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ORIGINAL ARTICLE

Anatomical medial patellofemoral ligament reconstruction improves sport participation and activity levels in adolescents with recurrent patellar dislocation

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Lateral patellar dislocations (LPDs) are common knee injuries in adolescents.[1] They frequently cause injuries to the cartilage, bone, and ligament within the patellofemoral joint.[2-4] The risk of injury to these anatomical structures increases in recurrent patellar dislocation (RDP)[3,5] Cartilage damage can result in chronic pain, limited mobility, and reduced quality of life through degenerative changes in RDP.[6] Adolescent patients had a greater risk of LPD due to isolated medial patellofemoral ligament (MPFL).[1,2,4] In addition, adolescents with LPD have an average of 3.2 times higher risk of knee joint cartilage injury and associated patellofemoral osteoarthritis (PFOA).[6] It has been reported that it is important to detect cartilage lesions after patellar dislocation, since osteoarthritis can often be seen after RPD even in pediatric and adolescent patients.[4]

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ABSTRACT

Objectives: This study aims to evaluate the clinical outcomes of an anatomical medial patellofemoral ligament (MPFL) reconstruction and the effects of concomitant patellofemoral joint injuries and radiological findings on outcomes in adolescents with recurrent patellar dislocation (RPD).

Patients and methods: Between January 2011 and January 2020, a total of 34 patients (19 males, 15 females; median age: 15.6 years; range, 13 to 17 years) with RPD who underwent anatomic MPFL reconstruction were retrospectively analyzed. Lateral release was performed as indicated. Clinical outcomes were evaluated preoperatively and at the final follow-up using the Visual Analog Scale (VAS), Lysholm, Kujala, and Tegner activity rating scales. Magnetic resonance imaging was performed to detect concomitant injuries such as bone, cartilage, and soft tissue injuries.

Results: The mean follow-up was 5±2 years. All postoperative knee functions and activity levels were statistically significantly improved without re-dislocation ($p<0.001$). There was no statistically significant relationship between the presence and location of cartilage lesions and clinical outcomes ($p>0.05$). Patients with cartilage lesions had a significantly higher Caton-Deschamps index and a higher incidence of bone edema in both the patella and femur than patients without.

Conclusion: Anatomic MPFL reconstruction with meticulous physical therapy has successful clinical outcomes, prevents re-dislocation, and increases participation in sports and activity levels in adolescent patients with RPD. Although cartilage injuries are common after RPD, it has no adverse effect on clinical outcomes in the mid-term.

Keywords: Adolescents, medial patellofemoral ligament reconstruction, patellar instability, sports participation.

Despite high re-dislocation rates, conservative treatment is preferred after a 'first-time' LPD in adolescents.[7] In RDP and cases with concomitant anatomical predisposing factors such as trochlear dysplasia, patella alta, or ligamentous laxity in

first-time dislocations surgical treatments such as medial retinacular plication, lateral retinacular release or MPFL reconstructions must be considered.[8,9]

Considering the activity level and expectations of this age, appropriate treatment must be applied to avoid further constraints such as the inability to participate in social and sports activities, and complications such as cartilage, ligament, and bone injuries caused by RPD. Anatomical MPFL reconstruction is advocated as the treatment of choice in children and adolescent patients with RPD, with successful clinical outcomes, low complication rates, as well as increased patient activity levels.[8-11]

In addition, limited data are available regarding clinical outcomes and return to sports activity levels in adolescent patients undergoing MPFL reconstruction of additional injuries caused by LPD. In the present study, we aimed to evaluate the clinical outcomes of anatomical MPFL reconstruction in adolescents with RDP, such as pain and knee functional scores, as well as the activity level and return to sports in addition to examining the effect of accompanying injuries, such as cartilage lesions, on the results, particularly in this age group.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Acıbadem Adana Ortopedia Hospital, Department of Knee and Sport Surgery between January 2011 and January 2020. A total of 36 adolescent patients with RPD who were treated with anatomic MPFL reconstruction were included. Lateral release was performed in cases with negative patellar tilt test and/or patellar glide test less than one quarter. Inclusion criteria were patellar instability with at least two previous patellar dislocations undergoing reduction by a healthcare professional. Patients with previous surgery for patella and fractures involving the knee joint, congenital and acquired deformity, underlying syndromes with ligamentous laxity, and patients with an indication for tibial tubercle (TT) osteotomy (TT-trochlear groove distance (TT-TG) ≥20 mm and/or Caton-Deschamps index ≥1.4) were excluded. Two patients were lost to follow-up and 34 patients (19 males, 15 females; median age: 15.6 years; range, 13 to 17 years) were included in the study. Patients were examined for final follow-up in 2021 by a senior knee surgeon and were evaluated retrospectively. Patellar instability was assessed by including a positive patellar glide test (while a lateral glide of more than three quadrants), a positive apprehension test, and the presence of 'J sing' preoperatively, first-year follow-up, and at the final follow-up. All patients were evaluated pre- and postoperatively using the Visual Analog Scale (VAS), Tegner activity level, Kujala, and Lysholm knee score.[12,13] Standard radiographs (anteroposterior, lateral, and Merchant view) and leg-length radiographs were performed preoperatively and at one year postoperatively. All patients were examined using a 1.5-Tesla magnetic resonance imaging (MRI) unit (Siemens Magnetom Essenza) with sagittal T1-TSE, coronal STIR-TSE, transversal fat-suppressed PD-TSE, and sagittal fat-suppressed PD-TSE preoperatively and at one year postoperatively, preoperatively and at 1 year postoperatively (Figure 1). Cartilage lesions and bone bruises were classified according to location arthroscopically. Radiographic measurements to evaluate patellar instability were performed by a musculoskeletal radiologist such as the Caton-Deschamps index for patellar height, sulcus angle for trochlear dysplasia, and patellar tilt angle for patellar tilt. The MRI measurements were performed such as lateral trochlear inclination and trochlear facet asymmetry for trochlear dysplasia, patellar tilt angle for patellar tilt, and patellar height ratio for patellar height (Figure 2).[14] Patients with open physis were classified as skeletally immature and patients with closing or closed physis were classified as skeletally mature as described by Arendt et al.[14] The TT-TG was measured using MRI.[15] Trochlear dysplasia was classified according to Dejour and Le Coultre.[16]

Surgical technique

All patients were operated by the same senior knee surgeon. Standard arthroscopy was performed on the affected knee joint for evaluation of cartilage and intra-articular pathologies. The severity of cartilage lesion was defined as full thickness, partial thickness, or none. Partial-thickness cartilage lesions were debrided mechanically with a shaver or by radiofrequency ablation technique and microfracture was applied after debridement arthroscopically in full-thickness cartilage lesions. Lateral release was performed as indicated. After performing arthroscopy, the gracilis tendon was harvested and it was prepared by placing sutures at both ends. The patella was exposed with a vertical incision and the insertion area of the MPFL was prepared. The superomedial corner of the patella to the midpoint of the medial margin of the patella was prepared and the lateral retinacular release was performed. The fixation of the graft to the proximal

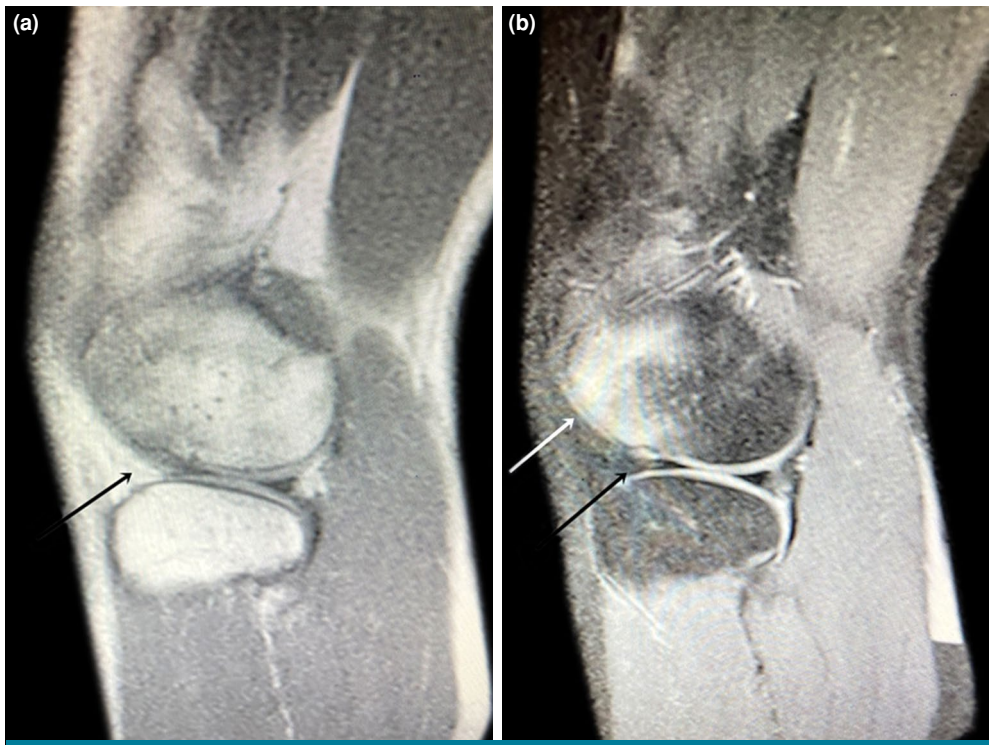

FIGURE 1. (a) Preoperatif sagital T1-weighted and **(b)** sagital fat-sat T2 weighted magnetic resonance images of cartilage lesion (black arrow) and bone edema (white arrow) of the femoral lateral condyle.

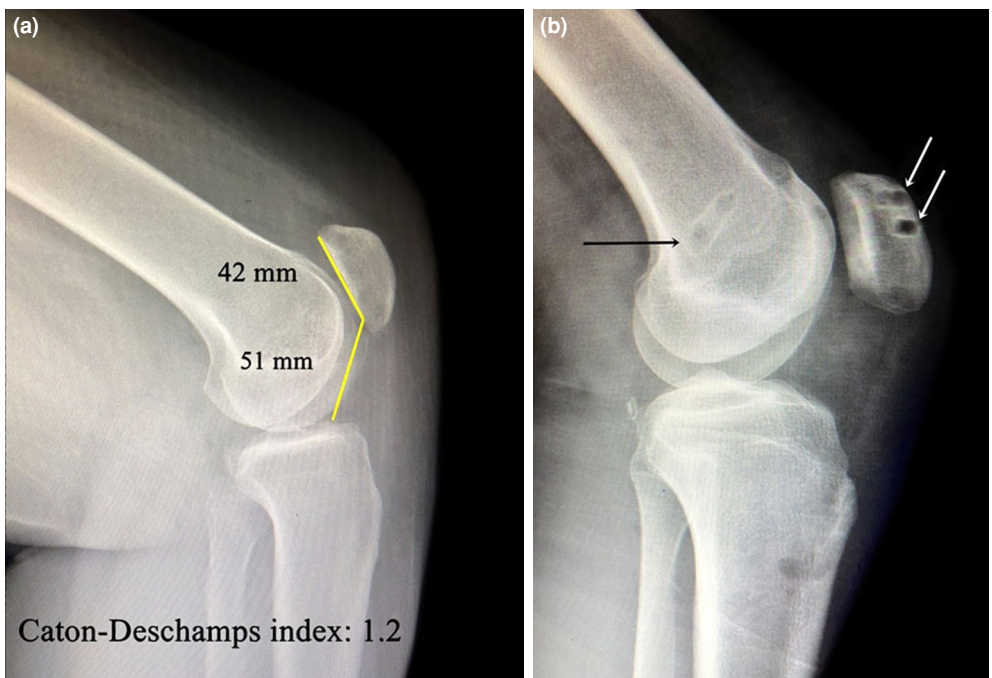

FIGURE 2. (a) Preoperative lateral knee radiograph images (Caton-Deschamps index: 1.2). **(b)** Postoperative lateral knee radiograph showing femoral (black arrow) and patellar (white arrow) bone tunnels.

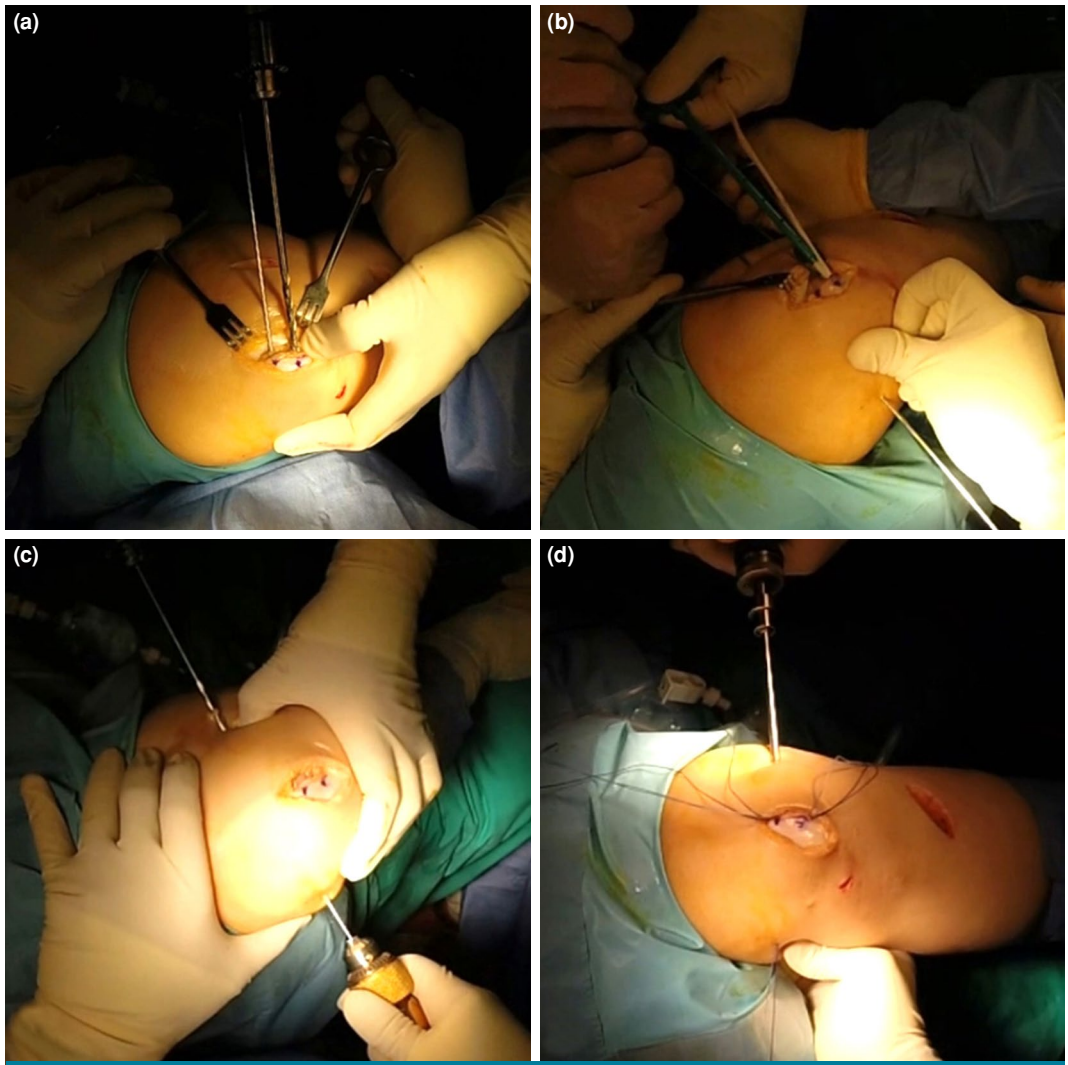

FIGURE 3. Intraoperative images of **(a)** patellar tunnel preparation, **(b)** knotless anchor placement in the patellar tunnels, **(c)** femoral tunnel preparation, and **(d)** femoral fixation with an interference screw.

to the midpoint of the patella, with a distance of approximately 10 mm between the two fixation points was performed by fixing the tendon body with two soft suture anchors (1.4-mm JuggerKnot; Biomet Inc., Warsaw, IN, USA) or by fixing the tendon ends to the patella with two knotless anchors (3.5 mm SwiveLock; Arthrex Inc., Naples, FL, USA) (Figure 3). Another vertical incision was performed to expose between medial epicondyle and adductor tubercle, which is the anatomic MPFL attachment site. The femoral tunnel entrance was confirmed with fluoroscopy as described by Schottle et al.[17] The femoral tunnel was prepared with an orientation of approximately 15° anterior and 15° superior. The graft was passed through the interval between layers 2 and 3 of the medial retinaculum and passed through the prepared femoral tunnel. The graft was tightened into the femoral drill hole and fixed with an interference screw when proper tension was achieved at 30° of flexion (Figure 3).[10]

Postoperative rehabilitation

Immediate partial weight-bearing was allowed postoperatively. No brace was used. Full weight-bearing was recommended after the third postoperative week, after quadriceps strength was restored. Range of motion exercises was started immediately and progressed gradually and the patients were discharged when 90° of knee flexion

was achieved. Quadriceps setting exercises were started from the first day after surgery. All patients were included in the physical therapy program immediately after discharge with the aim of achieving full joint movement and appropriate strength gain in the sixth postoperative week. Extended rehabilitation programs were applied to patients who could not achieve full range of motion against gravity with full resistance. The patients were allowed to return to jogging at four months and to sports at six months.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median and interquartile range (IQR), while categorical variables were expressed in number and frequency. The chi-square test was used to compare categorical variables between the groups. The normality of distribution for continuous variables was confirmed with the Shapiro-Wilk test. For the comparison of continuous variables between two groups, the Student t-test or Mann-Whitney U test was used depending on whether the statistical hypotheses were fulfilled or not. For comparison of pre/postoperative measurements, a paired-sample t-test was used. A p value of <0.05 was considered statistically significant.

RESULTS

The mean follow-up after the operation was 5±2 (range, 2 to 10) years. Ten patients experienced two dislocations, 15 three dislocations, and nine multiple dislocations (range, 4 to 12). The median time from the last dislocation to surgery was 40 (range, 2 to 300) days. Lateral release was performed in all cases as indicated. Patients' characteristics are given in Table I. Immediate physical therapy was started in all of the patients postoperatively. In addition, prolonged physical therapy was applied in 12 patients (35.2%).

Cartilage lesions were seen in 21 knees (61.7%) and are summarized in Table II. Cartilage lesion location was only patella (n=8, 22.8%), only lateral femoral condyle (n=5, 14.2%), both patella and femur (n=8, 22.8%), and none (n=13, 38.2%). There was no statistically significant relationship between the presence and location of cartilage lesions and VAS, Tegner activity score, Lysholm, and Kujala knee scores (p>0.05). No correlation was found between the number of dislocations and the severity of the cartilage lesions (p>0.05).

TABLE I
Patient characteristics

	n	%	Mean±SD	Median	IQR
Age at the time of surgery (year)				15.6	13-17
Sex					
Female	19	55.8			
Male	15	44.1			
Side					
Right	15	44.1			
Left	19	55.8			
Body mass index (kg/m^2)			24±4.4		
No. of dislocations				4.5	2-12
Follow-up time (year)				5	2-10
Anesthesia method					
Epidural	21	61.7			
General	13	38.2			
Operation time (min)				73.7	50-105
Day of hospitalization			2±0.3		
Physical therapy					
Standard treatment	22	64.7			
Prolonged treatment	12	35.2			

SD: Standard deviation; IQR: Interquartile range.

TABLE II
Radiological, surgical findings and measurements

	n	%	Mean±SD	Median	IQR
Caton-Deschamps index			1.17±1		
TT-TG (mm)			14±5		
MPFL injury					
Total	26	76.4			
Partial	7	20.5			
None	1	2.9			
Bone edema					
Patella	18	52.9			
Femur	19	55.8			
Both patella and femur	18	52.9			
None	15	44.1			
Trochlear dysplasia					
None	20	58.8			
Type A	10	29.4			
Type B	4	11.7			
Type C	-	-			
Type D	-	-			
Presence of cartilage injury					
+	21	61.7			
–	13	38.2			
Location of cartilage injury					
Patella only	8	23.5			
Femur only	5	14.7			
Both patella and femur	8	23.5			
None	13	38.2			
Level of cartilage injury					
Patella (n=16)					
Full thickness	12	75			
Partial thickness	4	25			
Femur (n=13)					
Full thickness	9	69.2			
Partial thickness	4	30.7			
Area of cartilage lesion (mm^2)					
Patella				66.5	25-200
Femur				98.7	25-300

SD: Standard deviation; IQR: Interquartile range; TT-TG: Tibial tubercle-trochlear groove distance; MPFL: Medial patellofemoral ligament

Pre- and postoperative clinical and functional outcomes and patient satisfaction results are given in Table III. All postoperative knee functions and activity levels were statistically significantly improved in the study group ($p<0.001$). The patients were able to return to activity level at the same level of performance in 16 cases (47%), above performance in 17 cases (50%), and below performance in one case (2.9%) postoperatively. Preoperatively, 16 patients (47%) were engaged in recreational and competitive sports activities (Tegner level 5 and above). Postoperatively, 27 patients (79.4%) were engaged in sports activity ($p=0.001$) and were able to return to their sports activities after a median of 5.5 (range, 4 to 12) months. The postoperative and improvement of the Lysholm and Kujala knee scores and VAS scores of 15 (44.1%) patients who underwent soft anchor and 19 (55.8%) patients who

TABLE III
Clinical outcomes

	n	%	Preoperative Mean±SD	Postoperative Mean±SD	Improvement Mean±SD	*p*
Lysholm knee score			69.4±17	98±3	27.6±16	**<0.001***
Kujala knee score			53.4±20	95.5±6	42.4±20	**<0.001***
Tegner activity score			4.6±1	5.7±1	0.9±1	**<0.001***
VAS			6±3	0.4±1	5.5±3	**<0.001***
Patients' satisfaction						N/A
Very satisfied	26	76.4	N/A		N/A	
Satisfied	5	14.7	N/A		N/A	
Moderate	3	8.8	N/A		N/A	
Not satisfied	-	-	N/A		N/A	

SD: Standard deviation; Paired-samples t-test was used for comparison of pre/postoperative measurements. * Statistically significant; N/A: Not applicable.

TABLE IV
Relationship between bone edema and cartilage lesion

	Cartilage lesion				
	Positive (+)		Negative (–)		
	n	%	n	%	*p*
Bone edema					
Patella					0.01*
(+)	15	67	3	29	
(-)	6	33	10	71	
Total	21	100	13	100	
Femur					0.01*
(+)	15	71	3	29	
(-)	6	29	10	71	
Total	21	100	13	100	

* Statistically significant; The Chi-square test was used to compare categorical variables between the groups.

underwent knotless anchor fixation methods were statistically comparable (p>0.05).

All patients were skeletally mature according to Arendt et al.[14] Radiological findings and measurements are shown in Table II. No statistically significant effect was found between radiological findings and measurements for the evaluation of patellar instability on cartilage injury except for the Caton-Deschamps index on the radiograph. Patients with cartilage lesions had a significantly higher Caton-Deschamps index than patients without cartilage lesions (1.2 *vs.* 1, p=0.01). Bone edema was observed in the patella in 67% and the femur in 71% of the patients with cartilage lesions, and it was statistically higher than the patients without cartilage lesions (p=0.01 and p=0.01, respectively) (Table IV). The median age of the patients with bone edema was lower than those without (14.7 *vs.* 16.7 years, p=0.005). No radiological findings were observed to indicate injury to the medial distal femoral physis and axis deviation of the leg in the first year postoperatively.

A positive apprehension sign was observed in four knees (11.7%) at the final follow-up. One more dislocation was not observed in any patients at the final follow-up. Three patients (8.8%) with patellar

chondromalacia on MRI complained of insistent patellofemoral pain. Twelve (35.2%) patients required a prolonged rehabilitation and three patients (8.8%) had a lack of flexion of 15° compared to the contralateral knee at the final follow-up.

DISCUSSION

In many previous studies, successful clinical results and low re-dislocation rates have been reported in children and adolescents with RPD after anatomical MPFL reconstruction.[5,8,10,11,18] Nelitz et al.[10] reported that the Kujala score showed a significant improvement after anatomical MPFL reconstruction in skeletally immature patients with RPD. Lind et al.[18] showed that after pediatric anatomical MPFL reconstruction using soft tissue femoral fixation technique, a significant improvement was observed in knee function and pain. In our study, Tegner activity score, Lysholm, and Kujala knee scores were statistically significantly improved in the study group (4.6 to 5.7, 69.4 to 98, and 53.4 to 95.5, respectively). In the current study, anatomic MPFL reconstruction reduced the risk of recurrence patellar dislocation, increased the level of sportive activity, and improved the quality of life in adolescent patients.

Cartilage lesions in LPD cases are very common in adolescents and detecting cartilage lesions is important to evaluate treatment after LPD. Nomura et al.[19] showed that 95% of the patients had cartilage injuries in the patella and 31% in lateral femoral condyle in LPD cases. The aforementioned authors reported that the severity of cartilage lesion in the patella and/or lateral femoral condyle increased in patients with RPD. In previous studies, it has been shown that the development of osteoarthritis is common even in young patients due to cartilage injuries encountered after LPD and RPD.[19,20-22] In a study evaluating the incidence of osteochondral injury of the knee joint was detected in 46 of 122 patients (38%).[23] Conchie et al.[6] reported that experiencing a patellar dislocation increased the likelihood of the development of PFOA. In a radiological study evaluating risk factors for cartilage injury in children with patellofemoral instability, a high-riding patella was associated with central patellar cartilage damage.[9] Similarly, in our study, cartilage lesion was detected in 61.7% of patients in direct arthroscopic visualization and there was a positive correlation between Caton-Deschamps index and cartilage lesion. Kim et al.[9] showed that the presence of medial retinacular damage and bone edema on MRI was associated with a higher grade of medial patellar cartilage damage. In our study, there was a significant relationship between cartilage lesion and bone edema in both the patella and the femur. In particular, in younger adolescent patients with bone edema findings on MRI, performing diagnostic arthroscopy during MPFL reconstruction may prevent possible cartilage injury from being ignored. In addition, there was no significant relationship between the presence and location of the cartilage lesion and clinical outcomes.

In a study of adolescent patients undergoing anatomic MPFL reconstruction, the Tegner activity score decreased from 6.0 preoperatively to 5.8 postoperatively and patients were able to return to sports activities at the same level or higher of performance in 80% of cases.[10] In our study, the majority of the patients (58.8%) had a sedentary life (below Tegner level 5) due to the complaints of local patellar instability, and 14 of 34 patients (41.1%) were doing active sports (Tegner level 5 and above) preoperatively. In the aforementioned study, postoperatively, 26 of the patients (76.4%) were able to continue or start sports activities ($p=0.001$).[10] Previous studies have shown a statistically significant improvement in the preoperative Tegner activity scores of the sedentary patient group with low Tegner activity scores.[24-26] In our study, all postoperative knee functions and activity levels were statistically significantly improved in the study group ($p<0.001$). In our study, quality of life and sports activity levels increased after anatomic MPFL reconstructions, particularly in adolescents who lead a sedentary life due to patellar instability. Postoperatively, 27 patients (79.4%) who did active sports preoperatively were able to go above the activity level postoperatively and were able to return to their sports activities after a median of 5.5 (4 to 12) months.[27]

In a systematic study evaluating 477 children and adolescents (510 procedures), a total of 87% of the patients returned to sports and the mean time to return to sports was 6.1±1.1 months.[28] In a retrospective study of 69 skeletally immature patients who experienced recurrent LPD and were treated with anatomical MPFL reconstruction, 57 of the 63 patients (90.5%) who were playing sports before the injury returned to competitions at the same or higher level.[29] Similarly in our study, 27 (79.4%) patients started sports activities and were able to return to sports activities after a median of 5.5 months.

Physical therapy is essential for successful clinical outcomes after MPFL reconstruction. The high-quality physical therapy was required and it was emphasized that the entire kinetic chain should be addressed by working on the strength and control of the lower limbs to optimize balance and movement patterns for best results.[30] In our study, physical therapy was started for all patients after discharge, and extended rehabilitation programs were applied to patients whose rehabilitation progressed slowly. Twelve patients (35.2%) required prolonged physical therapy treatment due to limited range of motion and insufficient muscle strength, while flexion deficit remained in three (8.8%) patients postoperatively.

Non-surgical methods, MPFL repair, and distal and proximal soft tissue procedures for patellar instability have high complication and re-dislocation rates. The MPFL reconstruction has a reduced complication rate.[31] Migliorini et al.[32] reported that the probability of major complications was 4.1% and minor complications were 9.1% in the surgical treatment for RPD and the rate of re-dislocation was 12% in skeletally immature patients. In a study evaluating the complications of MPFL reconstruction in young patients, 38 complications were detected in 29 of 179 knees (16.2%). Most of the complications (89.4%) were major complications, including recurrent lateral patellar instability, flexion deficits, patella fracture, and PFOA.[33] Patellar chondromalacia was detected on MRI in three (8.8%) patients with patellofemoral pain complaints during a median of five years of follow-up. No growth disturbance and recurrent dislocation were observed.

One of the main limitations to this study is the lack of long-term follow-up to better evaluate the clinical outcome of cartilage injuries. Secondly, our study has a retrospective design with no control group such as an immature adolescent or patients treated conservatively. Thirdly, it includes a limited group of patients, which prevents us from making decisions about RPD in the entire adolescent population. Another limitation is the absence of imaging performed to detect any signs of patellofemoral chondral degeneration except in patients with clinical findings. Future studies with longer follow-up times, involving wider age groups, and larger patient groups are needed.

In conclusion, anatomic MPFL reconstruction with meticulous physical therapy provides successful clinical outcomes and prevents re-dislocation in skeletally mature adolescents with RPD. It can predict that adolescents who have decreased sports activity due to patellar instability and lead a sedentary life, increase their participation in sports and activity levels after anatomic MPFL reconstructions. Cartilage lesions are frequently encountered in adolescents undergoing anatomic MPFL reconstruction due to RPD; however, its effect on mid-term clinical outcomes has not been determined in our study and long-term follow-up studies are needed.

Ethics Committee Approval: The study protocol was approved by the Çukurova University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (date: 04.0.3.2022, no: 120/40/07.04.2022). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the parents and/or legal guardians of the patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, control/supervision, analysis and/or interpretation, materials: C.O.; Data collection and/or processing: C.O., Y.S.; Literature review, writing the article: C.O., O.K., R.C.; Critical review: Y.S.; References and fundings: C.O., O.K.; Other: R.C., O.K.

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