

# Morphological Changes of the Posterior Femoral Condyle After Medial Patellar Retinaculum Plasty in Skeletally Immature Patients With Recurrent Patellar Dislocation and Trochlear Dysplasia

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**Background:** Surgical correction for recurrent patellar dislocation (RPD) can improve femoral trochlear morphology; nonetheless, the effects of surgical correction on femoral condyle morphology are unclear.

**Purpose:** To investigate the morphological changes in the posterior femoral condyle in skeletally immature patients with RPD and trochlear dysplasia (TD) after surgical correction.

**Study Design:** Cohort study; Level of evidence, 3.

**Methods:** A total of 20 skeletally immature patients with bilateral RPD and TD were included in this study. For each patient, the knee that was dislocated more frequently or had sustained a recent injury was treated with medial patellar retinaculum plasty (group S; n = 20 knees), and the asymptomatic or only occasionally dislocated contralateral knee was treated conservatively (group C; n = 20 knees). The lengths of the anterior medial and lateral femoral condyles and the lengths of the posterior medial and lateral femoral condyles were evaluated preoperatively and at the final follow-up. Trochlear morphological characteristics, tibial tuberosity–trochlear groove distance, and patellar tilt angle were compared between preoperative and final follow-up values with the 2-sample paired Student *t* test and were compared between groups S and C with the independent-samples *t* test.

**Results:** The mean follow-up time was  $60.7 \pm 4.8$  months. No knee in group S experienced a redislocation, whereas 80% (16/20) of knees in group C experienced a dislocation. There were significant group differences in the ratio of the posterior medial femoral condyle (PMFC) to the posterior lateral femoral condyle (PLFC) (group S,  $1.08 \pm 0.05$ ; group C,  $1.14 \pm 0.06$ ;  $P = .042$ ). There was no significant difference in the ratio of the anterior lateral femoral condyle to the anterior medial femoral condyle (group S,  $1.16 \pm 0.13$ ; group C,  $1.18 \pm 0.09$ ;  $P = .635$ ). In group S, all trochlear morphological characteristics and patellofemoral joint characteristics improved compared with preoperatively ( $P \leq .047$  for all). In addition, all values significantly differed between groups S and C at the final follow-up ( $P \leq .044$  for all).

**Conclusion:** The study findings demonstrated that the morphology of the posterior femoral condyle in skeletally immature patients with bilateral RPD and TD changes after surgical correction, with the PLFC growing faster than the PMFC.

**Keywords:** femoral posterior condyle; recurrent patellar dislocation; trochlear dysplasia; trochlear morphology

Recurrent patellar dislocation (RPD) is a common orthopaedic disorder.<sup>9,36</sup> The cause of patellar dislocation is

multifactorial and includes trochlear dysplasia (TD), patella alta, lower limb malalignment, and relative rotation of the femur and tibia.<sup>5,6,30</sup> Dejour et al<sup>5</sup> reported that 85% of patients with RPD had TD. However, some studies have found that patients with RPD have not only an increased rate of TD but also a morphological abnormality in the posterior femoral condyle.<sup>3,34</sup> A study by Roger

The Orthopaedic Journal of Sports Medicine, 12(1), 23259671231225671  
DOI: 10.1177/23259671231225671  
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et al<sup>34</sup> reported that the posterior part of the lateral condyle is shorter and smaller than the medial condyle in patients with RPD and TD. Biedert and Bachmann<sup>3</sup> found that the posterior lateral femoral condyle (PLFC) was smaller and the posterior medial femoral condyle (PMFC) was larger in patients with TD than in normal controls. Moreover, valgus alignment is another risk factor for hypoplasia of the lateral distal femoral condyle and lateral patellar instability, which increases the Q angle and contributes to maltracking of the patella.<sup>38,33</sup> Excessive rotation can be expected during extension in patients with hypoplasia of the PLFC, contributing to patellar dislocation.<sup>12</sup>

Controversy still remains on how to manage skeletally immature patients with RPD and TD. Excellent results have been reported with medial patellofemoral ligament (MPFL) reconstruction in adults, whereas cases of failure have been reported in skeletally immature adolescents after MPFL reconstruction.<sup>2,11,35,15</sup> Considering the significant contribution of the distal femoral growth plate to longitudinal growth, injury of the physes must be avoided to prevent leg-length deformities of the limb.<sup>15</sup> In recent years, a soft tissue surgical technique called the medial patellar retinaculum plasty was proposed.<sup>8,16,20</sup> In this surgery, the vastus medialis oblique head and joint capsule are used to reconstruct the medial complex, which is thought to restore the MPFL by avoiding the femoral growth plate.<sup>16</sup> Excellent clinical results of soft tissue surgery have been demonstrated in the literature.<sup>8,10,23,25</sup>

The morphology of the trochlea can be significantly changed by early soft tissue surgery in skeletally immature patients with RPD and TD.<sup>2,10</sup> A study by Benoit et al<sup>2</sup> with an 11-year clinical follow-up period reported that the realignment surgery could remodel the TD at a young age. Another study also demonstrated that the femoral trochlear morphology could be changed by surgical correction in children with RPD and TD.<sup>10</sup> However, no author has focused on the morphological changes in the posterior femoral condyle for skeletally immature patients with RPD and TD after surgical correction.

Our study aimed to investigate the changes in the posterior femoral condyle after soft tissue surgery in skeletally immature patients with RPD and TD. It was hypothesized that the morphology of the posterior femoral condyle would change and that the PLFC would grow faster than the PMFC after surgical correction.

## METHODS

We followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for this study. Ethical approval for the study protocol was acquired

from our institutional ethics board, and informed consent was obtained from all patients before the initiation of this study.

All included patients were initially evaluated at our institution between January 2014 and August 2017. The patients were selected based on the following inclusion criteria: (1) bilateral RPD; (2) adolescent patients with open femoral growth plates—open femoral growth plates as confirmed on knee radiographs; (3) Dejour type A TD and a flat trochlea—Dejour type B<sup>5</sup>; and (4) concomitant MPFL injury. The exclusion criteria were as follows: (1) patients with previous knee surgery; (2) patients with closed physes; (3) patients with a convex trochlea—Dejour type B; (4) patients with high-grade TD (Dejour types C-D)—when high-grade TD is present, it is necessary to perform other procedures to counteract the adverse effect; (5) patients with concomitant cruciate ligament or collateral ligament injury; (6) patients with rheumatoid arthritis or osteonecrosis with cartilage damage >grade 2 (Outerbridge classification), as evaluated by arthroscopy; (7) patients who did not complete conservative treatment for at least 12 months.

Ultimately, 20 skeletally immature patients were included in our study. All patients were diagnosed with bilateral RPD and TD. For each patient, the knee that was more frequently dislocated or sustained the most recent injury underwent surgical medial patellar retinaculum plasty (group S; n = 20), and the asymptomatic or only occasionally dislocated contralateral knee was treated conservatively (group C; n = 20). A flowchart of patient selection is shown in Figure 1.

## Surgical Technique: Medial Patellar Retinaculum Plasty

All operations were performed by a senior orthopaedic surgeon (X.W.) with 20 years of experience in knee surgery, who specializes in osteoarthritis and patellar dislocation. The diagnostic arthroscopic assessment was performed, and chondral lesions and concomitant pathology were addressed in all patients before medial patellar retinaculum plasty was performed. Arthroscopic lateral retinacular release (ALRR) has been indicated for patients with lateral retinacular tightness or large patellar tilt.<sup>40</sup> A force-directed medial shift of the patella by less than one-fourth of its width indicates excessive tension of the lateral retinaculum.<sup>10</sup> For such patients, ALRR is often required.<sup>40</sup>

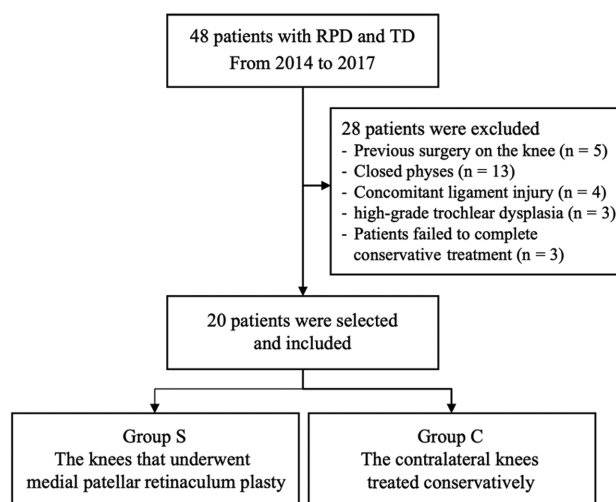
For medial patellar retinaculum plasty, the vastus medialis oblique head, the fascia, and the joint capsule were used to construct the new, stable medial complex, which formed a vector structure to prevent redislocation

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Final revision submitted August 12, 2023; accepted August 17, 2023.

The authors have declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from The Third Hospital of Hebei Medical University (ref No. 2022-072-1).



**Figure 1.** A flowchart of patient selection in this study. RPD, recurrent patellar dislocation; TD, trochlear dysplasia.

of the patella and avoid damage to the distal femoral physes.<sup>10,25</sup>

First, a longitudinal incision was made at the border between the medial border of the patella and the vastus medialis muscle, and the fascia and reticulum were identified. Then, a transverse incision was made at the junction of the vastus medialis muscle and the medial retinaculum of the patella to mobilize it. The knee joint was flexed 30°, and then the patella was held in the proper position within the trochlear groove. Second, after the position of the patella was adjusted, the medial retinaculum of the patella was pulled proximally and temporarily sutured to the proximal medial edge of the patella using polydioxanone synthetic absorbable suture (PDS-I) (DePuy Synthes). The vastus medialis muscle fibers were pulled distally and sutured to the distal end of the patella. The position of the patella during knee flexion and extension was evaluated to ensure that the patellofemoral joint closely matched the correct position.<sup>16</sup> Finally, the wound was rinsed thoroughly and sutured in layers.

### Postoperative Rehabilitation

**Group S.** All patients were guided by the same rehabilitation therapist and adopted the same rehabilitation method. Patients were asked to wear a motion-restricting knee brace after surgery. Quadriceps strength training, such as straight-leg raising, was started immediately after surgery. Then patients continued partial weightbearing. After 4 weeks, the knee brace was removed, and full weightbearing was resumed. Knee flexion up to 30° was permitted for 1 week, and up to 90° was permitted for 4 weeks. Patients were allowed to return to normal activities of daily living after 2 months and to resume normal sports after 4 months.

**Group C.** Nonoperative treatment on the contralateral knee was started immediately after surgery. First,

a motion-restricting knee brace was used to protect the patella from lateralization and limit the range of motion (ROM). Quadriceps muscle strengthening to restore the dynamic component of the patellar soft-tissue stabilizers and kinesiotherapy to recover full ROM were necessary for patients.<sup>28,32</sup> The most common strategy includes isometric and isotonic quadriceps strengthening exercises, such as straight-leg raises, squats, and lunges.<sup>24</sup>

### Outcome Evaluation

Axial computed tomography (CT) scans were performed preoperatively and at the final follow-up in all patients to assess the morphology of the femoral condyle and femoral trochlea as well as the changes in patellar positioning. All measurement methods are shown in Table 1. At the final follow-up, CT scans were undertaken again to evaluate the changes in the femoral condyle. Patellar, femoral trochlear, and condylar morphologies were measured with the transcondylar axis as the reference line, respectively.<sup>5</sup> The best CT cross-section of the Roman dome was selected to show the morphology of the femoral trochlea and femoral condyle (Figure 2).<sup>37</sup> Given that the medial condyle was flat in patients with TD, the vertical distance from the inflection point or vertex of the medial trochlea to the transcondylar line was selected to express the length of the medial anterior condyle. The measurements of the femoral condyle characteristics are shown in Figure 2. To reduce the effect of individual height on bone volume, the ratio of the lengths of the femoral condyles was used to show the relative changes: anterior lateral femoral condyle (ALFC)/anterior medial femoral condyle (AMFC) and PMFC/PLFC. The methods for evaluating trochlear morphology and the tibial tubercle–trochlear groove (TT-TG) distance are shown in Figures 3 and 4, respectively. All data were measured using RadiAnt DICOM Viewer software (Medixant Ltd), which has an accuracy of 0.01° for angles and 0.01 mm for distance.

### Statistical Analysis

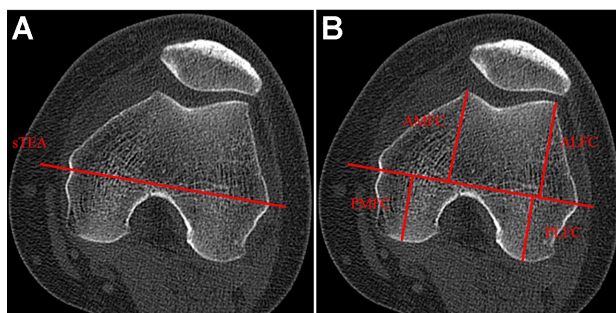
Statistical analysis was performed using SPSS statistical software Version 26.0 (SPSS Inc). All data are expressed as the mean ± standard deviation. The Kolmogorov-Smirnov test was used to test the normality of numerical data; all numerical variables showed a normal distribution or equal variance. Measurements between the preoperative assessment and the final follow-up were compared using the 2-sample paired Student *t* test, and the Student *t* test was used to compare the differences in variables between groups S and C. Also, statistical significance was set at  $P < .05$ . Given the effect of ALRR, subgroup analysis was conducted by stratifying the results according to whether the ALRR was performed.

To reduce measurement errors, all data were measured by 2 researchers (Z.S. and A.F.) under the same conditions, and after a 6-week interval, all data were measured again by a single researcher (Z.S.). The intraclass correlation coefficient (ICC) was used to test the intra- and interrater

TABLE 1  
Description of Morphometric Parameters<sup>a</sup>

Parameter	Description
sTEA	A straight line from the most medial to the most lateral aspect of the femur (see Figure 2A).
Anterior condyle characteristics	
ALFC	Defined by drawing a perpendicular axis from sTEA crossing the most anterior point of the lateral condyle. The length was defined as the distance between sTEA and the anterior point <sup>34</sup> (see Figure 2B).
AMFC	Defined by drawing a perpendicular axis from sTEA crossing the most anterior point of the medial condyle. The length was defined as the distance between sTEA and the anterior point <sup>34</sup> (see Figure 2B).
ALFC/AMFC ratio	If >1, then the lateral anterior condyle is larger than the medial anterior condyle.
Posterior condyle characteristics	
PMFC	Defined by drawing a perpendicular axis from sTEA crossing the most posterior point of the medial condyle. The length was defined as the distance between sTEA and the posterior point <sup>34</sup> (see Figure 2B).
PLFC	Defined by drawing a perpendicular axis from sTEA crossing the most posterior point of the lateral condyle. The length was defined as the distance between sTEA and the posterior point <sup>34</sup> (see Figure 2B).
PMFC/PLFC ratio	If >1, then the medial posterior condyle is larger than the lateral posterior condyle.
Trochlear morphological characteristics	
Sulcus angle	The angle between the slopes of the medial and lateral trochlea <sup>4</sup> (see Figure 3A).
Congruence angle	Line 1 is drawn to bisect the sulcus angle. Line 2 is drawn from the lowest point of the trochlear groove to the lowest point of the patella. A positive angle is designated as one that is toward the lateral side <sup>4</sup> (see Figure 3D).
Lateral trochlear inclination	Line 1 is drawn across the posterior margins of the medial and lateral condyles. Line 2 is drawn along the lateral slope of the trochlear groove. The lateral trochlear inclination is the angle between the 2 lines <sup>4</sup> (see Figure 3B).
TGD	Line 1 is drawn across the anterior margins of the medial and lateral condyles. The TGD is the distance from the center and deepest point of the trochlear groove <sup>4</sup> to line 1 (see Figure 3C).
Patellofemoral joint characteristics	
TT-TG distance	Two planes: The first plane passes through the proximal end of the femoral trochlea, and the second plane passes through the proximal end of the tibial tubercle. Overlap the 2 planes, mark the lowest point of the femoral trochlea and the midpoint of the tibial tubercle, project them onto the reference line, and measure the distance between them <sup>4</sup> (see Figure 4A).
Patellar tilt angle	Line 1 is drawn across the posterior margins of the medial and lateral condyles, and line 2 is drawn through the transverse axis of the patella <sup>4</sup> (see Figure 4B).

<sup>a</sup>ALFC, anterior lateral femoral condyle; AMFC, anterior medial femoral condyle; PLFC, posterior lateral femoral condyle; PMFC, posterior medial femoral condyle; sTEA, surgical transepicondylar axis; TGD, trochlear groove depth; TT-TG, tibial tubercle–trochlear groove.

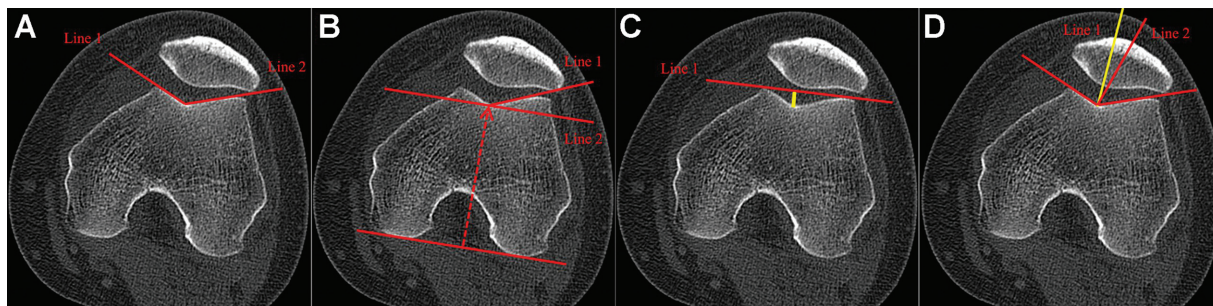


**Figure 2.** Measurement of the length of the femoral condyles. (A) The anteroposterior dimensions of the sTEA at the level of the Roman dome. (B) The characteristics of the anterior and posterior condyles. ALFC, anterior lateral femoral condyle. AMFC, anterior medial femoral condyle. PLFC, posterior lateral femoral condyle; PMFC, posterior medial femoral condyle; sTEA, surgical transepicondylar axis.

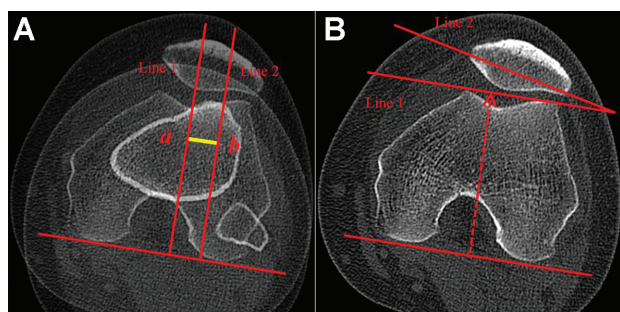
reliability of the measurements. An ICC of >0.75 indicated excellent reliability. An a priori power analysis with a pre-specified alpha level of .05 and an effect size of 0.8 showed that a minimum sample size of 18 participants was necessary for this study.

## RESULTS

The mean age of the 20 study participants was  $13.7 \pm 1.9$  years (range, 10–15 years). Thirteen patients had patellar dislocation due to trauma, while the other 7 patients had no history of trauma. The mean follow-up time was  $60.7 \pm 4.8$  months (range, 53–67 months). The characteristics of patients are summarized in Table 2. At the final follow-up, no knee in group S experienced patellar redislocation; however, occasional discomfort was felt in 2 knees, and these patients could not return to sports activities.



**Figure 3.** Measurements of trochlear morphological characteristics. (A) Sulcus angle: the angle between Line 1 and Line 2. (B) Lateral trochlear inclination: the angle between Line 1 and Line 2. (C) Trochlear groove depth (yellow line): the distance from the center and deepest portion of the trochlear groove to Line 1. (D) Congruence angle: Line 1 (yellow line) is drawn to bisect the sulcus angle of the trochlear groove. The congruence angle is the angle between Line 1 and Line 2.



**Figure 4.** (A) TT-TG distance: Line 1 is perpendicular to the tangent to the posterior condyle and passes through the lowest point of the femoral trochlea. Line 2 is parallel to Line 1 through the most anterior portion of the tibial tuberosity. The TT-TG distance (yellow line) is the distance between *a* and *b*. (B) Patellar tilt angle: Line 1 is the tangent line of the medial and lateral posterior condyle, and Line 2 is across the maximum transverse diameter of the patella. The patellar tilt angle is the angle between them. TT-TG, tibial tubercle-trochlear groove.

Sixteen knees in group C experienced another instance of patellar dislocation.

### Evaluation of the Femoral Condyle

Preoperatively, the ratio of the anterior femoral condyle length to the posterior femoral condyle length was not significantly different between the 2 groups ( $P \geq .884$ ) (Table 3). At the final follow-up, the ALFC/AMFC ratio was not significantly different between the 2 groups. However, significant group differences were observed in the PMFC/PLFC ratio (group S:  $1.08 \pm 0.05$ ; group C:  $1.14 \pm 0.06$ ;  $P = .042$ ). The outcomes of the subgroup analysis regarding the influence of arthroscopic lateral retinacular release are shown in Table 4. In group S, 12 of 20 knees underwent medial patellar retinaculum plasty combined with ALRR, and 8 of 20 knees underwent isolated medial patellar retinaculum plasty in group S. We noted no significant difference between groups with versus without ALRR

in the length ratio of the posterior and anterior femoral condyles (Table 4).

### Evaluation of Trochlear Morphology and Patellofemoral Joint Stability

There were no significant differences in any of the trochlear morphological and patellofemoral joint characteristics between the groups preoperatively. At the final follow-up, however, significant group differences were seen on all variables, including the sulcus angle (SA) (group S,  $132.67^\circ \pm 7.16^\circ$ ; group C,  $143.89^\circ \pm 6.95^\circ$ ;  $P = .004$ ), congruence angle (group S,  $19.25^\circ \pm 10.46^\circ$ ; group C,  $31.50^\circ \pm 9.89^\circ$ ;  $P = .03$ ), lateral trochlear inclination (group S,  $26.50^\circ \pm 3.73^\circ$ ; group C,  $21.43^\circ \pm 3.78^\circ$ ;  $P = .034$ ), patellar tilt angle (PTA) (group S,  $18.65^\circ \pm 5.86^\circ$ ; group C,  $24.11^\circ \pm 3.80^\circ$ ;  $P = .044$ ), trochlear groove depth (TGD) (group S,  $4.87 \pm 1.17$  mm; group C,  $3.84 \pm 0.61$  mm;  $P = .033$ ), and TT-TG distance (group S,  $12.01 \pm 2.33$  mm; group C,  $16.54 \pm 2.59$  mm;  $P = .004$ ) (Table 5). In addition, all parameters improved significantly in group S compared with their preoperative values ( $P \leq .047$  for all).

The ICC values for intra- and interrater reliability of all measurements are shown in Table 6. Most of the ICCs of the radiological measurements were excellent. The intra-observer ICCs ranged from 0.503 to 0.989, and the interobserver ICCs ranged from 0.670 to 0.987, indicating that the radiographic measurements were highly reliable.

### DISCUSSION

The most important finding of our study was that the morphology of the posterior femoral condyle in skeletally immature patients with RPD and TD changed after surgical correction, with the PLFC growing faster than the PMFC. When the ratio of femoral condyles between the knees that underwent surgical versus conservative treatment was compared, significant changes were found at the final follow-up ( $P = .042$ ). In addition, the PMFC/PLFC ratio decreased from  $1.11 \pm 0.07$  preoperatively to  $1.08 \pm 0.05$  at the final follow-up in the surgically

TABLE 2  
Characteristics of the Study Population (N = 20)<sup>a</sup>

Characteristic	Value
Age at surgery, y	13.7 ± 1.9 (10-15)
Sex	
Male	8 (40)
Female	12 (60)
Side affected	
Right	14 (70)
Left	6 (30)
Weight, kg	60 ± 21 (30-95)
Height, cm	162.3 ± 13.6 (142-186)
BMI, kg/m <sup>2</sup>	22.08 ± 4.4 (14.88-27.76)
Follow-up, mo	60.7 ± 4.8 (53-67)

<sup>a</sup>Data are reported as mean ± SD (range) or n (%). BMI, body mass index.

TABLE 3  
Characteristics of Femoral Condyles Preoperatively and at the Final Follow-up<sup>a</sup>

Parameter	Group S	Group C	P <sup>b</sup>
ALFC/AMFC ratio			
Preoperative	1.149 ± 0.788	1.160 ± 0.078	.765
Final follow-up	1.158 ± 0.125	1.183 ± 0.093	.635
P <sup>c</sup>	.744	.268	
PMFC/PLFC ratio			
Preoperative	1.109 ± 0.065	1.105 ± 0.084	.910
Final follow-up	1.079 ± 0.053	1.139 ± 0.061	<b>.042</b>
P <sup>c</sup>	<b>.015</b>	.354	
ALFC/PMFC ratio			
Preoperative	1.449 ± 0.207	1.463 ± 0.208	.884
Final follow-up	1.393 ± 0.178	1.430 ± 0.162	.656
P <sup>c</sup>	.160	.304	
AMFC/PLFC ratio			
Preoperative	1.400 ± 0.208	1.394 ± 0.204	.951
Final follow-up	1.224 ± 0.090	1.383 ± 0.196	<b>.042</b>
P <sup>c</sup>	<b>.002</b>	.819	

<sup>a</sup>Data are reported as mean ± SD. Bold P values indicate statistically significant differences between groups (P < .05). ALFC, anterior lateral femoral condyle; AMFC, anterior medial femoral condyle; PLFC, posterior lateral femoral condyle; PMFC, posterior medial femoral condyle.

<sup>b</sup>Student t test.

<sup>c</sup>Paired Student t test.

treated knees (P = .015). We conducted a subgroup analysis considering the effects of ALRR on patients; however, there were no significant differences observed between patients with versus without ALRR. To our knowledge, this is the first study to investigate the changes in the femoral condyle after medial patellar retinaculum plasty.

The morphology of the trochlear and femoral condyles has been found to differ between people with versus without RPD.<sup>17,22,39</sup> Van Haver et al<sup>39</sup> also found the same phenomenon reported by Roger et al<sup>34</sup> and Liu et al<sup>22</sup> and explained the abnormal changes in femoral condyles as a compensatory enlargement to maintain the overall

TABLE 4  
Subgroup Analysis of the Changes in Femoral Condyles Between Knees Undergoing Medial Patellar Retinaculum Plasty With Versus Without ALRR<sup>a</sup>

Parameter	With ALRR	Without ALRR	P <sup>b</sup>
ALFC/AMFC ratio			
Preoperative	1.157 ± 0.038	1.140 ± 0.120	.771
Final follow-up	1.145 ± 0.102	1.175 ± 0.165	.749
P <sup>c</sup>	.794	.262	
PMFC/PLFC ratio			
Preoperative	1.127 ± 0.074	1.087 ± 0.052	.387
Final follow-up	1.083 ± 0.063	1.050 ± 0.034	.378
P <sup>c</sup>	<b>.043</b>	<b>.027</b>	
ALFC/PMFC ratio			
Preoperative	1.370 ± 0.153	1.546 ± 0.244	.225
Final follow-up	1.310 ± 0.730	1.498 ± 0.152	.121
P <sup>c</sup>	.340	.394	
AMFC/PLFC ratio			
Preoperative	1.329 ± 0.747	1.487 ± 0.289	.265
Final follow-up	1.238 ± 0.110	1.350 ± 0.217	.347
P <sup>c</sup>	<b>.014</b>	<b>.037</b>	

<sup>a</sup>Data are reported as mean ± SD. Bold P values indicate statistically significant differences between groups (P < .05). ALFC, anterior lateral femoral condyle; ALRR, arthroscopic lateral retinaculum release; AMFC, anterior medial femoral condyle; PLFC, posterior lateral femoral condyle; PMFC, posterior medial femoral condyle.

<sup>b</sup>Student t test.

<sup>c</sup>Paired Student t test.

morphology of the femur. The morphology of the distal femur is affected by genes and acquired mechanical alignment.<sup>13,14,21,26</sup> Early surgical intervention was able to change the morphology of the femoral trochlea in pediatric patients, and we believe that femoral changes are not isolated but have effects throughout the distal femur; early surgical intervention appears to affect not only the trochlea but also the posterior femoral condyle.

The TT-TG distance has been described as an important measure to gauge coronal-plane malalignment as a risk factor for patellar instability.<sup>27</sup> A TT-TG distance of ≥20 mm represents an excessively lateral position of the tuberosity and malalignment of patellar tracking.<sup>18,19,27</sup> Patellar tracking is governed by a complex interaction between soft tissues and bony structures.<sup>18</sup> Therefore, a medializing osteotomy is necessary for patients with a TT-TG distance of ≥20 mm, given that soft tissue surgery cannot correct malalignment of patellar tracking.<sup>1,29,31</sup> The mean TT-TG distance was <20 mm in both study groups (group S, 16.50 ± 4.67 mm; group C, 16.72 ± 3.99 mm; P > .05); therefore, the soft tissue surgery for skeletally immature patients with RPD and TD was able to treat patellar dislocation.

The PTA is an excellent indicator for evaluating the change in patellar position. Dejour et al<sup>5</sup> compared the PTA of healthy people to that of people with patellar dislocation and concluded that the inclination angle of the patella in the patients with PD was 16.3° ± 3.3°. The PTA was 24.75° ± 4.27° preoperatively and 18.65° ±

TABLE 5  
Morphological Characteristics Preoperatively and at the Final Follow-up<sup>a</sup>

Parameter	Group S	Group C	P <sup>b</sup>
Sulcus angle, deg			
Preoperative	144.56 ± 8.38	145.67 ± 7.25	.767
Final follow-up	132.67 ± 7.16	143.89 ± 6.95	<b>.004</b>
P <sup>c</sup>	<b>.037</b>	.285	
Congruence angle, deg			
Preoperative	34.38 ± 14.74	32.88 ± 10.78	.820
Final follow-up	19.25 ± 10.46	31.50 ± 9.89	<b>.030</b>
P <sup>c</sup>	<b>.047</b>	.092	
LTI, deg			
Preoperative	21.67 ± 4.08	21 ± 2.83	.735
Final follow-up	26.50 ± 3.73	21.43 ± 3.78	<b>.034</b>
P <sup>c</sup>	<b>.005</b>	.356	
PTA, deg			
Preoperative	24.75 ± 4.27	24.25 ± 4.17	.816
Final follow-up	18.65 ± 5.86	24.11 ± 3.80	<b>.044</b>
P <sup>c</sup>	<b>.026</b>	.946	
TGD, mm			
Preoperative	3.56 ± 1.11	3.58 ± 0.68	.952
Final follow-up	4.87 ± 1.17	3.84 ± 0.61	<b>.033</b>
P <sup>c</sup>	<b>.004</b>	.332	
TT-TG, mm			
Preoperative	16.50 ± 4.67	16.72 ± 3.99	.925
Final follow-up	12.01 ± 2.33	16.54 ± 2.59	<b>.004</b>
P <sup>c</sup>	<b>.014</b>	.915	

<sup>a</sup>Data are reported as mean ± SD. Bold P values indicate statistically significant differences between groups (P < .05). LTI, lateral trochlear inclination; PTA, patellar tilt angle; TGD, trochlear groove depth; TT-TG, tibial tuberosity-trochlear groove distance.

<sup>b</sup>Student t test.

<sup>c</sup>Paired Student t test.

5.86° postoperatively in group S, representing a statistically significant change (P = .026). Benoit et al<sup>2</sup> evaluated children with patellar dislocation for an mean of 13 years and found that surgically treated patients with patellar dislocation had significant changes in the SA. The SA was also significantly different between groups S and C (132.67° ± 7.16° vs 143.89° ± 6.95°, respectively; P = .004). Dejour et al<sup>5</sup> found that 85% of knees with patellar instability had a depth that measured ≤4 mm. The TGD significantly differed between groups (group S: 4.87 ± 1.17 mm; group C: 3.84 ± 0.61 mm; P = .033). Charles et al<sup>4</sup> and Escala et al<sup>7</sup> showed that the mean TGD in healthy people was >6 mm, while a TGD of <4 mm indicated patellar instability and TD. The results found in the present study were consistent with the measurements reported by Fu et al.<sup>10</sup>

There is a lack of relevant research on the changes in the femoral anterior condyle after soft tissue surgery. Roger et al<sup>34</sup> mentioned how to measure the bilateral anterior condyles on axis CT but did not explain the difference between the bilateral anterior condyles of patients with RPD and those of healthy people. In our study, the ALFC/AMFC ratio was not significantly different between groups (group S, 1.16 ± 0.13; group C, 1.18 ± 0.09; P = .635); nonetheless, the values of TGD were significantly different, which suggested that the major changes took place in the trochlear groove after surgery. Therefore, the mechanism of morphology about the anterior femoral condyle is complicated and requires further research.

Limitations

This study is not without limitations. The sample size was too small; increasing the sample size would make the study

TABLE 6  
Intra- and Interrater Reliability of the Measurements<sup>a</sup>

Parameter	Intraobserver Reliability	Interobserver Reliability
Group S		
ALFC/AMFC ratio	0.784 (0.490-0.908)	0.958 (0.902-0.982)
PMFC/PLFC ratio	0.829 (0.597-0.928)	0.978 (0.948-0.991)
ALFC/PMFC ratio	0.835 (0.610-0.930)	0.934 (0.844-0.972)
AMFC/PLFC ratio	0.853 (0.653-0.938)	0.819 (0.574-0.923)
Sulcus angle	0.902 (0.768-0.958)	0.908 (0.782-0.961)
Congruence angle	0.503 (0.171-0.789)	0.768 (0.452-0.901)
Lateral trochlear inclination	0.695 (0.281-0.871)	0.840 (0.624-0.932)
Patellar tilt angle	0.982 (0.967-0.990)	0.931 (0.887-0.960)
Trochlear groove depth	0.696 (0.282-0.871)	0.707 (0.310-0.876)
TT-TG distance	0.986 (0.974-0.992)	0.924 (0.874-0.956)
Group C		
ALFC/AMFC ratio	0.629 (0.124-0.842)	0.679 (0.285-0.871)
PMFC/PLFC ratio	0.721 (0.342-0.882)	0.670 (0.222-0.860)
ALFC/PMFC ratio	0.840 (0.624-0.932)	0.899 (0.761-0.957)
AMFC/PLFC ratio	0.801 (0.532-0.916)	0.868 (0.689-0.944)
Sulcus angle	0.977 (0.947-0.990)	0.964 (0.916-0.985)
Congruence angle	0.843 (0.629-0.933)	0.801 (0.532-0.916)
Lateral trochlear inclination	0.989 (0.974-0.995)	0.929 (0.833-0.970)
Patellar tilt angle	0.764 (0.443-0.900)	0.987 (0.970-0.995)
Trochlear groove depth	0.952 (0.886-0.979)	0.776 (0.473-0.905)
TT-TG distance	0.921 (0.813-0.966)	0.722 (0.344-0.882)

<sup>a</sup>Data are reported as ICC (95% CI). ALFC, anterior lateral femoral condyle; AMFC, anterior medial femoral condyle; ICC, intraclass correlation coefficient; PLFC, posterior lateral femoral condyle; PMFC, posterior medial femoral condyle; TT-TG, tibial tuberosity-trochlear groove distance.

results more accurate. CT assessment can accurately reflect the development of bones; nevertheless, this study did not consider the influence of cartilage factors in the population with patellar dislocation, and different cartilage thicknesses also affected the measurement of the length of the posterior femoral condyle. Finally, without a healthy control group, we cannot conclusively infer what is normal or abnormal or determine whether the changes in the posterior femoral condyles would tend to normalize or abnormalize over time. All of these questions need further investigation.

## CONCLUSION

Study findings indicated that the morphology of the posterior femoral condyle in skeletally immature patients with RPD and TD had changed, and the PLFC grew faster than the PMFC after surgical correction.

## ACKNOWLEDGMENT

The authors thank the staff of the participating departments for their support during the study.

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