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The effect of surgery for multipleligament knee injuries on patellar position and patellofemoral function: a retrospective study

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Abstract

Background Patients who undergo reconstruction for multiligament knee injuries (MLKIs) often exhibit knee instability and poor overall knee function during postoperative follow-up. This may be related to the changes in patellar position and decline in patellofemoral function after surgery.

Objective To evaluate the outcomes following reconstruction of MLKIs through the assessment of: (1) changes in patellar height; (2) anatomical changes in patellofemoral alignment, such as tilt or displacement; and (3) functional outcomes of the patellofemoral joint.

Methods This retrospective study included 45 patients who underwent reconstruction for MLKIs at our hospital between November 2015 and September 2022, with complete data and meeting the inclusion criteria. These patients formed the case group. An additional 20 outpatients without ligament injuries or patellar dislocation were selected as the normal control group. Patellar height changes in the case group were assessed preoperatively and postoperatively using the Caton-Deschamps (CD) and Insall-Salvati (IS) indices on lateral X-rays. Magnetic resonance imaging (MRI) was used to measure patellofemoral alignment parameters in both groups, including the sulcus angle (SA), patellar tilt angle (PTA), lateral patellofemoral angle (LPA), congruence angle (CA), and patellofemoral index (PI), to evaluate patellofemoral positioning. Additionally, the Kujala score questionnaire was used to assess the stability function of the patellofemoral joint.

Results Preoperative patellar height in the case group, measured by the CD and IS indices, was (1.07 ± 0.10, 1.10 ± 0.09), showing a statistically significant difference when compared to postoperative measurements (0.96 ± 0.13, 1.05 ± 0.10) ($P < 0.05$). However, postoperative patellofemoral alignment parameters, including SA, PTA, LPA, CA, and PI, in the case group showed no statistically significant differences compared to the control group ($P > 0.05$). At the latest follow-up, the patellofemoral function score in the case group was (89.0 ± 5.3), which was not significantly different from the control group (91.0 ± 2.9) ($P > 0.05$).

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Conclusion After reconstruction of MLKIs, patellar height decreased but remained within the normal range. Patellofemoral alignment was well-maintained, and patellofemoral function was maintained.

Keywords Multiligament knee injuries , Patellar height , Patellofemoral position , Patellofemoral function

Introduction

Multiligament knee injuries (MLKIs) refer to the simultaneous injury of two or more ligaments within the knee joints and represent a complex and severe condition in sports medicine [1, 2]. These injuries are primarily observed in high-intensity sports and accidents, with an incidence rate of approximately 0.02% to 0.20% in orthopedic trauma cases [3]. With the increasing participation in sports and the rapid development of the transportation, the incidence of MLKIs is gradually rising. Since the stability of the knee depends on the coordinated function of multiple ligaments, MLKIs often result in severe knee dislocations, further compromising overall joint stability [4, 5].

In recent years, arthroscopic ligament reconstruction techniques have rapidly advanced, enabling the restoration of dislocated knee joints to their original anatomical positions, thereby maximizing knee stability and yielding significant clinical outcomes [6, 7]. However, postoperative follow-up results indicate that MLKIs reconstruction surgery does not fully restore patients to their pre-injury activity levels.In a systematic literature review involving 439 patients, it was found that only 58.91% of the patients were able to return to high-level sports [8]. Patients often experience symptoms of patellofemoral instability after surgery, such as knee instability, peripatellar pain, and reduced range of motion [9–11]. Furthermore, studies have shown that even after ligament reconstruction, the position and morphology of the patella are not fully restored. Compared to healthy knees, the stability of the patellofemoral joint in the injured knee remains significantly compromised, exacerbating postoperative patellofemoral instability [12, 13].

The causes of patellofemoral instability are multifaceted, primarily related to the anatomical structure and overall alignment of the patella and femoral trochlea [13]. The patella plays a key role in knee joint movement, and its position and movement trajectory directly influence patellofemoral stability [14]. Abnormal patellar positioning not only affects the mechanical stability of the knee joint and pressure distribution in the patellofemoral joint, but may also lead to articular surface wear, resulting in knee pain and reduced mobility [15].

Clinical data suggests that most MLKIs cases are often accompanied by anterior and posterior cruciate ligament ruptures and damage to at least one collateral ligament complex, which severely disrupts the biomechanical balance of the knee joint, affecting its stability [9]. Although ligament reconstruction partially restores the original position and morphology of the patella, some patients still experience knee joint instability postoperatively. We believ that this may be related to postoperative changes in patellar position. Furthermore, to the best of our knowledge, there are currently no studies reporting about patellar position or movement trajectory in patients following MLKIs surgery, which may negatively affect postoperative functional outcomes.

Therefore, this study will use imaging analysis methods to evaluate patients following MLKIs reconstruction, with a focus on the changes in patellar height as well as any anatomical alterations, such as displacement, tilt, or dislocation of the patellofemoral joint. Additionally, we will assess patellofemoral functional outcomes postoperatively. We hypothesize that this residual instability may be related to postoperative changes in patellar position and alignment. Specifically, we propose that MLKI surgery may lead to changes in patellar height and anatomical positioning, which could negatively impact patellofemoral joint stability and result in poorer functional outcomes.Through this research, we aim to provide scientific evidence for clinical diagnosis and treatment, ultimately improving patients' quality of life.

Materials and methods

This is a retrospective cohort study aimed at evaluating the patellofemoral position in patients who underwent multiple ligament knee injury reconstruction surgery at our hospital from November 2015 to September 2022. The study was approved by the ethics committee of our hospital, and all participants provided informed consent. Demographic and clinical data of the patients were obtained from our hospital's medical records and imaging archives.

Study design and patient enrollment

Inclusion criteria: All the patients completed relevant imaging examinations. For the case group: (1) patients underwent reconstruction/repair surgery due to multiple ligament knee injuries (MLKIs), defined as ≥ 2 ligament injuries, including the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL); (2) age ≥ 18 years; and (3) undergoing the first-staged operation. For the control group: physical examination and

imaging reports from the outpatient clinic confirmed no ligament injuries or patellar dislocation.

Exclusion criteria: (1) ligament rupture accompanied by fractures, nerve, or vascular injuries; (2) combined injuries such as craniocerebral, thoracoabdominal, or spinal injuries; (3) history of knee surgery; (4) history of patellar instability; (5) incomplete follow-up or imaging data.

A standardized case report form was used to record the demographic characteristics of both groups, including age, sex, BMI, etc. This study was approved by the ethics committee of our hospital, and all patients signed informed consent forms.

Surgical technique and postoperative rehabilitation

All patients underwent single-stage surgical repair or reconstruction, performed by the same experienced surgeon, and received a standardized perioperative management protocol.

Following routine anesthesia, the patient was placed in a supine position. A standard arthroscopic approach was employed to explore the joint cavity, confirming ACL and PCL tears and varying degrees of posterior medial complex (PMC) and posterior lateral complex (PLC) injuries. An anatomical reconstruction strategy was implemented, with the ACL and PCL reconstructed arthroscopically using autologous tendons, suspensory titanium plates, and interference screws. A limited incision was made to address PMC and PLC injuries based on the severity: Grade I-II PMC and PLC injuries were treated conservatively, while Grade III PMC injuries or avulsions were repaired with sutures and anchors. Grade III PLC injuries were reconstructed using the LaPrade technique with autologous tendons [16].

All patients followed a similar postoperative rehabilitation protocol. Postoperatively, the affected limb was wrapped with an elastic bandage and immobilized in extension with a brace. Early rehabilitation focused on quadriceps strengthening exercises and ankle pump movements. The drainage tube was removed within 48 h, and a personalized rehabilitation plan was developed based on intraoperative findings. Typically, the knee joint range of motion reached 60° within the first two weeks postoperatively, 90° between weeks 2 and 4, 120° between weeks 4 and 6, and returned to normal after six weeks. Patients were allowed non-weight-bearing ambulation with brace protection one week after surgery, partial weight-bearing after four weeks, full weight-bearing and proprioception training after eight weeks, and removal of the brace and resumption of daily activities by week 12.

Imaging acquisition

Imaging monitoring was conducted according to standard procedures. Anteroposterior and 30° lateral X-rays of the knee joint were taken using the Kodak Direct View DR7500 system with automatic exposure settings. For magnetic resonance imaging (MRI) of the knee joint, a Philips Ingenia 3.0 T superconducting MR scanner equipped with a 16-channel coil was used. Scanning parameters included: spin-echo T1W1 sequence (TR 500 ms, TE 10 ms), fast spin-echo T2W1 sequence (TR 4500 ms, TE 10 ms), and proton density-weighted sequence (TR 2300 ms, TE 30 ms). The imaging field of view was set at 350 mm × 320 mm, with a slice thickness of 4.0 mm and an interslice gap of 0.5 mm.

Outcome measurements

Patella height measurement

Patella height was measured preoperatively and postoperatively using 30° lateral X-ray images in the case group. The Caton-Deschamps (CD) index and the Insall-Salvati (IS) index were used for the measurements.

CD index: The distance from the inferior edge of the patellar articular surface to the anterior corner of the tibia (A) / the length of the patellar articular surface (B).

Insall-Salvati index: The length of the patellar tendon (C) / the longest diagonal length of the patella (D).

Patella baja (low-lying patella) was defined as CD < 0.6 or IS < 0.8. Patella alta (high-lying patella) was defined as CD or IS > 1.2 [17].Fig. 1.

Measurement of patellofemoral position parameters

Postoperative MRI images of the case group and outpatient MRI images of the control group were collected. Two experienced orthopedic surgeons independently measured patellofemoral position parameters in both groups. Commonly used parameters for assessing patellofemoral position include the sulcus angle (SA), patellar tilt angle (PTA), lateral patellofemoral angle (LPA), congruence angle (CA), and patellofemoral index (PI). These parameters help quantify the displacement, tilting, and dislocation of the patella, providing a better understanding of the patellofemoral position post-surgery [18–21].Fig. 2.

SA: The angle between the lines defining the lateral and medial trochlear facets. The measurement is made on an axial cross-sectional image at the level of the patella's maximum transverse diameter. A larger angle may indicate a higher risk of patellofemoral instability[19].

PTA: Measured as the angle between the tangent to the posterior aspect of the femoral condyle and the

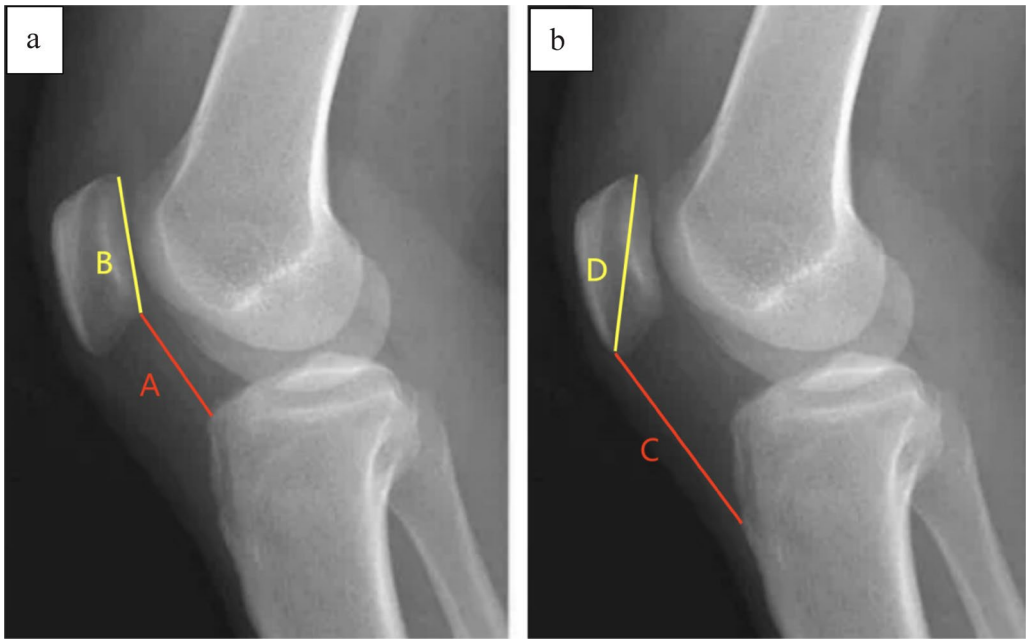

Fig. 1 Patella Height Measurement. *Note*: **a** Caton-Deschamps index; **b** Insall-Salvati index

longest axis of the patella. This measurement reflects patellar tilt and the balance between medial and lateral support forces [19, 22, 23].

LPA: The angle between the line connecting the highest points of the medial and lateral femoral condyles and the tangent to the posterior edge of the lateral patellar articular surface. Changes in LPA are important for assessing patellofemoral alignment [24].

CA: The congruence angle is the angle between a line drawn from the midpoint of the femoral trochlea and the lowest point of the patella. A negative angle indicates inward displacement, while a positive angle indicates outward displacement [25].

PI: The ratio of the narrowest width of the medial patellofemoral joint space to the narrowest width of the lateral patellofemoral joint space. A PI value greater than 1.6 may indicate abnormal patellar tilt [26].

Patellofemoral function assessment

Postoperative patellofemoral function were evaluated using the Kujala score questionnaire. The Kujala score is a specialized tool designed to assess anterior knee pain and patellofemoral function. This scoring system evaluates the patients daily activities and pain levels through 13 questions, with a total score ranging from 0 to 100. A higher score indicates better knee function and less pain or discomfort experienced by the patient [27].

All image analysis and patellofemoral function assessments were performed by two experienced senior orthopedic surgeons. For all measurements, the values were averaged from two separate measurements.

Statistical analyses

All statistical analyses were performed by using SPSS version 27.0 (SPSS Inc. USA). Continuous measurement data were expressed as mean ± standard deviation ($x \pm s$) if normally distributed, and as median with interquartile range if not normally distributed. Paired t-tests were used for comparisons between preoperative and postoperative measurements, while independent samples t-tests or Wilcoxon rank-sum tests were used for comparisons between groups. A p-value of < 0.05 was considered statistically significant.

Results

General information

A total of 83 patients were initially considered for this study. After applying the inclusion and exclusion criteria, 18 patients were excluded, resulting in a final cohort of 65 patients, with 45 in the case group and 20 in the control group (Fig. 3). Baseline characteristics were compared between the two groups, and no statistically significant differences were observed ($P > 0.05$), indicating good comparability. Table 1 summarizes the descriptive features of the cohort. Notably, in the case group, only Schenck classification types III-M (55.6%), III-L (8.89%), and IV (35.6%) were included.

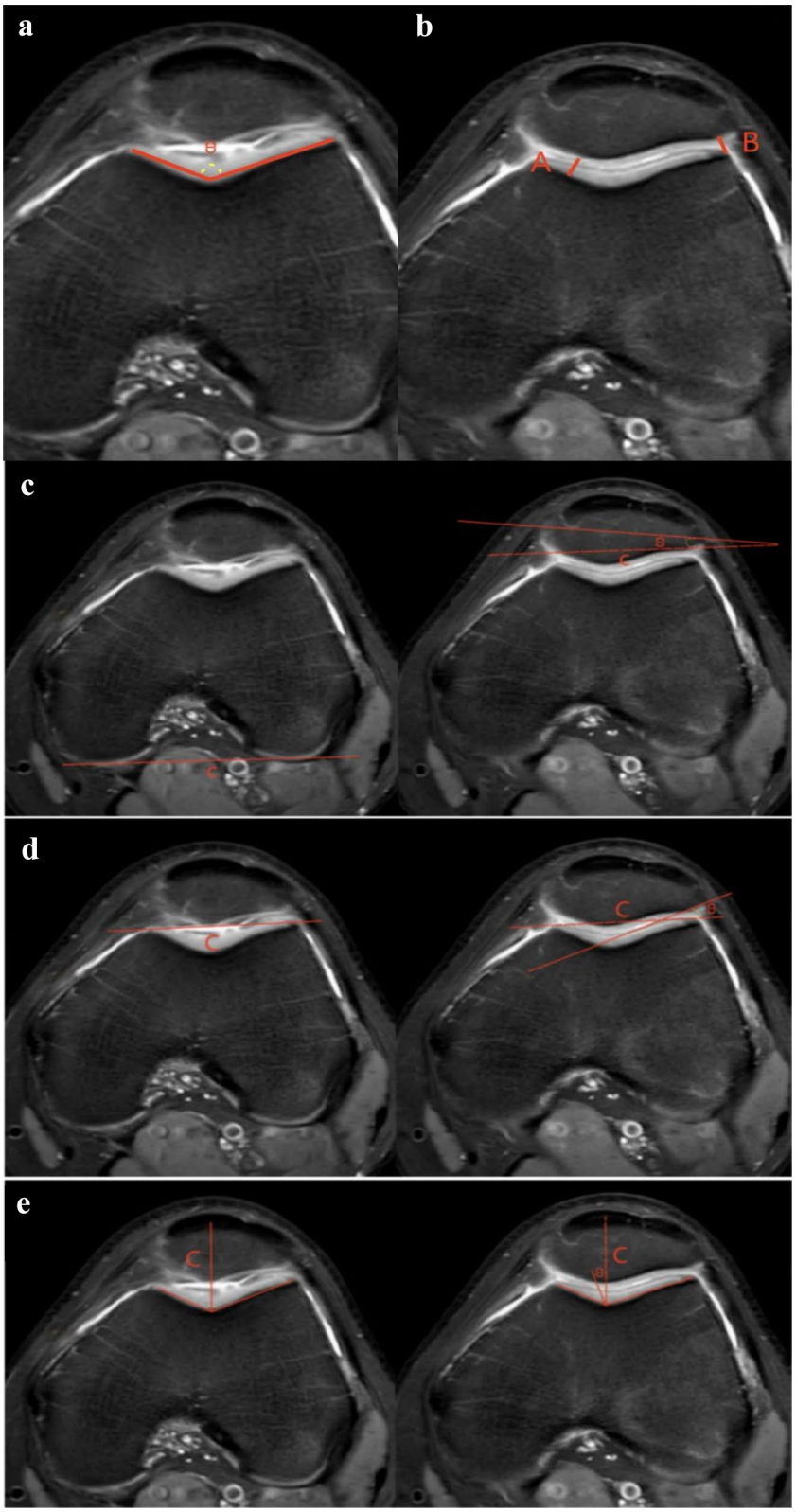

Fig. 2 Magnetic resonance images demonstrating the measurements of the indices to assess Patellofemoral Position. **a** sulcus angle; **b** patellofemoral index(A/b); **c** patellar tilt angle; **d** lateral patellofemoral angle; **e** congruence angle

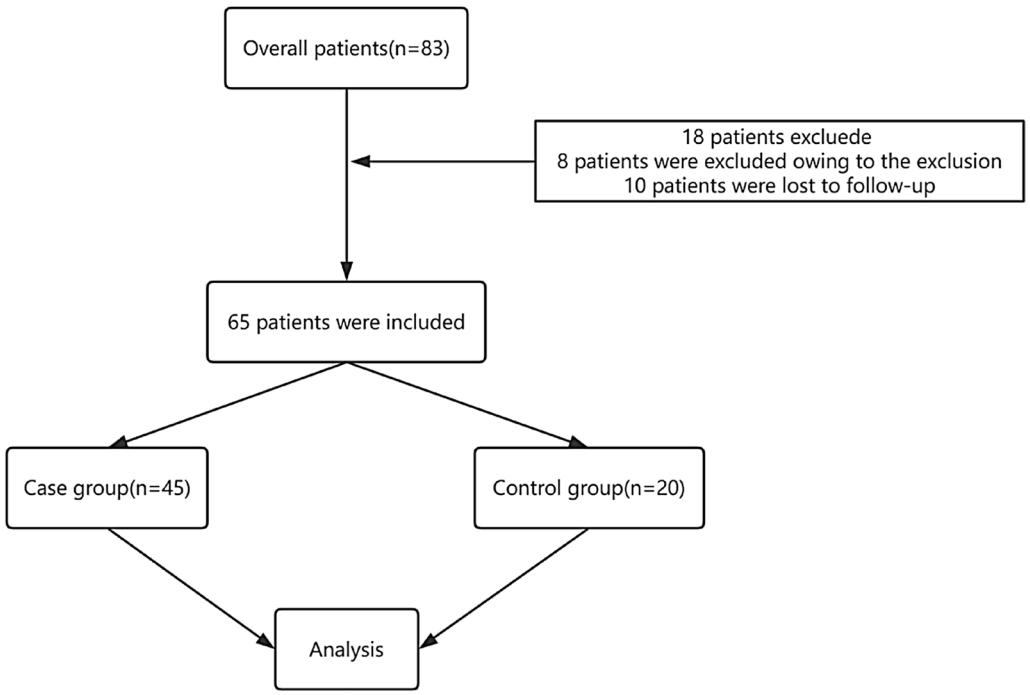

Fig. 3 Patient flow through the study

Table 1 Baseline and other characteristics of the enrolled patients

Variables	Case group(n = 45)	Control group(n = 20)	P-value
Demographic characteristics			
Age, years	40.8 ± 9.7	37.4 ± 6.0	0.093
Female gender, no. (%)	15(33.3%)	9(45%)	0.368
BMI(kg/m^2)	26.0 ± 3.7	24.8 ± 1.0	0.070
Schenck knee dislocation classification, n			
III-M	25(55.6%)	–	–
III-L	4(8.89%)	–	–
IV	16(35.6%)	–	–
Reason of injury		–	–
Tumble, no. (%)	18(40%)	–	–
Falling from height	7(15.6%)	–	–
Traffic accident	19(42%)	–	–
Others, no. (%)	1(2.2%)	–	–
Comorbidities			–
Meniscus injury	18(40%)		–
Multiligament knee injurie	23(51.1%)		–
Time from injury to surgery	20.6 ± 36.5	–	–
Follow-up (month)	68.0 ± 22.9	–	–

* BMI: Body mass index = Weight/Height^2;

Patella height

In the case group, the mean preoperative CD and IS index were 1.07 ± 0.10 (range: 0.90–1.28) and 1.10 ± 0.09 (range: 0.88–1.25), respectively. Postoperatively, the mean CD index decreased to 0.96 ± 0.13 (range: 0.64–1.22), and the IS index to 1.05 ± 0.10 (range: 0.87–1.24). These changes were statistically significant ($P < 0.01$) (Detailed results are presented in Table 2).

Patellofemoral position-related parameters

In the postoperative MRI images, we measured key patellofemoral position-related parameters, including SA, PTA, LPA, CA, and PI. The results showed that there were no statistically significant differences between the two groups ($P > 0.05$). Detailed results are presented in Table 3.

Patellofemoral function score

At the latest follow-up, the Kujala score in the case group was 89.0 ± 5.3, which did not significantly differ from the control group (91.0 ± 2.9) ($P > 0.05$). These results are depicted in Fig. 4.

Discussion

MLKIs have been extensively discussed in orthopedic literatures [10, 28]; however, to our knowledge, this study is the first to evaluate the changes in patellar position

Table 2 Comparison of patellar heights measured by two methods before and after arthroscopic multiple ligament reconstruction. (x ± s, n = 45)

Variables	Case group(n = 45)		T value	*P* value
	Preoperative height	Postoperative height		
Caton-Deschamps index	1.07 ± 0.10	0.96 ± 0.13	3.916	< 0.01
Insall-Salvati index	1.10 ± 0.09	1.05 ± 0.10	2.567	0.016

Table 3 Patellofemoral position parameters

Variables	Case group(n = 45)	Control group(n = 20)	T value	*P* value
SA	136.2 ± 5.4	134.4 ± 6.5	1.03	0.311
PTA	3.7 ± 4.5	3.6 ± 2.2	0.134	0.894
LPA	12.4 ± 7.3	15.2 ± 4.6	− 1.681	0.099
CA	− 5.5 ± 5.8	− 6.8 ± 2.6	1.062	0.293
PI	1.06 ± 0.38	0.96 ± 0.17	1.088	0.282

*SA, sulcus angle; PTA, patellar tilt angle; LPA, lateral patellofemoral angle; CA, congruence angle; PI, patellofemoral index

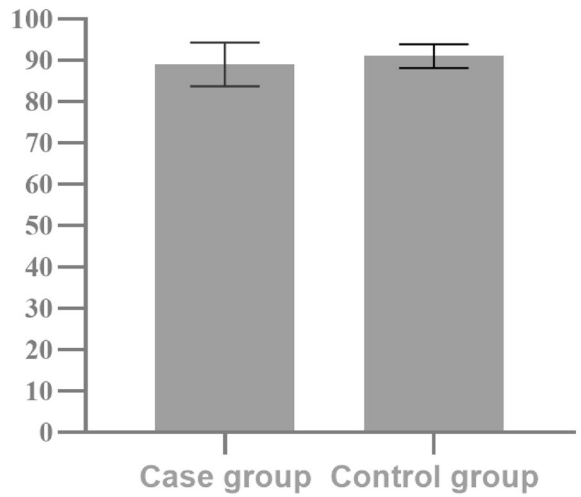

Fig. 4 Mean Kujala scores (± SD) in patients with case group and control group

and patellofemoral function following MLKIs reconstruction. Based on existing clinical observations and biomechanical principles, we hypothesized that changes in patellar position, such as patellar height, displacement, or tilt, could lead to postoperative patellofemoral instability, ultimately impacting clinical outcomes. In this retrospective study, our findings are as follows: (1) Following MLKIs reconstruction, the overall patellar height of patients decreased compared to preoperative levels but remained within the normal range (0.8–1.2). This partially supports our hypothesis that the patellar position may change postoperatively. (2) After surgery, there were no significant differences in patellofemoral position parameters (SA, PTA, LPA, CA, PI) between the case group and the control group, indicating that the knee joint maintained normal alignment and stability in these critical indices. No anatomical abnormalities, such as displacement, tilt, or dislocation, were observed. These results contradict the hypothesis regarding changes in patellofemoral anatomical positioning, as the postoperative patellofemoral joint alignment was found to be well-preserved. (3) During a mean follow-up of 68 months, the patients demonstrated good patellofemoral function.This contradicts our hypothesis, as although there was a slight decrease in patellar height postoperatively, its impact on the recovery of patellofemoral joint function was limited.

The height of the patella plays a critical role in knee joint function and stability. Both patella alta and patella baja can lead to varying degrees of patellofemoral pain and knee instability[14, 29]. In this study, we observed the decrease of patellar height in patients following MLKIs reconstruction compared to their preoperative status. However, the specific factors influencing these changes of patellar height remain unclear. Factors commonly mentioned in existing literatures include joint line elevation, increased tibial slope, and shortening of the patellar tendon [30, 31]. Based on our findings, we hypothesize that surgical factors, postoperative rehabilitation, and altered knee biomechanics are the main contributors to the changes of patellar height. Regarding surgical factors, the incision is close to the medial and lateral sides of the patellar tendon, and if the surgery involves reconstruction or adjustment of the patellar tendon or quadriceps tendon, there is a risk of injury to the patellar ligament. This can lead to fibrosis, scarring, and shortening of the patellar ligament, potentially affecting patellar height [31, 32].Furthermore, intraoperative management of medial patellofemoral ligament (MPFL) injuries is crucial, as the MPFL plays a vital role in maintaining patellar position [13]. Although studies have reported that the incidence of knee instability due to MPFL injury in MLKIs is only 5%, the small sample sizes make it difficult to rule out its potential impact on patellar positioning [33]. Additionally, the placement of grafts during surgery may also influence patellar height. If the graft is positioned too

anteriorly on the tibia, it may lead to impingement in the intercondylar notch, restricting patellar flexion–extension movement and affecting patellar height. Overly aggressive soft tissue release or excessive resection of the infrapatellar fat pad during surgery has also been shown to impact patellar height, as confirmed by clinical research [34, 35]. Postoperative rehabilitation plays a crucial role in restoring the strength and balance of the quadriceps and other peri-knee muscles, which significantly impacts patellar positioning. The quadriceps, which is directly connected to the patella via its tendon, is essential for maintaining the patella's normal trajectory [36]. Inadequate rehabilitation may lead to muscle atrophy, which has been shown to be closely associated with decreased knee joint stability and may further influence patellar height [36, 37]. Furthermore, insufficient knee extension during postoperative rehabilitation can result in limited flexion–extension and patellar impingement, potentially leading to infrapatellar contracture syndrome. Studies have reported that 16% of patients with infrapatellar contracture exhibit decreased patellar height, particularly in those undergoing intra-articular ligament reconstruction [38].

From a biomechanical perspective, the knee joint is a complex structure constrained by multiple ligaments, and it must withstand weight-bearing forces while maintaining range of motion in the sagittal, coronal, and rotational planes [39]. Following MLKIs reconstruction, knee biomechanics are altered. Although anatomical reconstruction partially restores the original biomechanical function of the knee, there are still several limitations, such as the placement of tibial and femoral tunnels and the issue of ligament isometry during reconstruction. It's worth noting that biomechanical disruption of the knee joint as a whole is often greater than the sum of individual ligament injuries [39]. Even after multiple ligament reconstructions, the original knee biomechanics may have changed, affecting patellar position. Additionally, individual biomechanical characteristics and the formation of scar tissue may limit normal patellar movement. Of course, there are other factors outside the scope of our study that should be considered, such as the presence of osteoarthritis or significant cartilage damage, both of which may also contribute to changes in patellar height.

Our study utilized MRI to measure clinically significant parameters related to patellofemoral malalignment. Among the measured results, the SA in the case group was 136°, showing no significant difference compared to the control group (134°). The normal range for SA has been documented in the literature, with a threshold value generally considered to be less than 145°[19]. An angle greater than 145°–150°is indicative of trochlear dysplasia [40]. An abnormal SA is often regarded as a risk factor for ligament injuries [41].PTA and LPA are primarily used to assess the tilt of the patella relative to the trochlear groove. In our case group, the PTA was 3.7° and the LPA was 12.4°, with no significant difference compared to the control group (3.6° and 15.2°, respectively). Ronald's study, which measured MRI parameters in 51 healthy knees, found that the PTA was less than 10°, while Panayiotis' research indicated that the average normal LPA in the healthy control group was 18°, which is consistent with our findings [42, 43]. Additionally, CA and PI are also important clinical indicators for diagnosing patellofemoral malalignment. In our study, the CA value was -5.5°, which was not significantly different from the control group (−6.8°). This aligns with Maquet's research, which found the normal mean CA to be −6°, with a standard deviation of 11°[25]. The PI in the case group was 1.06, showing no significant difference compared to the control group (0.96). This result is consistent with Laurin's findings, which suggest that a normal PI value should be less than 1.6 [44]. Based on these findings, we believe that MRI measurements indicate that patellofemoral alignment in patients following MLKIs reconstruction is generally consistent with both the control group and literature reports. This suggests that the postoperative position and alignment of the patella within the trochlear groove were not negatively affected by the surgery, and the patella remained in good anatomical alignment. Precise preoperative planning, advanced arthroscopic techniques, and accurate anatomical reduction during surgery may be key factors in maintaining normal patellofemoral positioning.

Finally, at the last follow-up, we assessed the stability of the patellofemoral joint using the Kujala questionnaire. The results showed that the patients in the case group achieved good patellofemoral stability, with an average score of 89.0 at the final follow-up. This score falls within the range of previously published data (74.7 to 94.5) [27]. We believe that although there was a slight decrease in patellar height postoperatively, it did not affect the early to mid-term functional recovery of the patellofemoral. This may be related to the specifics of our study, where we observed a significant decrease in patellar height; however, the majority of patients remained within the normal range. Some patients developed patella alta but did not report symptoms of extensor weakness or restricted movement, likely due to the relatively small actual decrease in patellar height. Furthermore, the patellofemoral maintained good anatomical alignment postoperatively, which may have mitigated functional disruption, contributing to favorable clinical outcomes. The advancements in surgical techniques and the development of postoperative rehabilitation protocols may

also have played a positive role in improving the postoperative function of patients with MLKIs [2].

The limitations of this study include its retrospective design and relatively small sample size. However, given the rarity of MLKIs, to our knowledge, this remains the largest single-center study currently. Secondly, due to concerns about radiation exposure, we do not measure patellar height in the contralateral healthy knee, which may influence our findings on postoperative patellar height changes. Additionally, although we used clinically common measurement methods, variations in measurement techniques could potentially yield different results. Finally, our study only included patients with grade III and IV MLKIs according to the Sheck classification. While these are the most common in clinical practice, the biological diversity and complexity of MLKIs make it difficult to generalize our findings to other classifications [45].

Based on our study results, we recommend closely monitoring changes in patellar height following MLKIs reconstruction. Careful preoperative planning, precise intraoperative techniques, and scientifically guided postoperative rehabilitation are essential. Given the complexity of such knee injuries, it is crucial to thoroughly assess the ligament damage in each patient and tailor surgical strategies accordingly. Personalized postoperative rehabilitation plans should be adjusted based on the "individual characteristics" of the knee to optimize outcomes for each patient.

Conclusion

Arthroscopic reconstruction of MLKIs resulted in the reduction in patellar height; however, this decrease remained within the normal range. Patellofemoral alignment was well-preserved and patellofemoral function was maintained.

Author contributions

Honglue Tan designed this study.Xiao Wang and Xiaotao Shi collected the data.Yuanping Liao wrote the manuscript. Guorui Cao and Honglue Tan revised the manuscript. All authors reviewed the final manuscript. All authors agreed to be accountable for all aspects of the work.

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Availability of data and materials

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Luoyang Orthopedic Hospital, Henan Province. The requirement for informed consent was waived due to the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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