BMC Musculoskeletal Disorders

RESEARCH

Open Access

MPFL reconstruction vs. Insall procedure for adolescent patellar instability: nine-year follow-up on osteoarthritis, redislocations, and return to sports

Maija Jääskelä[1,7*], Marja Perhomaa[1,2], Lasse Lempainen[3,4,5] and Jaakko Sinikumpu[1,6]

Abstract

Background Medial patellofemoral ligament reconstruction (MPFLR) has become increasingly common in treating patellofemoral instability (PFI). Previously, proximal realignment surgeries, such as Insall's procedure, were preferred in adolescents with open physes. More evidence is needed on the long-term outcomes of MPFLR and Insall's procedures, particularly regarding the risk of early postoperative osteoarthritis and redislocation.

Methods A total of 129 patients under 17 years of age who underwent surgery for PFI between 2005 and 2019, with a minimum follow-up time of 24 months, were retrospectively evaluated. Inclusion criteria comprised isolated medial patellofemoral ligament reconstruction (MPFLR) or Insall's proximal realignment with at least partially open physes at surgery and residence within the hospital district to enable follow-up. Of the 129 patients, 31 met the inclusion criteria, and 24 patients (25 knees; 77%) participated in long-term clinical and radiographic follow-up. Most patients were female (62%) with a mean surgery age of 14.5 ± 1.3 years. Osteoarthritis, redislocations, return to sports, subjective knee-specific recovery, and health-related quality of life were investigated. The mean follow-up time 9 years (range 2 to 18). The long-term outcomes were compared between the treatment groups.

Results Patellofemoral osteoarthritis (Kellgren and Lawrence II–IV) was found in one knee (6.7%) after MPFLR and in six (60%) knees after Insall's procedure (P=.004). No tibiofemoral osteoarthritis was found after MPFLR but was present in four (40%) knees after Insall's (P=.008). No MPFLR patients required reoperation compared to a 40% (4/10) in the Insall's group (P=.008). At follow-up 26.7% (4/15) of MPFLR and 80% 8/10) of Insall's patients were unable to return in pivoting sports due to residual symptoms (P=.008). No significant differences were found in IKDC (MPFLR 77.8 [SD 14.9] vs. Insall 's77.5 [SD 18.4], P=0.973) or Lysholm scores (MPFLR 80.5 [SD 12.9] vs. Insall's 77.1 [15.2], P=0.589).

Conclusion MPFLR showed superior long-term outcomes compared to Insall's procedure in skeletally immature patients with recurrent PFI, with lower rates of osteoarthritis and reoperation.

Keywords Patellar lateral dislocation, Patellofemoral instability, Skeletal immaturity, MPFL reconstruction, Proximal realignment procedure, Osteoarthritis

*Correspondence:
Maija Jääskelä
Maija.jaaskela@student.oulu.fi

Full list of author information is available at the end of the article

Introduction

Acute patellar lateral dislocation (PLD) is one of the most common knee injuries during childhood and adolescence, with an incidence of 0.3–1.2 per 1,000 in children aged 9–15 years [1–3]. As many as half of these children may develop recurrent instability, usually within five years of initial injury [4]. Without appropriate treatment, PLD can lead to recurrent dislocations, instability, anterior knee pain, and patellofemoral (PF) degeneration [4–6]. Younger age, open growth plates, trochlea dysplasia, an increased tibial tuberosity-trochlear groove (TT–TG) distance, and patella alta have been identified as key risk factors for PLD recurrence [7]. Furthermore, joint hypermobility is more common among patients with recurrent patellar instability [8].

Given that patellofemoral instability (PFI) is usually multifactorial in etiology, its treatment in skeletally immature patients is particularly challenging. The presence of open growth plates excludes most bone procedures due to the risk of premature or asymmetric closure of growth plates and the subsequent limb deformity [9]. In general, surgical procedures to treat PFI are classified as non-anatomic or anatomic. Non-anatomic procedures include extensor mechanism realignment techniques that aim to center the patella within the trochlear groove. Examples include proximal realignment procedures (e.g., Insall's and Madigan's operations) and distal realignment procedures (i.e., tibial tuberosity osteotomies). Conversely, anatomic procedures aim to restore the PF joint anatomy, such as by repairing ruptured ligaments or fixing osteochondral fractures [10, 11].

Historically, non-anatomic proximal realignment procedures were commonly used to treat PFI in skeletally immature patients, supported by the idea that growing bones were not harmed. However, surgical management has evolved toward anatomical reconstruction, and the popularity of ligament reconstruction procedures has increased substantially over the past 15 years [11]. Correspondingly, medial patellofemoral ligament reconstruction (MPFLR) has become the first-line treatment for recurrent PLD among most knee surgeons [12].

In this study, we compared the long-term outcomes of MPFLR and Insall´s proximal realignment procedure in patients, with at least partially open physes at the time of surgery. In particular the risk of early postoperative osteoarthritis (OA) and redislocation.

Methods

Approval for the study protocol was provided by the ethics committee was of the study center. All study participants or their legal guardians provided their informed consent. In this single-center study, children and adolescents under 17 years of age ($N = 129$) who had undergone surgical treatment for patellofemoral instability between 2005 and 2019, with a minimum follow-up of 24-month at the time of data collection (January 2022) were initially included in the evaluation. Hospital journals and radiographs were reviewed to confirm the diagnosis and eligibility of the patients. The inclusion criteria for the study were age under 17 years and at least partially open physes confirmed on radiographs at the time of PFI surgery, having undergone either an isolated medial patellofemoral ligament reconstruction (MPFLR) or an Insall's proximal realignment procedure. Additionally, eligible patients were required to reside within the hospital district at the time of follow-up to ensure their ability to participate in the clinical and radiographic evaluation. Patient were excluded ($N = 98$) from the study if they were residence outside the Hospital district, had closed physes, or had been treated with procedures other than isolated MPFL reconstruction or Insall's proximal realignment procedure (e.g., lateral release or lengthening, tibial tuberosity transfer, or sulcus deepening trochleoplasty). Ultimately, 31 patients met the inclusion criteria and were enrolled in the study. All eligible patients were invited to a clinical and radiographic follow-up visit conducted between May and October 2022.

The surgery performed was based on the treating surgeon's decision and selected individually for each patient. Insall´s proximal realignment procedures were performed until 2010, after which MPFLR became the standard procedure at the study center. The proximal realignment procedure was performed through an anterior midline incision according to the technique described by Insall [13]. The lateral retinaculum was first released or lengthened while preserving the integrity of the third layer (the capsule). The vastus medialis oblique (VMO) was then released and reattached to the lateral border of the patella or the lateral aspect of quadriceps tendon using non-absorbable sutures. Finally, the medial capsule was tightened to improve patellar stability.

Outcome Measures

Early postoperative osteoarthritis of the patellofemoral joint was considered as the main outcome. Standardized weight-bearing radiographs were taken to assess both patellofemoral (PF) and/or tibiofemoral (TF) OA according to the Kellgren and Lawrence classification system (KL) [14]. All imaging studies were assessed by a senior radiologist with 30 years of clinical experience in the field. The radiologist was blinded to the treatment allocation, except in cases where a presence of a clearly visible tenodesis drill canal was on radiographs rendered blinding unfeasible.

The principal clinical outcome was redislocation, defined as the need for a reoperation due to recurrent patellar dislocation. This was based both on the review of the hospital journals and operational notes and

questioning the information from the patient and the parents. AT the follow-up visit, participants were also asked about their current symptoms, ability to return to their preinjury level of sports, general and knee-specific pain, and their subjective satisfaction with the surgery. The participants completed surveys that included patient-reported outcome instruments for knee-specific recovery and health-related quality of life. The patient-reported outcome instrument was selected according to the age of the patient at the time of follow-up.

Knee-specific recovery was evaluated using the IKDC Subjective Knee Form and the Lysholm knee scoring scale, both scored from 0 to 100, with higher scores indicating better function [15, 16]. Patients under 18 years of age at the time of the follow-up visit completed the pediatric version of the IKDC (Pedi-IKDC) [17]. To determine satisfactory knee recovery, the age- and sex-matched normative data for the IKDC 2000 for men and women with no current or past knee problem were used as cutoff scores: 95.5 for men and 93.4 for women aged 18–24 years and 94.6 for men and 92.5 for women aged 25–34 years [18]. For patients under 18 years, a published median value of 94.6 was used as the cutoff score [19]. A Lysholm score of 95 was used to indicate satisfactory recovery, based on reference value for individuals with normal knees [20].

Health-related quality of life was measured using the EuroQol five-level EQ-5D (EQ-5D-5 L) for patients > 18 years old and the youth EQ-5D (EQ-5D-Y) for patients < 18 years old [21, 22]. In part 1, the patients chose responses from five levels for the EQ-5D-5 L (*no problems* to *extreme problems*) or from three levels for the EQ-5D-Y (*no problems* to *a lot of problems*) in response to five categories: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. In part 2, the patients recorded their health on the day of the survey on a visual analog scale (0 = worst, 100 = best). In radiographs, axial linear patellar displacement and patellar tilt by Laurin's angle, loose bodies, joint effusion, and the Caton–Deschamps index (CDI) for patella height were assessed [23–26]. The clinical examination included manual tests for patellar instability (e.g. J-sign, apprehension test, patellar glide, grind, and crepitation). Physical measurements included height, weight, body mass index (BMI), knee range of motion (ROM), and side-to-side differences in thigh and shin circumferences in centimeters. Muscle strength differences in leg extension and flexion were measured using a leg extension/curl gym machine (arthrometer). A minimum of 5 kg strength difference between the sides was considered significant by the authors. General joint laxity was assessed using the Beighton method [27].

Statistical analysis

The outcomes were compared between patients who underwent MPFL reconstruction and those who underwent Insall's procedure. Descriptive statistics are presented as the means, ranges, and standard deviations for normally distributed continuous variables. The normality of the dataset was investigated using the Shapiro–Wilk test. Mean values were compared using the independent samples *t*- test. Dichotomous variables are presented as frequencies and proportions. Differences between the proportions of the variables were analyzed using the standardized nominate deviation test, and the distribution of the variables was examined using the chi-square test or Fisher's exact test in cases of small sample sizes ($n < 5$). The threshold for statistical significance was $P < .05$. We required that all analyses were two-tailed and that 95% confidence intervals were used wherever possible. The statistical analyses were performed using SPSS version 27.0 (IBM Corp.) and StatsDirect version 3.0 (StatsDirect Ltd.).

All patients, who met the predetermined inclusion criteria were initially included and recruited for the study. The participation rate for the long-term follow-up visit was 77.4%. A post-hoc power analysis was performed using the observed difference in the primary outcome (OA in 60% vs. 7%), with alpha 0.05 and treatment group sample sizes of 10 and 15. This yielded a satisfactory statistical power of 84%.

Results

Patient characteristics

Overall, 24 out of 31 patients (77%) who initially met the inclusion criteria participated in the follow-up examinations. One patient in the Insall's group had both knees operated before the age of 17. Thus, the final number of knees included in this study was 25, with 15 treated using MPFLR (15) and 10 treated using Insall's proximal realignment procedure.

The majority of patients were females ($n = 17$, 62.1%). The mean age at the time of surgery was 14.5 ± 1.3 years (14.4 ± 1.5 in the MPFLR group vs. 14.7 ± 1.0 in the Insall's group $P = .565$). The overall mean follow-up time was 8.8 ± 4.4 years (6.1 ± 2.7 years in the MPFLR group vs. 13.0 ± 2.8 years in the Insall's group, $P = < 0.001$).

Gracilis tendon (GT) was the most commonly used autograft for MFPL reconstruction (10/15, 66.7%), followed by the semitendinosus (4/15 26.7%) and the quadriceps tendons (1/15, 6.7%).

MRI was performed significantly more often for patients treated with MPFLR than those in Insall's group (100% vs. 20% $P = < 0.001$). Underlying anatomical risk factors for recurrent instability (e.g., high-riding patella, dysplastic trochlea, laterally located tibial tuberosity, lower extremity malalignment or any bony deformation)

Table 1 Characteristics of the study patients

		All N=25 (24 persons)			MPFL Reconstruction N = 15 (15 persons)			Insall N=10 (9 persons)			Diff. (95% CI)	P-value[a]
		Mean (SD)	N	%	Mean (SD)	N	%	Mean (SD)	N	%		
Age at the time of surgery (years)		14.5 (1.3)			14.4 (1.5)			14.7 (1.0)			0.3 (–0.7 to 1.3)	.565
Sex	Female		17	62.1		9	60.0		8	88.9	28.9 (–10.7 to 57.5)	.107
	Male		7	37.9		6	40.0		1	11.1		
Follow-up time (years)		8.8 (4.4)			6.1 (2.7)			13.0 (2.8)			6.9 (4.6 to 9.3)	**<.001**
BMI at the time of the last follow-up visit		25.3(4.0)			24.0 (2.6)			27.3(5.3)			3.3 (– 0.8 to 7.5)	.106
Injury side	Left		12	48.0		9	60.0		3	30.0	30.0 (–10.6 to 61.3)	.134
	Right		13	52.0		6	40.0		7	70.0		
General joint laxity (Beighton score)[b]		4.1 (2.4)			3.9 (2.7)			4.4 (1.9)			0.5 (–1.4 to 2.5)	.548
Any anatomic risk factors for dislocation[c]			24	96.0		14	93.3		10	100.0	6.7 (–22.8 to 30.4)	>.999
Pre-operative imaging	X-ray		23	92.0		13	86.7		10	100.0	13.3 (–16.9 to 38.5)	.250
	MRI		17	68.0		15	100.0		2	20.0	80.0 (48.3 to 94.5)	**<.001**
	Torsioprofile MRI		1	4.0		1	6.7		0	0.0	6.7 (–22.8 to 30.4)	>.999
	Mechanical axis radiographs		1	4.0		1	6.7		0	0.0	6.7 (–22.8 to 30.4)	>.999

Data are reported as mean ± SD or No. (%) of patients unless otherwise indicated

Table 2. Radiological findings at the time of the follow-up in mean 9 years postoperatively

	All N=25 (24 persons)			MPFL Reconstruction N=15 (15 persons)			Insall N=10 (9 persons)			Diff (95% CI)	P-value[a]
	Mean	N	%	Mean	N	%	Mean	N	%		
Patellofemoral osteoarthritis (KL≥2) [b]		7	28.0		1	6.7		6	60.0	53.3 (17.4 to 79.1)	**.004**
KL2 mild		4	16.0		1	6.7		3	30.0	23.3 (–7.2 to 55.8)	.142
KL3 moderate		3	12.0		0	0.0		3	30.0	30.0 (5.2 to 60.9)	**.026**
Tibiofemoral osteoarthritis (KL≥2) [b]		4	16.0		0	0.0		4	40.0	40.0 (6.9 to14.2)	**.008**
KL2 mild		2	8.0		0	0.0		2	20.0	20.0 (–3.6 to 51.6)	.07
KL3 moderate		2	8.0		0	0.0		2	20.0	20.0 (–3.6 to 51.6)	.07
Loose bone/cartilage fragment		9	36.0		6	40.0		3	30.0	10.0 (–27.6 to 43.3)	.610
Joint effusion		3	12.0		3	20.0		0	0.0	20.0 (–10.3 to 40.7)	.132
Caton-Deschamps index (crude value)	1.1 (0.2)			1.2 (0.1)			1.1 (0.2)			0.1 (–0.1 to 0.2)	.419
High-riding patella (CDI>1.3)		3	12.0		2	13.3		1	10.0	3.3 (–30.3 to 31.1)	>.999
Patellar lateralization [c]	0.6 (1.2)			0.3 (0.7)			1.1(1.5)			0.8 (–0.4 to 1.9)	.164
Increased Patellar tilt [d]		3	12.0		1	6.7		2	20.0	13.3 (–15.0 to 46.5)	.298

Data are reported as mean ± SD or No. (%) of patients unless otherwise indicated

were common and present in all but one knee ($n = 24$, 96%). (Table 1).

Osteoarthritis

In total, osteoarthritis was identified in seven of 25 knees (28%). Patellofemoral OA (KL ≥ 2) was observed in one knee (6.7%) in the MPFLR group and in six (60%) knees in the Insall's group ($P = .004$). No tibiofemoral OA was found in the MPFLR group, whereas four knees (40%) in the Insall's group showed signs of TF OA ($P = .008$). All patient with TF OA also had PF OA. The relative risk (RR) of developing PF OA following MPFLR was 0.10 compared to the Insall's procedure (95% Cl: 0.02 to 0.79, $P = .001$).

No statistically significant differences were found between treatment groups regarding the presence of loose bodies (40% in the MPFLR group vs. 30% in the Insall's group), joint effusion (20% vs. 0%), high-riding patella (13.3 vs. 10%), abnormal patellar lateralization (0% vs. 20%), or abnormal patellar tilt (6.7% vs. 20%) (Table 2.; Fig. 1).

Redislocations

No patient in the MPFLR group required reoperation due to recurrent patella dislocation. In contrast, four patients (40%) in the Insall's group underwent reoperation for redislocation ($P = .008$). The mean time to reoperation was approximately 3.4 years followingr the primary surgery. The relative risk (RR) of treatment failure—defined as either clinical signs of patellofemoral instability at final follow-up or reoperation due to redislocation—was 0.10 in the MPFL reconstruction group compared to the Insall's procedure group (95% CI: 0.02–0.79, $P = .01$) (Table 3).

Other surgical interventions

Overall, seven patients (28%) underwent reoperation for any reason;20% in the MPFLR group and 40% in the Insall's group ($P = .227$). In the Insall's group two patients underwent tibial tubercle osteotomy with distal and medial transfer of the tendon attachment. On patient had a femoral varus osteotomy and another underwent subsequent MPFL reconstruction following initial Insall's procedure.

In the MPFLR group, one patient experienced a surgical site infection requiring graft and implant removal.

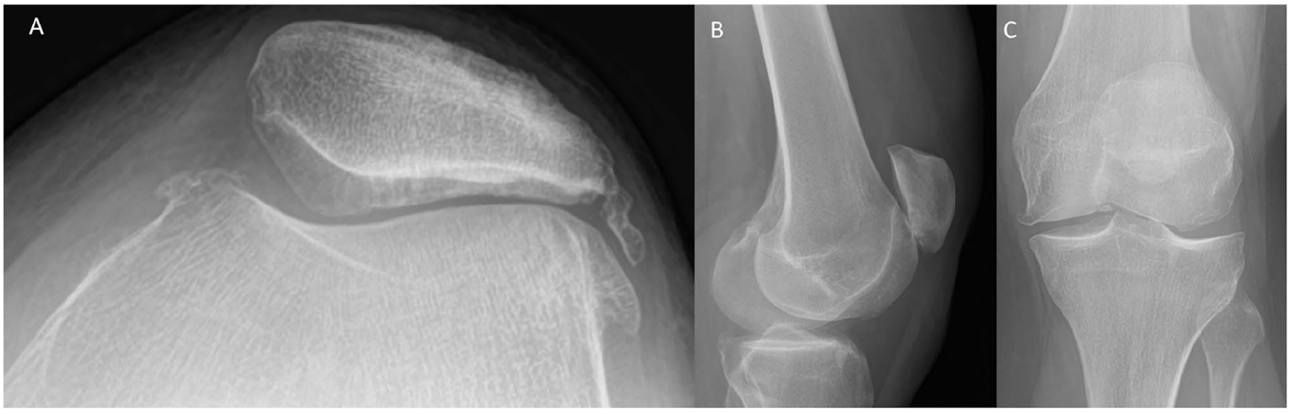

Fig. 1 X-ray of a 32-year-old female patient, 17 years after Insall's procedure, showing moderate (KL III) patellofemoral and mild (KL II) tibiofemoral osteoarthritis

Table 3 Reoperations and patient reported outcomes at the time of follow-up visit in mean 9 years postoperatively

	All N=25 (24 persons)			MPFL reconstruction N = 15 (15 persons)			Insall N=10 (9 person)			Diff. (95% CI)	
	Mean	N	%	Mean	N	%	Mean	N	%		P-value[a]
Redislocation*		4	16.0		0	0.0		4	40.0	40.0 (14.2 to 69.2)	**.008**
Other reoperations (all)		7	28.0		3	20.0		4	40.0	20.0 (−16.0 to 54.3)	.227
FDO due to anterior knee pain**		1	4.0		1	6.7		0	0.0	6.7 (−22.8 to 30.4)	>.999
Removal of cartilage loose fragment		1	4.0		1	6.7		0	0.0	6.7 (−22.8 to 30.4)	>.999
Graft removal due to deep surgical site infection		1	4.0		1	6.7		0	0.0	6.7 (−22.8 to 30.4)	>.999
Age at the time of the reoperation (mean)	18.6 (2.0)			17.6 (2.3)			19.0 (2.0)			1.4 (−7.3 to 10.3)	.534
Reopertion timing after index surgery (years)	3.8 (2.0)			4.6 (3.0)			3.4 (1.8)			1.2 (−14.2 to 16.7)	.665
Clinical signs of PFI* at time of the final follow-up**		3	12.0		1	6.7		2	20.0	13.3 (− 15.0 to 46.5)	.298
Treament failure (reoperation for recurrence and/or clinical signs of PFI)		7	28.0		1	6.7		6	60.0	53.3 (17.4 to 79.1)	**.004**
Treament failure (subjectively reported redislocation and/or PFI reoperation)		9	36.0		2	13.3		7	70.0	56.7 (17.8 to 81.1)	**.005**
Patient reported PFI at the time of final follow-up											
Dislocation		5	20.0		2	13.3		3	30.0	16.7 (−16.0 to 50.8)	.211
Subluxation		10	40.0		5	33.3		5	50.0	16.7 (−21.2 to 51.8)	.282
Knee pain reported at the time of FU		17	68.0		11	73.3		6	60.0	13.3 (−23.1 to 47.6)	.484
Anterior knee pain		4	16.0		2	13.3		2	20.0	6.7 (−23.1 to 37.8)	.656
VAS pain 1-10 (mean)	1.0 (2.0)			0.9 (1.6)			1.1 (2.6)			0.2 (−1.9 to 2.3)	.805
Patient reported satisfaction with surgery		20	80.0		14	93.3		6	60.0	33.3 (− 0.7 to 64.3)	.062
Return to sport											
At preinjury level		6	25.0		5	33.3		1	11.1	22.2 (−16.5 to 51.4)	.201
At lower level		10	40.0		8	53.3		2	22.2	30.1 (−10.6 to 61.7)	.122
Unable to return		8	32.0		2	13.3		6	67.7	53.3 (13.5 to 79.6)	**.011**
Unable to participate in a spesific sport		12	50.0		4	26.7		8	80.0	53.3 (12.8 to 78.1)	**.008**
IKDC/pedi-IKDC score (max 100)[b]	77.7 (15.9)			77.8 (14.9)			77.5 (18.4)			0.3 (−15.3 to 15.8)	.973
Lysholm (max 100)	79.2 (13.6)			80.5 (12.9)			77.1 (15.2)			3.4 (−9.6 to 16.3)	.589
Subjective overall health by EQ5D[c]											
EQ5D VAS (O-100)	76.3 (12.8)			74.5 (14.0)			79.4 (10.4)			4.9 (−5.5 to15.4)	.332
Mobility											
No problems (LEVEL 1)		20	83.3		13	86.7		7	77.8	8.9 (−22.8 to 45.0)	.373
Any problems (LEVEL2-5)		4	16.7		2	13.3		2	22.2		
Self-care											
No problems (LEVEL 1)		23	95.8		15	100.0		8	88.9	11.1 (−11.5 to 44.3)	.188
Any problems (LEVEL2-5)		1	4.2		0			1	11.1		
Usual activities											
No problems (LEVEL 1)		21	87.5		13	86.7		8	88.9	0.2 (−33.5 to 30.4)	>.999
Any problems (LEVEL2-5)		3	12.5		2	13.3		1			
Pain/Discomfort											
No problems (LEVEL 1)		5	20.8		0	0.0		5	55.6	55.6 (26.2 to 81.5)	**.002**
Any problems (LEVEL2-5)		19	79.2		15	100		4			
Slight problems (level 2)		14	73.7		11	73.3		3	33.3	40 (−1.5 to 70.1)	.051
Moderate problems (level 3)		5	22.3		4	26.7		1	11.1	15.6 (−22.3 to 44.9)	.367
Anxiety/Depression											
No problems (LEVEL 1)		12	50.0		6	40.0		6	66.7	26.7 (−15.0 to 59.6)	.245
Any problems (LEVEL2-5)		12	50.0		9	60.0		3	33.3		
EQ-5D Overall											
No problems (All level = 1)		3	12.5		0	0.0		3	33.3	33.3 (8.0 to 65.1)	**.02**
Any problems (all other)		21	87.5		15	100.0		6	67.7		

Data are reported as mean ± SD or No. (%) unless otherwise indicated

Table 4 Clinical findings of the operated knee at the follow-up visit in mean 9 years

	All N=25 (24 persons)			MPFL reconstruction N=15 (15 persons)			Insall N=10 (9 persons)			Diff. (95% CI)	
	Mean	N	%	Mean	N	%	Mean	N	%		P-value[a]
J-sign postive laterally		9	36.0		4	26.7		5	50.0	23.3 (–15.1 to 57.2)	.457
J-sign positive medially		4	16.0		3	20.0		1	10.0	10.0 (–24.8 to 38.6)	.315
Side-to-side difference in J-sign N=22		14	63.6		7	50.0		7	77.7	27.7 (–5.7 to 66.1)	.093
Apprehension test positive		9	36.0		4	26.7		5	50.0	23.3 (–15.0 to 56.2)	.234
Patellar glide test positive[b]		7	28.0		3	20.0		4	40.0	20.0 (–16.0 to 54.2)	.227
Patellofemoral crepitation		13	52.0		7	46.7		6	60.0	13.3 (–26.1 to 48.4)	.457
Patellar grind test positive		5	20.0		2	13.3		3	30.0	16.7 (–16.0 to 50.7)	.211
Number of scars	2.9 (1.4)			3.5 (1.2)			2.1 (1.4)			1.4 (0.2 to 2.5)	**.021**
Max lenght of the scars (in mm)	8.4 (3.5)			7.2 (3.3)			10.3 (3.1)			3.1 (0.4 to5.8)	**.029**
Max width of the scars (in mm)	1.3 (0.8)			1.2 (0.8)			1.5 (0.8)			0.3 (–0.4 to 1.0)	.385
Flexion ROM (in degrees)	141.1 (17.6)			139.5 (21.7)			143.5 (9.0)			4.0 (–9.0 to 17.1)	.529
Extension ROM (in degrees)	186.3 (3.8)			186.9 (4.0)			185.5 (3.5)			1.4 (–1.8 to 4.6)	.374
Tigh circumference diffenrence (in cm) [c]	-1.1 (1.3)			-1.5 (1.3)			-0.4 (1.0)			1.1 (0.0 to 2.1)	**.044**
Shin circumference difference (in cm)[c]	0.0 (1.0)			-0.36 (1.2)			0.6 (0.7)			0.9 (0.1 to 1.7)	**.030**
Knee flexion strength difference >5kg		10	45.5		7	50.0		3	37.5	12.5 (–30.0 to 49.5)	.440
Knee extension strength difference >5kg		9	40.9		7	50.0		2	25.0	25.0 (–18.9 to 58.1)	.227

Data are reported as mean ± SD or No. (%) unless otherwise indicated

Another patient reported anterior knee pain, attributed to significantly increased femoral neck anteversion; a derotational femoral osteotomy was performed later. In total, the mean time to reoperation for any reason, was 3.8 ± 2.0 years after the index surgery at a mean patient age of 18.6 ± 2.0 years.

Return to play (RTP)

Return to preinjury level of sports (RTP) was achieved by six out of 24 patients (25%). Overall, eight patients (32%) were unable to return to their previous sport at all: two patients (13.3%) in the MPFLR group and six patients (60%) in the Insall's group (P=.011). The reported reasons for non-return were pain (n=2), fear (n=2), and redislocation (n=4). Half of the patients (n=12) reported inability to participate in a specific sports, most commonly pivoting sports (e.g., skiing, basketball, soccer), at the time of the final follow-up visit (Table 3). In seven cases the reason for finishing the sport was unrelated to patellar instability.

Clinical findings at follow-up visit

At the time of the final follow-up J-sign was found to be positive in 13 (52%) knees. Among these nine (36%) cases demonstrated a lateral shift and four (16%) cases a medial shift. No significant difference were found between the MPFLR and Insall's groups in any clinical examinations related to patellar tracking. The number of surgical scars was higher after MPFLR (3.5 ± 1.2 vs. 2.1 ± 1.4, P=.021), but the maximum length of the scars was greater after Insall's procedure (7.2 ± 3.3 cm in MPFLR vs. 10.3 ± 3.1 cm in Insall's, P=.029) (Table 4).

Subjective satisfaction and quality of life

The mean IKDC/Pedi-IKDC score was 77.7 ± 15.9, with no significant difference between the MPFLR and the Insall's group (77.8 ± 14.9 vs. 77.5 ± 18.4, P=.973). However, the IKDC/Pedi-IKDC scores were significantly lower in both groups than the sex- and age-matched normative values (92.5–95.5) reported in the literature [18, 19]. The mean Lysholm scores were 80.5 ± 12.9 in the MPFLR group and 77.1 ± 15.2 in the Insall's group (P=.589), indicating impaired knee function in both treatment groups. Despite this, the majority of patients (n=20, 80%) reported satisfaction with their surgery.

At the final follow-up 17 patients (68%) reported knee pain, with no significant difference between groups (73.3% after MPFLR and 60% after Insall's, P=.484). Out of the 17 patients who complained knee pain, four (16.0%) described the pain as anterior knee pain. The mean pain severity on the visual analog scale (VAS), was 1.0 ± 2.0, with no differences between the groups (Table 3).

Discussion

The main finding of this comparative study, with a satisfactory long follow-up time (mean 9 years) was the markedly higher (60%) rate of PT osteoarthritis following Insall's proximal realignment procedure, compared to MRFLR. Early-onset osteoarthritis is a significant condition, often resulting pain, functional limitations and affecting negatively in the quality of life. In contrast, the low incidence of OA after MPFLR observed in this study is noteworthy and clinically important finding. MPFLR may preserve PF joint biomechanics more effectively, as it does not appear to increase the compression forces within the PF joint, which is a known disadvantage of Insall's type proximal realignment operations. The elevated risk of PF osteoarthritis following PFI surgery is supported by previous studies. Sillanpää et al. reported that 78% of adult patients treated with non-anatomic distal realignment procedures demonstrated

full-thickness cartilage lesions on follow-up MRI, regardless of whether they had PFI or not [28]. Schuttler et al. examined 42 adult patients who underwent the Insall's procedure and observed a significant progression of patellofemoral osteoarthritis over a mean follow-up period of 52 months. The incidence of PF OA increased from 10% a the time of the surgery to 43% at follow-up [29]. In contrast, long-term data on MPFLR show more favorable cartilage outcomes. Shatrow et al. found mild PF OA in one-third of patients at a minimum of 10 years after MPFLR [30]. On the other hand, another study of 22 patients treated with MPFLR with a mean follow-up time of 12 years found that only two knees had definite progression from none to mild-to-moderate-grade osteoarthrosis [31]. Thus, although cartilage lesions were not absent in the MPFLR group, the procedure appears to be significantly safer for knee cartilage, which aligns with current research findings. This is likely due to the non-anatomic nature of proximal realignment procedures, which can alter patellofemoral joint mechanics, increase contact pressure on the articular surfaces, and thereby predispose the knee to cartilage degeneration. The markedly higher incidence of patellofemoral osteoarthritis observed following Insall's procedure in this study reinforces concerns about long-term cartilage health associated with such techniques. This study supports the growing consensus in adolescent sports medicine that emphasizes the importance of early detection and appropriate management of cartilage damage in the treatment of knee injuries in adolescent [32]. In particular, the need to prioritize surgical approaches that minimize biomechanical disruption and better preserve cartilage integrity in skeletally immature patients.

There was also significantly lower rate of redislocations requiring further interventions after MPFLR than after Insall's procedure. No patient was reoperated due to redislocation after MPFLR. One patient (6.7%) in the MPFLR group presented unstable patella in clinical examination but did not suffer from the finding. Two cases treated with MPFLR reported patellar instability, but objective instability findings were lacking. These findings altogether support the recent change in treatment from proximal realignment procedures to reconstruction of medial constrains, while MPFLR has been taken as a first-line treatment by most knee surgeons in the last 10–15 years [12]. The previously reported rate of recurrent dislocation following MPFLR in children and adolescents varies from 0–30% [33–36]. The current study agrees with these.

The rate of redislocations requiring reoperation was 40% after Insall's in this research. The subjective results of Insall's were even worse, as 70% of the cases operated upon Insall's had subjective feelings of instability. The reported rate of late stage redislocation after proximal realignment procedure was lower (22%) in a previous study, as compared to the current research, but the follow-up time in that study was short (2 years) [37]. In the current study, the follow-up time was 13 years after Insall's, which could explain the higher redislocation rate compared with other published outcome results. The high rate of objective recurrence (60%) after Insall's suggests choosing methods other than proximal realignment procedure when improving stability after lateral patellar dislocation in children and adolescents.

Many studies have shown excellent MPFLR results in adults. However, MPFLR is not a completely anatomical procedure for skeletally immature patients because the anatomical insertion point in the femur is within the proximity of the growth plate. For this reason, femoral fixation of the graft cannot be performed on Schottle's point, which is the preferred site for the graft insertion [38]. Several different growth plate-sparing surgical techniques have been published to avoid iatrogenic lesion, but the outcomes of MPFLR have been poorer in adolescents than in adults [34, 39–41] In this study, only patients with at least partially open physes were included, which is important given that there is a lack of high-standard studies of PFI in children and adolescents [35, 42, 43].

RTP on preinjury sports was achieved by 87% of the patients after MPFLR and by 33% of the patients after Insall's. Preinjury level of the sport performance was achieved by a minority of patients after MPFLR (33%) and modified Insall's (11%). These numbers emphasize the severe nature of PFI in junior athletes. Regarding return to specific sports, there was no difference between the treatment groups. The RTP outcomes in this study were poorer than those previously reported. Migliorini et al. concluded that 87% of patients were able to return to their previous sports following MFPLR, while one in three (27%) patients had a reduced level of sports. However, patients' skeletal maturity was not addressed, and the follow-up time was significantly shorter (33.7 + 28.8 months) compared with this study [43].

The long-term subjective recovery was unsatisfying in both treatment groups compared with the sex- and age-matched normative data scores, which, again, strengthens the idea that PFI is still a clinical challenge among adolescents. Nevertheless, most of the patients (80%) were still happy with the surgery. Although the patients in the MPFLR group reported knee pain more often, it was slight according to VAS. There was no difference between the MPFLR and Insall's groups in other subjective knee-specific recovery or quality of life measurements nor in any clinical exams considering patella tracking or PF joint problems. Therefore, considering all the pros and cons, the main advantage of MPFLR compared with proximal realignment procedure is its lower risk of redislocation

and OA, while there seems to be no difference in RTP or subjective outcomes.

This study has some limitations. First due to the retrospective study design, the primary treatment was based on the surgeon's preference for each patient, and the patients were not randomized into two comparative treatment groups. Furthermore, as surgical management of PFI evolved toward MPFLR after the 2010's, patients in the Insall's group had longer follow-up period, which may have affected on the differences between the groups. Another limitation is that IKDC radiographic osteoarthritis rating could not be used, as Rosenberg view was not obtained in accordance with institutional imaging protocols. As the study was limited to skeletally immature patients with open growth plates, the pool of eligible participants was inherently small, despite the inclusion of all consecutive cases meeting the criteria. The final sample size was relatively limited due to the study's exclusive focus on soft-tissue procedures, with patients treated using alternative surgical techniques being excluded. Additionally, detailed numbers of excluded cases by specific eligibility criteria were unavailable, as such data was not separately recorded in the research database. The single-center nature of the study may also restrict the broader generalizability of the results.

Despite these limitations, the study has notable strengths. The exclusive focus on soft-tissue procedures is justified, as MPFLR has become a cornerstone in the treatment of PFI in the skeletally immature population. Post hoc power analysis indicated adequate statistical power (84%), and the study achieved a high participation rate (77%) despite a long mean follow-up of nine years. The long follow-up time strengthen the reliability of the outcomes. Additional, clinical investigations were comprehensive, and imaging was performed for all patients. Moreover, the patients were inquired about subjective symptoms, satisfaction, and performance. RTP after treatment was thoroughly evaluated to determine the potential differences between the procedures. To the best of the authors' knowledge, this is the largest population-based study comparing the long-term outcomes of MPFLR and Insall's proximal realignment procedures in children and adolescents with open physes.

Future research is planned to investigate long-term cartilage degeneration and osteoarthritic progression using magnetic resonance imaging (MRI), which may provide more detailed insights into structural joint changes over time.

Conclusion

MPFLR is superior to Insall´s proximal realignment procedure in treating recurrent patellar lateral dislocation in children and adolescents. Although both groups demonstrated relatively good subjective outcomes, MPFLR was associated with a lower incidence of osteoarthritis in both the patellofemoral and tibiofemoral joints, as well as fewer reoperations for recurrent dislocations.

Abbreviations

MPFLR	Medial patellofemoral ligament reconstruction
PFI	Patellofemoral instability
KL	Kellgren and Lawrence classification
IKDC	International Knee Documentation Committee
PLD	Patellar lateral dislocation
PF	Patellofemoral
TF	Tibiofemoral
TT–TG	Tibial tuberosity to trochlear groove distance
OA	Osteoarthritis
VAS	Visual analog scale
RTP	Return to play
BMI	Body mass index
CDI	Caton–Deschamps index
VMO	Vastus medialis oblique

Acknowledgements

The authors thank Physical Therapist Susanna Löytynoja for her assistance in clinical examination of the patients.

Authors' contributions

M.J.: Performed the clinical examinations and collected the data, analyzed and interpreted the data, drafted the manuscript and approved the version to be publishedM.P.: Contributed to the study conception and design, analyzed and interpreted the data, revised the manuscript and approved the version to be published. L.L.: Contributed to the study conception and design, revised the manuscript, approved the version to be publishedJ.S.: Contributed to the study conception and design, analyzed and interpreted the data, revised the manuscript, supervised the project and approved the version to be published.

Funding

Open Access funding provided by University of Oulu (including Oulu University Hospital). None.

Data availability

Data is available upon reasonable request from the corresponding author. In the use of data, the EU general data protection regulation (EU 2016/679) and the Finnish Data Protection Act are followed. Access to personal data is based on written informed consent provided by the cohort participants or their legal guardians during their latest follow-up. These consent limitations may restrict the extent to which the data can be shared.

Declarations

Ethics approval and consent to participate

Approval for the study protocol by was provided by the regional medical research ethics committee of the Wellbeing services county of North Ostrobothnia, Finland. EETMK 80/2019§295 All study participants, or their legal guardians if the participant was under 18 years of age, provided written informed consent prior to participation**.**The research was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Consent for publication

Written informed consent for the publication of clinical details and images was obtained from study participants, or their legal guardians, if the participant was under 18 years of age.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Pediatric Orthopaedics and Surgery, Research Unit of Clinical Medicine, Oulu University Hospital, University of Oulu; and Medical Research Center, Oulu, Finland
[2]Research Unit of Health Sciences and Technology, Department of Radiology, Oulu University Hospital, Oulu, Finland

[3]FinnOrthopaedics/Hospital Pihlajalinna, Turku, Finland
[4]Department of Physical Activity and Health, Paavo Nurmi Centre, University of Turku, Turku, Finland
[5]Ripoll y De Prado FIFA Medical Centre of Excellence, Madrid, Spain
[6]Hospital TerveysTalo, Oulu, Finland
[7]Department of Pediatric Orthopaedics and Surgery, Oulu University Hospital, PO Box10, Oulu 90029 OYS, Finland

Received: 11 November 2024 / Accepted: 9 July 2025
Published online: 04 August 2025

References

1. Fithian DC, Paxton EW, Stone M, Lou, Silva P, Davis DK, Elias DA, et al. Epidemiology and natural history of acute patellar dislocation. Am J Sports Med. 2004;32:1114–21.
2. Nietosvaara Y, Aalto K, Kallio PE. Acute patellar dislocation in children: incidence and associated osteochondral fractures. J Pediatr Orthop. 1994;14:513–5.
3. Askenberger M, Ekström W, Finnbogason T, Janarv PM. Occult intra-articular knee injuries in children with hemarthrosis. Am J Sports Med. 2014;42:1600–6.
4. Sanders TL, Pareek A, Hewett TE, Stuart MJ, Dahm DL, Krych AJ. High rate of recurrent patellar dislocation in skeletally immature patients: a long-term population-based study. Knee Surg Sports Traumatol Arthrosc. 2018;26:1037–43.
5. Nomura E, Inoue M. Second-look arthroscopy of cartilage changes of the patellofemoral joint, especially the patella, following acute and recurrent patellar dislocation. Osteoarthritis Cartilage. 2005;13:1029–36.
6. Matic GT, Magnussen RA, Kolovich GP, Flanigan DC. Return to activity after medial patellofemoral ligament repair or reconstruction. Arthroscopy. 2014;30:1018–25.
7. Huntington LS, Webster KE, Devitt BM, Scanlon JP, Feller JA. Factors associated with an increased risk of recurrence after a first-time patellar dislocation: a systematic review and meta-analysis. Am J Sports Med. 2020;48:2552–62.
8. Nomura E, Inoue M, Kobayashi S. Generalized joint laxity and contralateral patellar hypermobility in unilateral recurrent patellar dislocators. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2006;22:861–5.
9. Andrish J. Surgical options for patellar stabilization in the skeletally immature patient. Sports Med Arthrosc Rev. 2007;15:82–8.
10. Samelis PV, Koulouvaris P, Savvidou O, Mavrogenis A, Samelis VP, Papagelopoulos PJ. Patellar dislocation: workup and Decision-Making. Cureus. 2023;15(10):e46743. https://doi.org/10.7759/cureus.46743.
11. Uimonen MM, Repo JP, Huttunen TT, Nurmi H, Mattila VM, Paloneva J. Surgery for patellar dislocation has evolved towards anatomical reconstructions with assessment and treatment of anatomical risk factors. Knee Surg Sports Traumatol Arthrosc. 2021;29:1944–51.
12. Liu Z, Yi Q, He L, Yao C, Zhang L, Lu F, et al. Comparing nonoperative treatment, MPFL repair, and MPFL reconstruction for patients with patellar dislocation: A systematic review and network Meta-analysis. Orthop J Sports Med. 2021;9(9):23259671211026624. https://doi.org/10.1177/23259671211026624.
13. Insall JN, Aglietti P, Tria AJ. Patellar pain and incongruence. Part II: clinical application. Clin Orthop Relat Res. 1983;176:225–32.
14. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16:494–502.
15. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, et al. Development and validation of the international knee Documentation committee subjective knee form. Am J Sports Med. 2001;29:600–13.
16. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with specialemphasis on use of a scoring scale. Am J Sports Med. 1982;10(3):150–4. https://doi.org/10.1177/036354658201000306.
17. Kocher MS, Smith JT, Iversen MD, Brustowicz K, Ogunwole O, Andersen J, et al. Reliability, validity, and responsiveness of a modified international knee Documentation committee subjective knee form (Pedi-IKDC) in children with knee disorders. Am J Sports Med. 2011;39:933–9.
18. Anderson AF, Irrgang JJ, Kocher MS, Mann BJ, Harrast JJ. The international knee Documentation committee subjective knee evaluation form: normative data. Am J Sports Med. 2006;34:128–35.
19. Nasreddine AY, Connell PL, Kalish LA, Nelson S, Iversen MD, Anderson AF, et al. The pediatric international knee Documentation committee (Pedi-IKDC) subjective knee evaluation form. Am J Sports Med. 2017;45:527–34.
20. Briggs KK, Steadman JR, Hay CJ, Hines SL. Lysholm score and Tegner activity level in individuals with normal knees. Am J Sports Med. 2009;37:898–901.
21. Herdman M, Gudex C, Lloyd A, Janssen M, Kind P, Parkin D, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Qual Life Res. 2011;20:1727–36.
22. Wille N, Badia X, Bonsel G, Burström K, Cavrini G, Devlin N, et al. Development of the EQ-5D-Y: a child-friendly version of the EQ-5D. Qual Life Res. 2010;19:875–86.
23. Paul RW, Brutico JM, Wright ML, Erickson BJ, Tjoumakaris FP, Freedman KB, et al. Strong agreement between magnetic resonance imaging and radiographs for Caton-Deschamps index in patients with patellofemoral instability. Arthrosc Sports Med Rehabil. 2021;3:e1621–8.
24. Caton J. Méthode de mesure de La hauteur de La rotule [Method of measuring the height of the patella]. Acta Orthop Belg. 1989;55:385–6.
25. Urch SE, Tritle BA, Donald Shelbourne K, Gray T. Axial linear patellar displacement: a new measurement of patellofemoral congruence. Am J Sports Med. 2009;37:970–3.
26. Laurin CA, Lévesque HP, Dussault R, Labelle H, Peides JP. The abnormal lateral patellofemoral angle: a diagnostic roentgenographic sign of recurrent patellar subluxation. Jounal Bone Joint Surg Am. 1978;60:55–60.
27. Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. Ann Rheum Dis. 1973;32:413.
28. Sillanpää PJ, Mattila VM, Visuri T, Mäenpää H, Pihlajamäki H. Patellofemoral osteoarthritis in patients with operative treatment for patellar dislocation: a magnetic resonance-based analysis. Knee Surg Sports Traumatol Arthrosc. 2011;19:230–5.
29. Schüttler KF, Struewer J, Roessler PP, Gesslein M, Rominger MB, Ziring E, et al. Patellofemoral osteoarthritis after Insall's proximal realignment for recurrent patellar dislocation. Knee Surg Sports Traumatol Arthrosc. 2014;22:2623–8.
30. Shatrov J, Vialla T, Sappey-Marinier E, Schmidt A, Batailler C, Lustig S, et al. At 10-year minimum follow-up, one-third of patients have patellofemoral arthritis after isolated medial patellofemoral ligament reconstruction using gracilis tendon autograft. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2023;39:349–57.
31. Nomura E, Inoue M, Kobayashi S. Long-term Follow-up and Knee Osteoarthritis Change after Medial Patellofemoral Ligament Reconstruction for Recurrent Patellar Dislocation. Am J Sports Med. 2007;35(11):1851–8. https://doi.org/10.1177/0363546507306161.
32. Turati M, Accadbled F, Tercier S, et al. Paediatric knee fractures: A currentconcept review. J Child Orthop. 2025;19(3):213-20. https://doi.org/10.1177/18632521251327129D.
33. Rueth MJ, Koehl P, Schuh A, Goyal T, Wagner D. Return to sports and short-term follow-up of 101 cases of medial patellofemoral ligament reconstruction using gracilis tendon autograft in children and adolescents. Arch Orthop Trauma Surg. 2023;143:447–52.
34. Lind M, Enderlein D, Nielsen T, Christiansen SE, Faunø P. AQ clinical outcome after reconstruction of the medial patellofemoral ligament in paediatric patients with recurrent patella instability. Knee Surg Sports Traumatol Arthrosc. 2016;24:666–71.
35. Ambrosi R, Corona K, Capitani P, Coccioli G, Ursino N, Peretti GM. Complications andRecurrence of Patellar Instability after Medial Patellofemoral Ligament Reconstruction inChildren and Adolescents: A Systematic Review. Children (Basel). 2021;8(6):434. https://doi.org/10.3390/children8060434.
36. Husen M, Milbrandt TA, Shah V, Krych AJ, Stuart MJ, Saris DBF. Medial Patellofemoral Ligament Reconstruction Using Allografts in Skeletally Immature Patients. Am J Sports Med. 2023;51(6):1513–24. https://doi.org/10.1177/03635465231164400.
37. Efe T, Seibold J, Geßlein M, Schüttler K, Schmitt J, Schofer MD, et al. Non-anatomic proximal realignment for recurrent patellar dislocation does not sufficiently prevent redislocation. Open Orthop J. 2012;6:114.
38. Schöttle P, Schmeling A, Romero J, Weiler A. Anatomical reconstruction of the medial patellofemoral ligament using a free gracilis autograft. Arch Orthop Trauma Surg. 2009;129:305–9.
39. Ladenhauf HN, Berkes MB, Green DW. Medial patellofemoral ligament reconstruction using hamstring autograft in children and adolescents. Arthrosc Tech. 2013;2:e151-4.
40. Uppstrom TJ, Price M, Black S, Gausden E, Haskel J, Green DW. Medial patellofemoral ligament (MPFL) reconstruction technique using an epiphyseal

femoral socket with fluoroscopic guidance helps avoid physeal injury in skeletally immature patients. Knee Surg Sports Traumatol Arthrosc. 2019;27:3536–42.
41. Parikh SN, Nathan ST, Wall EJ, EismannEA. Complications of medial patellofemoral ligament reconstruction in young patients. Am JSports Med. 2013;41(5):1030–8. https://doi.org/10.1177/0363546513482085.
42. Shamrock AG, Day MA, Duchman KR, Glass N, Westermann RW. Medialpatellofemoral ligament reconstruction in skeletally immature patients: a systematicreview and meta-analysis. Orthop J Sports Med. 2019. https://doi.org/10.1177/2325967119855023.
43. Migliorini F, Maffulli N, Bell A, Betsch M, Outcomes. Return to sport, and failures of MPFL reconstruction using autografts in children and adolescents with recurrent patellofemoral instability: A systematic review. Children (Basel). 2022;9(12):1892. https://doi.org/10.3390/children9121892.

Publisher's Note