 2 cases of instability in the MPFL + TTO group within the cohort of interest.<br>• Within the iMPFLR group, there was 1 case of patellar fracture and 1 case of sensory nerve injury, although it is not reported if these complications occurred in the cohort of interest.<br>• Within the MPFLR + TTO group, there were 2 cases of stiffness requiring MUA, 1 sensory nerve injury, and 1 case of screw irritation. It was not reported if these complications occurred in the cohort of interest. |
| Pakuts (2021)[27] | 2/0/0 | 0 | 2 | • There were 2 cases of pain or subjective instability; it was not specified if these cases were in the cohort of interest.<br>• There were no cases of postoperative redislocation during the survey and the clinical follow-up. No revision surgery was recorded. |
| Su (2021)[41] | — | — | — | • Out of the 6 knees with postoperative redislocations, 4 had medial subluxation, 4 had lateral subluxation, 4 had knee pain, 2 had incision disruption, 2 had fat liquefaction.<br>• Neither reoperations nor total complications were reported. |
| Zhao (2021)[48] | 9/11/10 | 7 | 28 | • Among the TT-TG >20-mm group, only 2 failure cases were reported. The cause of failure within the group was not specified. There were an additional 18 failure cases in the <20-mm TT-TG group.<br>• The totals of reoperations, subjective instability, and postoperative redislocations were reported but not by TT-TG group.<br>• There were 8 cases of stiffness requiring joint loosening under anesthesia but not specified by the TT-TG group.<br>• No major postoperative complications were reported. |

[a]Data are presented as number of cases. Dashes indicate data not available. iMPFLR, isolated medial patellofemoral ligament reconstruction; MPFLR, medial patellofemoral ligament reconstruction; MUA, manipulation under anesthesia; TTO, tibial tubercle osteotomy; TTO(m), tibial tubercle osteotomy medialization; TTO(m-d), tibial tubercle osteotomy medialization and distalization; TT-TG, tibial tuberosity–trochlear groove.

[b]The cohort of interest was patients with a TT-TG distance >20 mm.