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Medial patellofemoral ligament reconstruction with or without tibial tubercle transfer is an effective treatment for patellofemoral instability

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Abstract

Purpose The hypotheses were that medial patellofemoral ligament reconstruction (MPFLr) would improve the long-term symptoms of patellofemoral Instability (PFI) and control patellar tilt, based on computed tomography (CT), and that the addition of a TT transfer, when it is necessary, would not deteriorate the outcome. The purpose of this study was to evaluate the long-term clinical and radiographic outcomes of a large series of MPFLr, either isolated or associated with a TT transfer.

Methods From 133 MPFLr with a minimum of 4 years postoperatively, three groups were defined: isolated MPFLr, MPFLr with tibial tubercle (TT) medialisation or MPFLr with TT medialisation and distalisation. IKDC and Kujala scores were evaluated. Patellar tilt was evaluated on the patient's preoperative and the last available radiograph, and on CT scan measurements performed preoperatively and at 6-month postoperatively.

Results The mean follow-up was 6.3 ± 1.7 years [4.1–10.3] and four patients reported recurrent patellar dislocation. Between pre and postoperative at last follow-up a significant improvement in IKDC and Kujala functional scores was observed ($P < 0.01$), with no difference between the three groups. Regarding patellar tilt, there were significant decreases in Laurin and Merchant angles and an improvement of the Maldague stage ($P < 0.01$). The CT analysis of patellar tilt also demonstrates a significant improvement of the patella tilt ($P < 0.01$). The control of the patella tilt was correlated with a good functional result ($P < 0.01$).

Conclusion The MPFLr, whether isolated or associated with a TT transfer, provides good long-term clinical and radiological outcomes with a low rate of recurrence. The addition of a TT transfer, when necessary, results in the same good outcomes. This article provides a guide for surgeons evaluating PFI to choose the most appropriate procedure.

Level of evidence IV.

Keywords Patellofemoral instability · Medial patellofemoral ligament · Ligament reconstruction · CT scan analysis · Long follow-up

Introduction

Patellofemoral instability (PFI) is the most common complication of acute patellar dislocation. This can occur after a traumatic dislocation or, more commonly, occurring in knee joints with abnormal anatomical structures [8]. The medial patellofemoral ligament (MPFL) prevents lateral translation of the patella and is the primary damaged anatomical structure when patellar dislocation occurs [13]. Anatomical and biomechanical studies have provided understanding of the MPFL behaviour during knee flexion and its role in control of patellar tilt [1, 23].

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Over the past few years, several techniques have been described for the management of PFI based on reconstruction of the medial soft tissue restraints, the medial retinaculum, or even the MPFL [9, 16]. The MPFL reconstruction (MPFLr), whether isolated or combined with a procedure such as lateral retinacular release, Tibial Tubercle (TT) transfer, or trochleoplasty, has become an effective and standard treatment for PFI [16]. Recent systematic reviews reported good clinical outcomes with low redislocation rates, although they reported many different techniques with a large variability in patient age [5, 17]. Comparatives studies with non-operative management have reported conflicting outcomes for redislocation rates and functional results [3, 6]. The heterogeneity of these results seem to be due to the variability of pathoanatomies among the subjects and the variability of techniques available, in terms of graft positioning and fixation, and other associated surgical procedures. Given the inconsistency in outcomes and a lack of clinical data, a large series with a significant follow-up is required to help surgeons give patients clear information about the expected results.

With several surgical treatment options available, managing patients with PFI remains a challenge with no clear guidelines for optimal treatment. A recent randomised controlled trial demonstrated that MPFLr in addition to TT transfer enhanced alignment parameters, such as the patellar tilt, but did not improve the clinical score and the redislocation rates [7]. Given the good results of isolated MPFLr [5], some surgeons do not perform any additional TT transfer even if there are bony risk factors to avoid complications which may affect the outcomes [20, 24]. Therefore, forming an algorithm for PFI surgical management based on the assessment of clinical and radiological outcomes is required.

The hypotheses were that MPFLr would improve the long-term symptoms of PFI and control patellar tilt, based on computed tomography (CT) and that the addition of a TT transfer, when necessary, would not deteriorate the outcome. The purpose of this study was to evaluate the long-term clinical and radiographic outcomes of a large series of MPFLr, either isolated or associated with a TT transfer.

Materials and methods

From 2007 to 2013, 133 knees in 126 consecutively referred patients with symptomatic PFI were included. Patients were followed up at a minimum of 4 years postoperatively with a mean follow-up of 6.3 ± 1.7 years [4.1–10.3].

The inclusion criteria were as follows: (1) PFI with two or more episodes of lateral patellar dislocations; (2) a positive patellar apprehension sign; (3) skeletal maturity; (4) no/low grade trochlear dysplasia (grade A of Dejour's classification [8]); (5) no previous patellofemoral realignment procedure (bony or soft tissue) and no significant ligamentous knee injury; (6) no osteoarthritis of the patella-femoral joint (grade 0 of the Kellgren–Lawrence system [14]); (7) competence for the follow-up period. The exclusion criteria were: (1) previous knee surgery; (2) incomplete radiographic exams (3) high grade trochlear dysplasia, (grades B, C or D of Dejour's classification [8]); (4) pure patella alta with Caton-Deschamps (C-D) index greater than 1.4 with a TT–Trochlear groove (TT–TG) distance lower than 20 mm. Based on these criteria, 31 patients were excluded leaving 126 patients for data analysis in this study (Fig. 1).

A complementary TT medialisation (TTm) was performed if the preoperative TT–TG distance was greater than 20 mm. For patients who also had patella alta with a C-D index greater than 1.4 [18, 27], TT medialisation was combined with a TT distalisation (TTm − d) (Fig. 1) [18]. No patient with isolated TT distalisation was included because only one patient had a pure patella alta (C-D index > 1.4) with TT–TG lower than 20 mm. No trochleoplasty was performed because patients with high trochlear dysplasia grade were not included (grade B, C and D of Dejour's classification). According to these indications, iMPFLr group comprised of patients who underwent isolated MPFL reconstruction (n = 89 knees), MPFLr + TTm group comprised patients who underwent MPFL reconstruction combined with TT medialisation (n = 31 knees) and MPFLr + TTm − d group comprised patients who underwent MPFL reconstruction combined with TT medialisation and distalisation (n = 13 knees) (Fig. 1). The demographic data of all patients are reported in Table 1. No statistically significant differences were found between the three groups for sex, BMI, age at surgery, and time between first dislocation and surgery.

Surgical technique

All surgical procedures were performed by a senior author. A primary arthroscopy was performed in case of osteochondral lesion. All grafts were gracilis autografts and prepared in "Y" shape to have a double bundle anatomic MPFL reconstruction. Positioning of the femoral and patellar tunnels was based on native MPFL anatomy as demonstrated in cadaver studies [22, 23]. The blind femoral tunnel was positioned at mid-distance between the adductor tubercle and the medial femoral epicondyle, and checked by fluoroscopy according the Schöttle criteria [25, 26]. For the patella, two anchors were used and placed at the upper pole and the junction between the middle and upper thirds of the patella. After manually reducing the lateral subluxation of the patella, the graft was simply positioned and tensioned with the knee in 30° of flexion void of any over constraint, and finally fixed with an interference screw on the femoral tunnel. Patellar tracking and graft tensioning were controlled prior to wound closure. The objective was to obtain a favourable isometry,

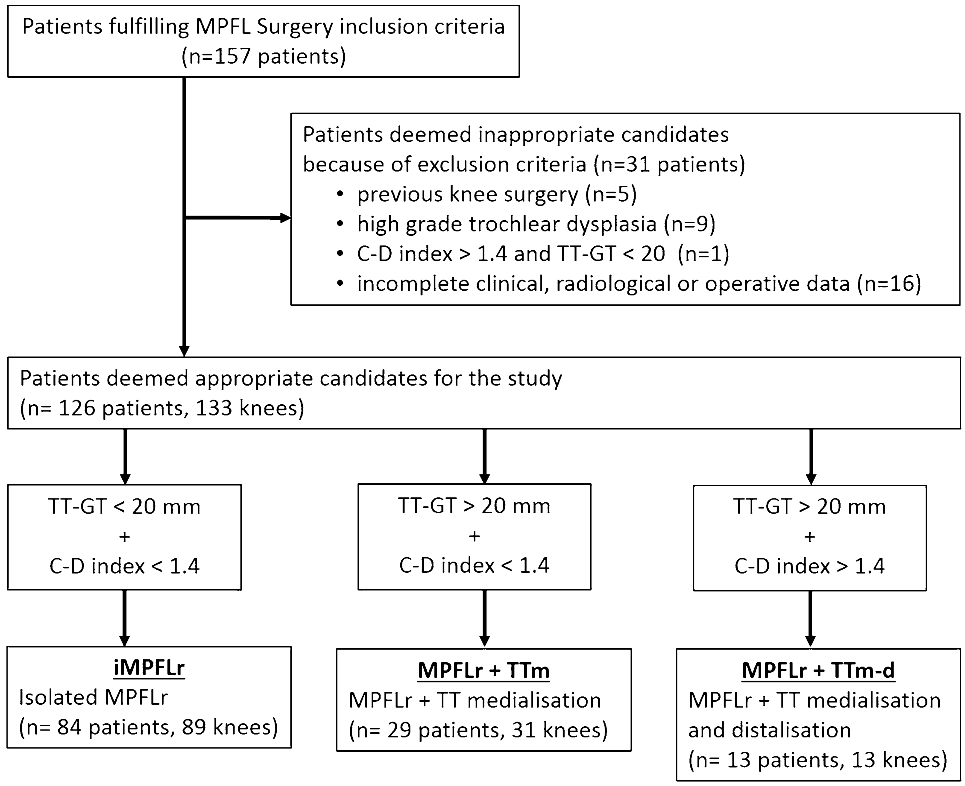

Fig. 1 Study flowchart demonstrating recruitment and selection of the surgical procedure. (*TT–TG* TT–Trochlear Groove distance, *C-D* caton-deschamps index, *iMPFLr* isolated medial patello femoral ligament reconstruction, *TTm* tibial tubercle medialisation, *TTm – d* tibial tubercle medialisation and distalisation)

Table 1 Demographic data

	iMPFLr	MPFLr + TTm	MPFLr + TTm – d	All patients	Difference between groups
Sex Male/female, *n* (SR)	34/55 (0.62)	12/19 (0.63)	5/8 (0.63)	51/82 (0.62)	n.s.
BMI Mean, SD (range)	24 ± 5 [16–37]	24 ± 5 [19–34]	23 ± 5 [18–365]	24 ± 5 [16–37]	n.s.
Age at surgery (years) Mean, SD (range)	24 ± [16–41]	24 ± 6 [16–39]	23 ± 6 [16–38]	24 ± 7 [16–41]	n.s.
Delay of surgery (years) Mean, SD (range)	5 ± 5 [0–16]	5 ± 3 [0–10]	4 ± 3 [1–9]	4 ± 4 [0–16]	n.s.

SR sex ratio, *BMI* body mass index, *delay of surgery* time between first dislocation and surgery, *iMPFLr* isolated medial patello femoral ligament reconstruction, *TTm* tibial tubercle medialisation, *TTm – d* tibial tubercle medialisation and distalisation

as described by Thaunat et al. [29], such that the graft was tight at 30° of flexion when the patella engages into the trochlea and relaxed beyond 60° of flexion to avoid stiffness.

Clinical and radiological evaluation

Clinical evaluation was performed using the International Knee documentation Committee (IKDC) and Kujala scores [15], in addition to a standardised clinical examination of knee range of motion (± 1°). The functional scores were performed preoperatively, at 6 months, 12 months and at a minimum of 4 years at final follow-up. Plain radiographs were performed concurrent to the clinical evaluation follow-up (preoperatively, at 6 months, 12 months and every 12 months). Patellar height was assessed on lateral view according to the Caton-Deschamps index (± 0.01). The patellar tilt angle was evaluated on an axial view (Merchant and Laurin views) and a lateral view (Maldague's classification, illustrated in Fig. 2), reported in degrees (± 1°) [19]. The postoperative femoral tunnel positioning was analysed according the Schöttle criteria [25]. For the radiographic analysis we compared the preoperative with

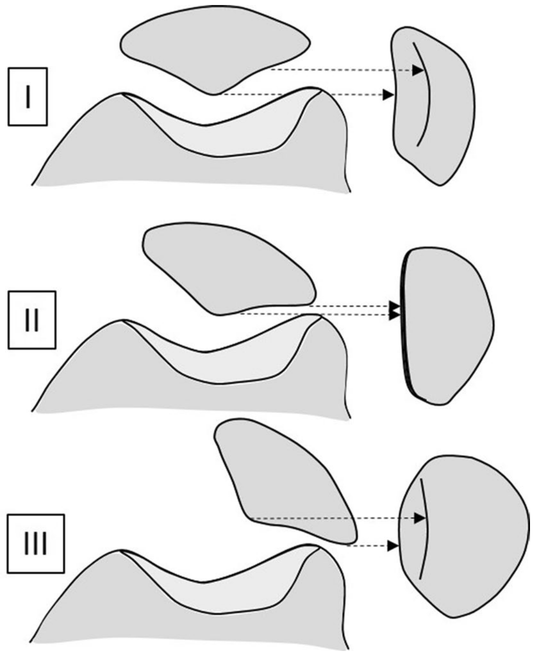

Fig. 2 Maldague's stages on lateral radiographic view. Depending on the patella tilt, the shape of the patella changes on lateral radiograph

the final radiograph, and the 6 months with the 12 months radiograph. A CT scan was performed preoperatively and at 6-month postoperatively to measure the TT–TG distance and quantify patellar tilt with quadriceps contracted (QC) and relaxed (QR) in degrees (± 1°). The threshold of 20° was set to define a pathological patellar tilt. All participants gave informed consent prior to their enrolment. The institutional review board (IRB) approval (number IRBN492015) was authorised by the ethics committee of Saint-Etienne university hospital.

Statistical analysis

All statistical analyses were performed using SPSS Statistics software (version 21, SPSS Inc., Chicago, IL, USA) and the significance threshold was set at $P < 0.05$.

The change in functional scores, clinical and radiological data, for the three groups were compared between pre- and postoperative time periods, after adjusting for baseline variables using analysis of variance (repeated-measures analysis of variance: ANOVA). Comparisons of pre and postoperative qualitative variables were performed using the Chi-squared test. Where conditions were not fulfilled, we used a Fisher's exact test. Correlations between femoral tunnel positioning and the change of functional scores (between pre and postoperative measurements for both scores) were determined with a Pearson correlation test. Correlations between femoral tunnel positioning and stiffness levels were also determined with Pearson correlation tests. The stiffness levels were defined in flexion by a reduced flexion ≤ 120°, and in extension by a lack extension ≥ 5°. We also analysed with Pearson test the correlations between functional score changes (for both scores, between preoperative time and last follow-up) and patellar tilt control (for QC and QR, between preoperative time and 6 months).

A post-hoc power analysis indicated that a large effect size ($f = 0.4$), $a = 0.05$ and a total sample size of 133 knees, produced the power of 0.99 ($b = 0.01$) (G*Power, version 3.1).

Results

Functional scores and clinical results

Between pre- and postoperative (12 months), a significant improvement for IKDC and Kujala functional scores was observed ($P < 0.01$), with no difference between the three groups (n.s.) (Fig. 3). After 4 years, functional scores were maintained or improved in comparison with the 12-month follow-up (n.s.), although there was no statistical significance between the three groups (n.s.). The mean flexion remained unchanged between the preoperative (140° ± 9 [100–160]) and the last follow-up (142° ± 9 [120–160]), and there were no significant differences between the three groups (n.s.). At the last follow-up, two patients still had stiffness in flexion (< 130°), but no patient had a flexion ≤ 110° or lacked full extension.

Imaging results

Regarding patellar height, C-D index decreased over time for MPFLr + TTm − d and a minima for MPFLr + TTm groups ($P < 0.01$), with no modification for the iMPFLR group (n.s.) (Table 2).

The distribution of femoral tunnel positioning according to Schöttle criteria is illustrated in Fig. 4. There were no significant correlations between femoral tunnel malpositioning and unfavourable functional outcomes (Kujala and IKDC) and between malpositioning and stiffness level of extension. Because all cases of anterior and proximal malpositioning induced reduced flexion (≤ 120°), a significant correlation was observed between malpositioning and a stiffness level of flexion ($P < 0.01$).

Regarding patellar tilt, the mean Merchant and Laurin angle improved significantly for all the patients over the time ($P < 0.01$), with no difference between the three groups (n.s.) (Table 2). At the last follow-up, a significant improvement in the patellar tilt according to the Maldague classification was observed for all patients ($P < 0.01$) with zero cases of stage three and no reports of aggravation of patellar tilt (Fig. 5).

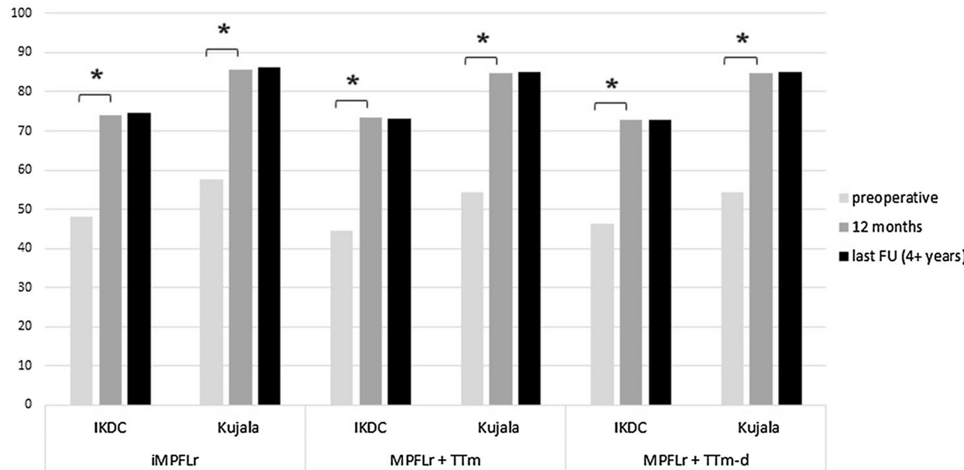

Fig. 3 Evolution of IKDC and Kujala scores for the three groups between preoperative, 12 months and the last follow-up with a minimum of 4 years. (*iMPFLr* isolated medial patello femoral ligament reconstruction, *TTm* tibial tubercle medialisation, *TTm − d* tibial tubercle medialisation and distalisation). *Significantly greater improvement for all groups and for the both scores between preoperative and 12 months of follow-up

Table 2 Assessment of patellar height using C-D index and patellar tilt using Merchant, Laurin angles and a CT scan analysis with quadriceps contracted (QC) and relaxed (QR)

	iMPFLr	MPFLr + TTm	MPFLr + TTm − d	All patients
C-D index				
Preoperative	1.10 ± 0.11 [0.81–1.37]	1.25 ± 0.09 [1.05–1.38]	1.44 ± 0.02 [1.42–1.53]	1.17 ± 0.15 [0.81–1.53]
Last FU (4+ years)	1.08 ± 0.11 [0.79–1.38]	1.10 ± 0.06 [0.9–1.25]	1.09 ± 0.07 [1–1.19]	1.09 ± 0.10 [0.79–1.38]
Diff	0.02 (n.s.)	0.15**	0.36**	0.08 (n.s.)
Merchant angle (°)				
Preoperative	14 ± 5 [0–26]	15 ± 6 [4–26]	15 ± 8 [2–26]	14 ± 6 [0–26]
Last FU (4+ years)	5 ± 5 [− 12 to 15]	5 ± 7 [− 10 to 16]	6 ± 3 [− 4 to 15]	5 ± 6 [− 12 to 16]
Diff	8.7**	9.3**	8.9**	8.9**
Laurin angle (°)				
Preoperative	6 ± 4 [0–16]	7 ± 4 [1–14]	6 ± 6 [1–16]	6 ± 4 [0–16]
Last FU (4+ years)	0 ± 4 [− 6 to 10]	1 ± 4 [− 6 to 12]	1 ± 4 [− 5 to 12]	0 ± 4 [− 6 to 12]
Diff	5.7**	6.1**	5.7**	5.8**
CT patellar tilt with QC (°)				
Preoperative	29 ± 8 [19–56]	31 ± 11 [13–48]	31 ± 14 [12–51]	30 ± 10 [12–56]
Last FU (4+ years)	16 ± 4 [5–29]	17 ± 4 [8–26]	17 ± 4 [9–24]	16 ± 4 [5–29]
Diff	13.1**	14**	13.7**	13.4**
CT patellar tilt with QR (°)				
Preoperative	26 ± 7 [18–46]	25 ± 11 [8–45]	26 ± 12 [8–44]	26 ± 9 [8–46]
Last FU (4+ years)	14 ± 4 [4–25]	15 ± 4 [8–26]	15 ± 5 [2–23]	14 ± 4 [2–26]
Diff	12.1**	9.8**	11.3**	11.5**

iMPFLr Isolated medial patello femoral ligament reconstruction, *TTm* tibial tubercle medialisation, *TTm − d* tibial tubercle medialisation and distalisation, *diff* difference between pre- and postoperative period: last follow-up or 6 months for the CT analysis

**$P < 0.01$

Quantitative CT analysis of patellar tilt demonstrates a significant improvement at 6 months, for all groups ($P < 0.001$) with no difference between the three groups (n.s.) (Table 2). From 82% (QC) and 68% (QR) of patients with a preoperative pathological patellar tilt, 5% (QC) and 3% (QR) remained pathological postoperatively (Fig. 6). All of these patients, with a persistent pathological tilt, had important preoperative patellar tilt, upper than 40° (QC and QR). None of the patients with initial normal patellar tilt reported pathological patellar tilt postoperatively. Regardless of the group, a significant correlation could be established between functional score improvement and CT scan correction of patellar tilt, for QC and QR (Table 3). There were strong positive correlations between variables, with significant coefficients between 0.6 and 0.79 ($P < 0.01$).

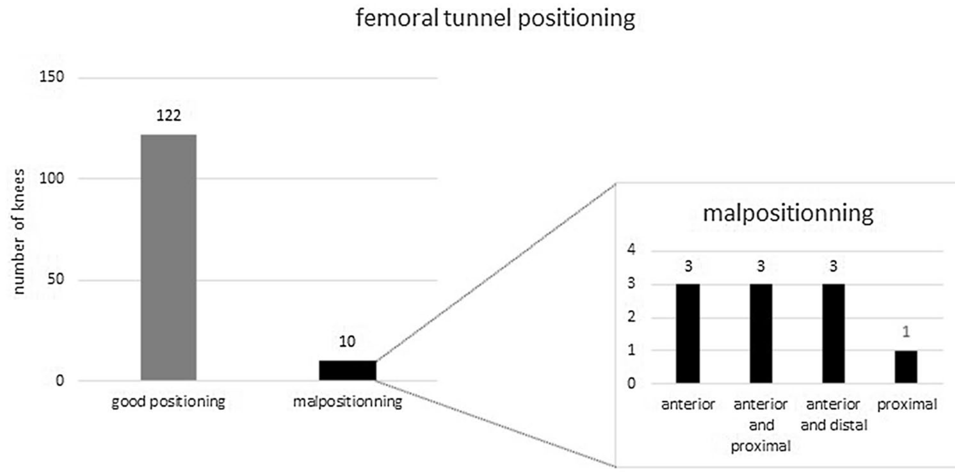

Fig. 4 Distribution of femoral tunnel positioning according to Schöttle criteria

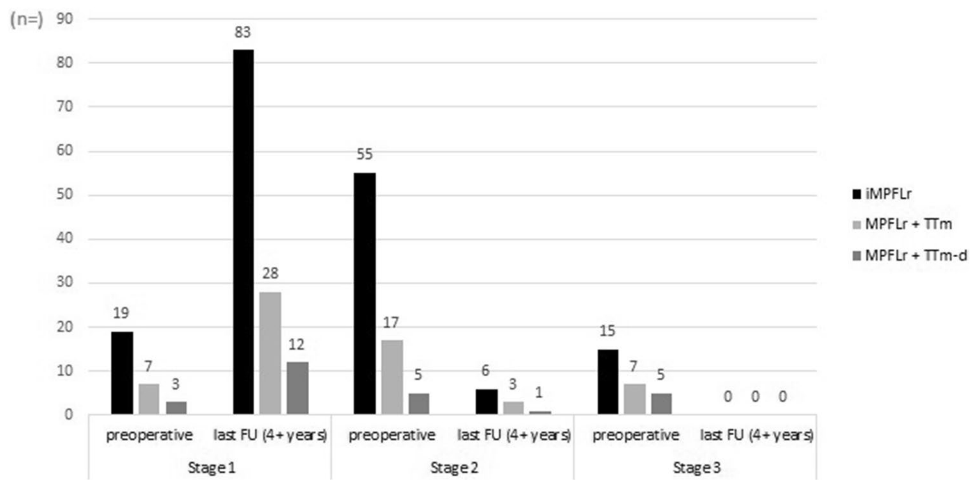

Fig. 5 Knee distribution according to Maldague's classification [19] for the three groups, between preoperative and the last follow-up with a minimum of 4 years

Table 3 Pearson correlation coefficients between CT patellar tilt control (for QC and QR) and functional improvement (for IKDS and Kujala score)

	Patella tilt with QC	Patella tilt with QR
Kujala	0.677**	0.658**
IKDC	0.732**	0.680**

QC Quadriceps contracted, *QR* quadriceps relaxed

**$P < 0.01$

Complications

Four patients (iMPLFr: $n = 3$, MPFLr + TTm: $n = 1$) had a recurrent patellar dislocation. In all cases, it was a high energy post-traumatic recurrence (fall from a bike, road accident, 3 m fall). They had iterative reconstruction using semitendinosus tendon graft and demonstrated no recurrent instability at last follow-up. One patient, having undergone a TT medialisation, reported tibial fracture requiring iterative osteosynthesis. Ten patients from the groups with TT transfer had anterior knee pain due to hardware soft tissue irritation and were improved by the hardware removal. In group iMPFLr, two patients with painful patellar fixation anchors had removal of protruding anchors resulting in pain relief which did not affect patellofemoral stability.

At 6 months postoperative, nine patients complained of stiffness in flexion (≤ 120°) (iMPLFr: $n = 5$, MPFLr + TTm: $n = 3$, MPFLr + TTm + d: $n = 1$), due to complex regional pain syndrome ($n = 4$), malpositioning of the femoral tunnel ($n = 3$), knee pain with soft tissue irritation due to screws of TT transfer (= 1) or patella anchors ($n = 1$). Two of them (both from group iMPFLr) had revision surgery because of high stiffness (flexion ≤ 110°); one manipulation under anaesthesia at 3 months and one case of disabling knee flexion contracture related to malpositioning of the femoral tunnel was managed with arthrolysis and arthroscopic medial capsulotomy at 6 months. Both patients returned to satisfactory mobility with no recurrent dislocation. From 21 cases of amyotrophic quadriceps reported at 6 months (iMPLFr: $n = 13$, MPFLr + TTm: $n = 5$, MPFLr + TTm + d: $n = 3$), seven still persisted at 12 months and at the last follow-up

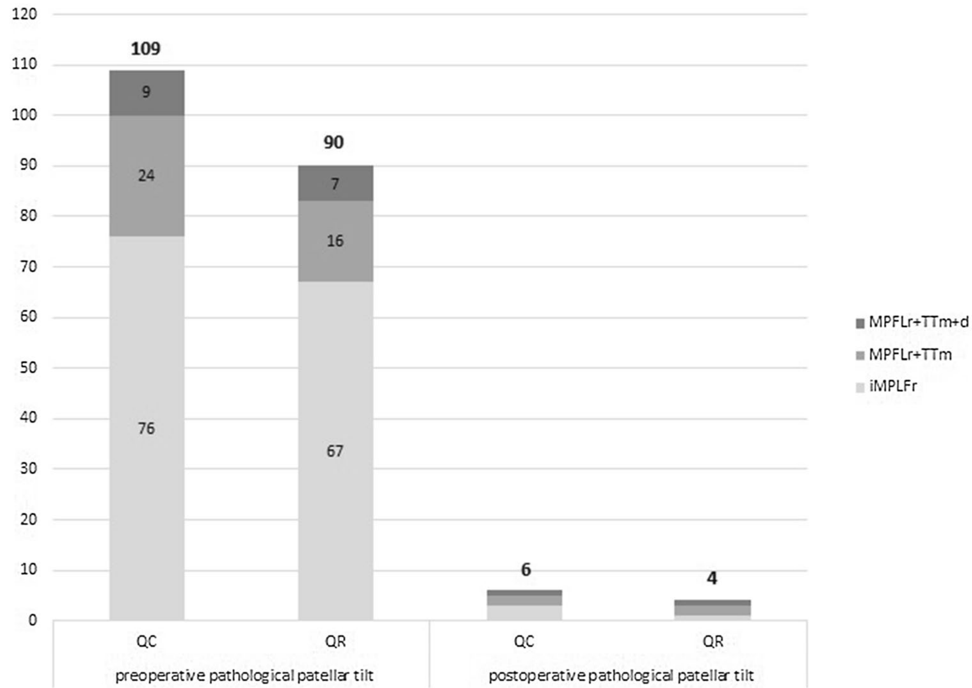

Fig. 6 Distribution of patellar pathological tilt, assessed by CT scan pre- and postoperatively

(iMPLFr: $n=4$, MPFLr + TTm: $n=2$, MPFLr + TTm + d: $n=1$).

Discussion

The most important finding of this study is that MPFLr, whether isolated or combined with a TT transfer, improves the long-term clinical results, as well as providing good control of the patellar tilt. The addition of TT transfer, when it is necessary, does not have a negative impact on these good outcomes.

Managing patients with PFI remains a challenge for surgeons. Therapeutic choice making is multifactorial and there are no clear guidelines for optimal treatment available [16, 24].

Given that isolated MPFL reconstruction has now proved its efficiency in the improvement of clinical results and dislocation rates at short and mid-term, and that this intervention is with few complications [5], the choice between several treatment options is difficult and some surgeons do not perform any additional bony procedure even if there are bony risk factors. Moreover, most long-term studies are small case series, using several MPFLr methods, often combined with soft tissue or bony additional procedure. To our knowledge, only one RCT which compared MPFLr and lateral release with TT transfer and lateral release, is available [7]. But this study does not directly compare an isolated MPFLr with MPFLr associated with a TT transfer. The authors concluded that there was insufficient evidence to determine if the addition of MPFLr to TT transfer is necessary; this question requires further studies with larger patient numbers and long-term results. Matsushita et al. reported in a comparative study, that overall clinical outcomes of isolated MPFLr were favourable with no redislocation, even in patients with an increased TT–TG distance [20]. However, it was a retrospective study based on a small sample. Although our study is not an RCT, making it difficult to compare patient groups with different predisposing factors, there is still reasonable validity. First, we demonstrated through a large series and with a long follow-up that isolated MPFLr improved the functional scores while allowing to obtain a good control of the patella tilt. Second, we have shown that even if the bony procedure seems more invasive, it does not affect the good clinical results of the patients. This will enable the surgeons to give clear information to the patient on the long-term post-surgical outcomes of these surgical procedures. However, our study is not designed to answer the question if isolated MPFLr is sufficient to control the PFI symptoms for patients with pathological TTGT or patella alta. As concluded, in the recent consensus statement from the American Orthopedic Society for Sports Medicine (AOSSM) and the Patellofemoral Foundation (PFF), TT medialisation is not commonly included in surgery for PFI, with no evidence to indicate medialisation as a necessary part of instability surgery [24].

Many studies have been conducted on patellar tilt in PFI. However, very few focused on patellar tilt correction following MPFLr. As demonstrated in the literature, analysis of simple radiographs could confirm patellar tilt correction.

Nevertheless, such analysis is subjected to a wide intra- and interobserver variability thus reducing result accuracy. As explained by Schöttle et al. the use of a CT scan with higher accuracy and reproducibility is preferable [25]. Damasena et al. demonstrated that isolated MPFLr could reduce patellar tilt [7]. Our study confirmed these results, reporting a significant correlation between patellar tilt correction and functional score improvement. Nevertheless, according to our qualitative analysis, such correction was not sufficient for some patients (3–5%) with an important preoperative pathological patellar tilt greater than 40°. This insufficient correction could not be correlated with recurrent PFI or inferior functional scores. Some authors even suggest that a hyper correction of the patellar tilt control, induced by graft over tensioning, could increase the medial patellofemoral contact pressures and cause subsequent damage to the medial patellofemoral cartilage [11, 12, 21, 28]. Our study, as well as that of Damasena et al. with a 5-year follow-up [7], suggest that MPFLr did not induce early osteoarthritis. However, further long-term studies are required to support this conclusion and surgeons must avoid graft over-tensioning.

There are two potential complications after MPFLr that should be carefully monitored and reported to patients. Whatever the procedure, 16% of our patients had quadriceps amyotrophy at 6 months with 5% still persisting at the last follow-up. Being a major return-to-play criterion, this complication should, therefore, be tracked and intensively corrected [31]. Thaunat et al. suggested that the persistent quadriceps inhibition is associated with over-tensioning of the MPFL in extension producing medial patella subluxation during terminal active extension, or even commonly an extension lag of 10°–15° [29, 30].

The second complication was stiffness (7% of our patients); the causes are multifactorial and will need to be analysed carefully. Regarding the soft tissue irritation due to the hardware, it will be necessary to carefully bury anchors and screws. We preferred use of anchors than tunnels for the patella fixation because of the risk of patella fracture. As explained by Bonazza et al., patella tunnels may weaken the patella and induce a fracture [4]. We also observed no case of fixation failure with the anchors. Nevertheless, it is absolutely necessary to fully penetrate them into the bone and cover them by the medial retinaculum to avoid soft tissue irritation. As demonstrated by our results, anatomical positioning of the femoral tunnel is challenging and femoral tunnel malpositioning could also lead to postoperative stiffness. Despite intra-operative radiological control, we reported 7.5% of MPFLr femoral tunnels were malpositioned. Only anterior and proximal malpositioning are correlated with reduced flexion. Of the three patients exhibiting this kind of tunnel malpositioning, one underwent revision surgery. Other tunnel malpositioning did not appear to be related with reduced flexion. Due to the small incidence of each case of malpositioning, statistical tests could not be performed. Consequently, we could not determine any correlation between clinical scores and malpositioning of the femoral tunnel. Data from the literature vary significantly. Melegari et al. showed that a non-anatomic tunnel placement will not adversely affect patellofemoral contact area and pressure [21]. Conversely, other authors suggest that femoral malpositioning leads to overconstraint of the patella [12]. Anterior malpositioning of the femoral tunnel [10] or proximal malposition [2] can induce a knee stiffness in flexion and an overloading of the PF medial cartilage. Stephen et al., found that only proximal or distal malpositioning of the femoral tunnel may result in a graft overtensioning [28].

Several limitations should be noted. As explained, for comparing the different procedures, it would have been preferable to have a randomised control prospective study. We compared three groups of patients non similar in regard to bony risk factors (TTGT distance, patella height). To limit any bias, we excluded patients with a high grade of trochlear dysplasia and pure patella alta. It would present an ethical challenge to perform only an isolated MPFLr without treating an excessive TTGT distance or a patella alta, knowing that the correction of these risk factors is recommended. Nevertheless, long-term clinical and radiological outcomes after each procedure was obtained. For the lack of correlation between clinical scores and malpositioning of the femoral tunnel, a larger study, with more statistical power is required to make a more thorough conclusion on this point.

Conclusion

The MPFLr, whether isolated or associated with a TT transfer, provides good long-term clinical and radiological outcomes with a low rate of recurrence. The addition of a TT transfer, when necessary, results in the same good outcomes. This article provides a guide for surgeons evaluating PFI to choose the most appropriate procedure.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of our institutional research committee and with the 1964 Helsinki declaration and its later amends or comparable standard.

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