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Treatment of recurrent patellar dislocation via knee arthroscopy combined with C-arm fluoroscopy and reconstruction of the medial patellofemoral ligament

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Abstract. Recurrent patellar dislocations were treated via knee arthroscopy combined with C-arm fluoroscopy, and reconstruction of the medial patellofemoral ligaments. Between October 2013 and March 2017, 52 cases of recurrent patellar dislocation [27 males and 25 females; age, 16-47 years (mean, 21.90 years)] were treated. Arthroscopic exploration was performed and patellofemoral joint cartilage injuries were repaired. It was subsequently determined whether it was necessary to release the lateral patellofemoral support belt. Pre-operative measurements were used to decide whether tibial tubercle osteotomy was required. Medial patellofemoral ligaments were reconstructed using autologous semitendinosus tendons. Smith and Nephew model 3.5 line anchors were used to double-anchor the medial patellofemoral margin. On the femoral side, the medial patellofemoral ligament was fixed using 7-cm, absorbable, interfacial compression screws. All cases were followed for 1-40 months (average, 21 months). The Q angle, tibial tuberosity trochlear groove distance, Insall-Salvati index, patellofemoral angle, lateral patellofemoral angle and lateral shift were evaluated on X-Ray images using the picture archiving and communication system. Subjective International Knee Documentation Committee (IKDC) knee joint functional scores and Lysholm scores were recorded. Post-operative fear was absent, and no patellar re-dislocation or re-fracture was noted during follow-up. At the end of follow-up, the patellofemoral angle (0.22±4.23˚), lateral patellofemoral angle (3.44±1.30˚), and lateral shift (0.36+0.14˚) differed significantly from the pre-operative values (all, P<0.05). Furthermore, IKDC and Lysholm scores (87.84+3.74 and 87.48+3.35, respectively) differed significantly from the pre-operative values (both, P<0.05). These findings suggest that, in the short term, recurrent patellar dislocation treatment via knee arthroscopy combined with C-arm fluoroscopy and reconstruction of the medial patellofemoral ligament was effective.

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Introduction

Recurrent patellar dislocation is most common in adolescents, with a male:female ratio of ~1:5 (1-3). Dislocation is triggered principally by trauma, which subsequently induces medial patellar instability, which, when accompanied by abnormal knee joint anatomy, may trigger repeated patellar dislocation or subluxation during knee torsion, flexion, or extension (4). The treatment of recurrent patellar dislocation include conservative treatment and operative treatment (5). Some patients may receive satisfactory therapeutic effects through conservative treatment including manual reduction, plaster immobilization and functional rehabilitation (6). Muscle recovery instruments may also strengthen the vastus medialis muscle and thus treat recurrent patellar dislocation. However, surgery is still utilized for patients with complex conditions (7). A number of surgical treatments are available, but it is difficult for a single surgical method to completely correct the complex pathology due to every case being unique to each patient (8). Combined surgical approaches are typically employed to restore the soft tissue balance of the patella, to correct abnormal anatomical structures and to restore stable patellar biomechanics (9). However, it is difficult to completely restore a normal anatomical relationship and stable mechanical balance via surgery alone. The principal aim of surgery is to restore the patellar trajectory, affording robust medial support and preventing further dislocation via reconstruction of the medial patellofemoral ligament (MPFL) (10). Thereby, It's more beneficial to later rehabilitation exercise. Sallay *et al* (11) reported that ~94% patients with patellar dislocation have a torn medial patellofemoral ligament. So MPFL reconstruction is important when treating recurrent patellar dislocation (12). The present study details the use of intraoperative arthroscopy to explore and repair patellofemoral joint cartilage injuries. In this procedure, the lateral collateral ligament is released and MPFL is positioned at the femoral isometric point by C-arm fluoroscopy (Siremobil Compact L; Siemens, Germany) (13). The MPFL was then reconstructed using the autologous semitendinosus muscle tendon.

Materials and methods

Materials. The picture archiving and communication system (PACS) was obtained from (Tianjian Technology Group, Beijing, China) and was utilized to collect the image data of patients and calculate parameters including congruence angle, lateral patellofemoral angle and the Insall-Salvati index (14). The Smith and Nephew model 3.5 line anchors (Smith & Nephew, Watford, UK) were used to double-anchor the medial patellofemoral margin. C-arm fluoroscopy (SIREMOBIL Compact L; Siemens AG, Munich, Germany) was employed to position the MPFL at the femoral isometric point during surgery.

Data and methods. Data was reviewed from 52 patients who underwent arthroscopic surgery on one knee, during which C-arm fluoroscopy was employed to position the MPFL at the femoral isometric point and the MPFL was reconstructed using the autologous semitendinosus muscle tendon. Between October 2013 and March 2017, a total of 27 males and 25 females aged 16-47 years (21.90±6.78 years) were treated in the third department of Orthopedics, Hospital of Traditional Chinese Medicine of Xinjiang Medical University (Urumqi, China). Patients had experienced dislocations on 2-60 occasions (7.75±10.27). Re-dislocations had developed in ≤6 weeks in 16 cases, between 6 weeks and 6 months in 7 cases, between 6 months and 3 years in 15 cases and after 3 years in 14 cases. The initial dislocation was typically associated with knee movement, with examples including skipping, falling, playing basketball, crouching and rising to full height. The principal clinical manifestations of 9 patients with primary dislocations were knee pain or instability, or leg weakness. Patients wore plasters or knee braces from 1 week-2 months. All patients were positive on the patella apprehension test (14), 30 exhibited different extents of femoral head four-muscle atrophy and 27 were positive on the knee patellar tilt test (15). X-ray results of a representative case of dislocation are presented in Fig. 1.

As recommended by Beaconsfield *et al* (16), X-ray measurements of the patellar axis were performed at 30˚ of knee joint flexion. PACS was utilized to collect images and calculate the following parameters: i) The congruence angle (CA; between the pulley angle bisector and center of the patellar central ridge at the lowest point of the pulley; normal, -8±6˚); ii) the lateral patellofemoral angle (AC; between the vertex of the femoral condyle and the extension of the lateral surface of the patella, typically increasing toward the exterior); iii) the patellar removal rate (LPE) (17), measured vertically to the outer condylar apex (the ratio of the transverse diameter of the lateral patella to that of the patella; normal, <0.5); and iv) the Insall-Salvati index [the ratio of the length of the patellar tendon (LT) to the length of the patella (LP); normal, <1.0]. Computed tomography (CT) was used to measure the length of the tibial tuberosity trochlear groove (TT-TG; normal, <15 mm) and the Q angle (that between the tension line of the four biceps muscles and the lengthening line of the patellar tendon at the patellar center; normal values, 8-10˚ in males and 15±5˚ in females). All normal ranges are obtained from (16).

Inclusion criteria were as follows: i) Recurrent patellar dislocation; and ii) epiphyseal plate closure or expiry of the peak growth period.

Exclusion criteria were as follows: i) Serious femoral condylar dysplasia (tilt angle ≤9˚) with accompanying knee valgus deformity; ii) a significantly elevated patella (Insall-Salvati index ≥1.2); and/or iii) significant knee osteoarthritic changes [Kellgren-Lawrance X-ray grade ≥III (18)].

The present study was approved by the Ethics Committee of the Hospital of Traditional Chinese Medicine of Xinjiang Medical University (Urumqi, China) and all patients provided written, informed consent prior to their inclusion.

Surgical methods

Arthroscopic exploration and loosening of the lateral retinaculum. All patients underwent arthroscopic exploration prior to ligament reconstruction. Synovial congestion and synovitis performance was exhibited in 2 patients and osteochondral loose bodies and synovitis performance in 12 patients. Patients with Patellofemoral joint cartilage injuries were scored according to Outerbridge (17) and were as follows: 14 of grade II, 5 of grade III, and 3 of grade IV. A total of 3 instances of patellar cartilage fracture were encountered, of which 1 (a large fracture) was treated via open reduction and suturing. Other patients' joint cartilage was normal and did not exhibit synovitis performance. Arthroscopy, performed 6 weeks later, revealed that the fracture had healed well. Fracture of the external condylar cartilage was exhibited by 1 case. The synovial cavity and free body of the joint cavity were arthroscopically cleared with simultaneous dressing and reconstruction of the damaged cartilage. In patients with grade II or grade III, local plasma knife gasification was used to repair the cartilage surface. Patients with grade IV injuries were treated via microfracture. Intra-operative reconstruction of the MPFL was performed to treat 3 patients who exhibited patellar lateral avulsion fractures. A total of 46 patients required arthroscopic release of the lateral retinaculum. Patient histories, physical examination data and intraoperative measurements of the patellar trajectory and impact were evaluated. If the pre-operative history was short (<6 weeks), the patellar range of motion normal, the patellar tilt negative, no obvious contracture of the lateral patellar retinaculum was apparent, the lateral patellar retinaculum was not loosened. Conversely, if the lateral patellar retinaculum was loosened by ~1 cm when the knee was stretched (over regions on either side of the upper and lower patellar poles), the retinaculum was loosened to the level of the deep fascia. Patellar dislocation had a marked improvement, which was assessed using arthoscopy (Fig. 2).

Reconstruction of the MPFL. To reconstruct the MPFL, the procedure of Schöttle *et al* (19) was followed. Initially, the MPFL was located at the medial femoral condyle and an isometric view was established using C-arm fluoroscopy during the surgery (Siremobil Compact L; Siemens AG,

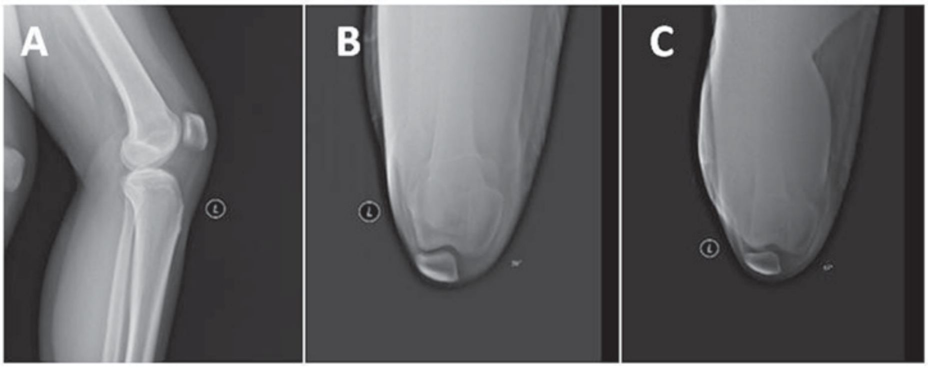

Figure 1. Pre-operative images. (A) lateral X-ray. (B) 30˚ and (C) 60˚ patellar axial radiograph in which the patella is clearly tilted outward.

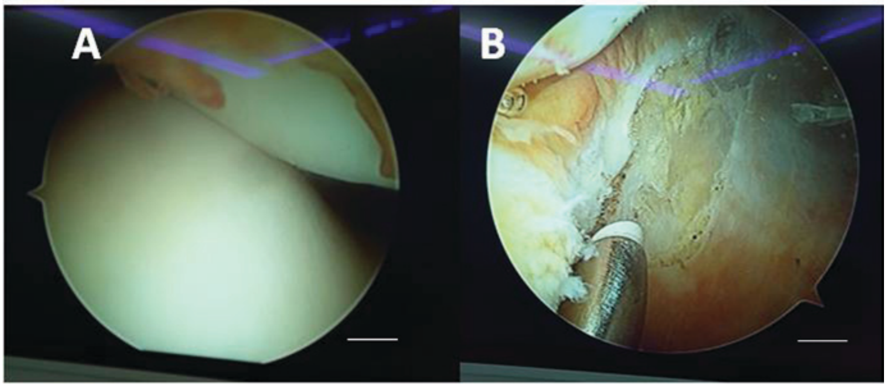

Figure 2. (A) Intraoperative arthroscopy revealed that the patella is obviously tilted outward. (B) A plasma knife is used to relieve the lateral support band. (Scale bar=5 mm).

Munich, Germany; Fig. 3A). The medial and lateral femoral condyles were then overlapped and fixed with Kirschner wire, commencing in the interior of this region, and progressing toward the exterior. At the pes anserinus attachment point, an outwardly extending 2.5-cm-long oblique incision was created in the skin and subcutaneous tissue of the medial tibial tubercle to reveal the semitendinosus muscle tendon, which was removed in a standard manner, with both ends then sutured to allow measurement of the diameter of the braided end of the graft. This allowed evaluation of the graft whip structure and to measure the pre-reserve. Creation of a 2-cm longitudinal incision in the inner edge of the patella. The osteophyte in the inner edge of patella was removed using a rongeur and a bony groove was formed. The groove was positioned between the articular surfaces and the cortex of bone, the size of which ranged from the patellar midpoint to the superior border of patellar. Two 3.5-grade studs (Smith & Nephew) were horizontally placed at either end of the fresh bone surface and the semitendinosus tendon was folded around the bone, pulled through the bone groove, and sutured. The skin and subcutaneous tissue were cut (incision lengths, ~1 cm) in the regions of the medial femur using a Kirschner wire. Blunt dissection to the bone surface followed and a femoral tunnel was drilled by reference to the diameter of the braided end of the graft, creating a shallow soft tissue channel. The woven ends of the two tendons were pulled along the soft tissue of the femoral tunnel. The tendon was flexed and contracted under tension to observe patellar motility and the anatomy of the patellofemoral joint. On application of external stress to the patella, it was ensured that the passive sliding distance was 25-50% of the patellar width. When the tendon attained physiological tension, it was fixed in the medial femoral tunnel using a 7-mm-diameter interface squeeze screw (Smith & Nephew).

Transposition of the tibial tubercle. In accordance with the Weber *et al* (20), 2 patients with pre-operative TT-TGs >20 mm and Q angles >20˚ underwent proximal tibial tubercular transposition using the Fulkerson method (21,22) (Fig. 3B and C). The distal and lateral oblique incisions were extended by ~3 cm, exposing the tibial nodule and distal 6 cm of the long tibial crest, and oblique (30˚) osteotomy was performed, commencing at the medial margin of the tibial tubercle and progressing to the lateral nodule, creating a wedge-shaped osteotomic block 6 cm in length and 7 mm in thickness. The block was moved 8-10 mm up along the osteotomy face, and the movable tibial tubercle temporarily fixed with two 4.5-grade hollow nail guide pins. The patellar trajectory was assessed via knee flexion and, if the surgeon judged it satisfactory, two 4.5-grade cannulated screws were used to fasten the nodules.

Post-operative treatment. Drainage tubes were not placed, but all operative sites were pressure-bandaged for 3 days and the sutures removed during the next 14 days depending on healing status. The knee joint was fixed for 3 months. At 2 days following surgery, ankle pumping and four-head muscle and straight leg elevation exercises were commenced. Knee stretch

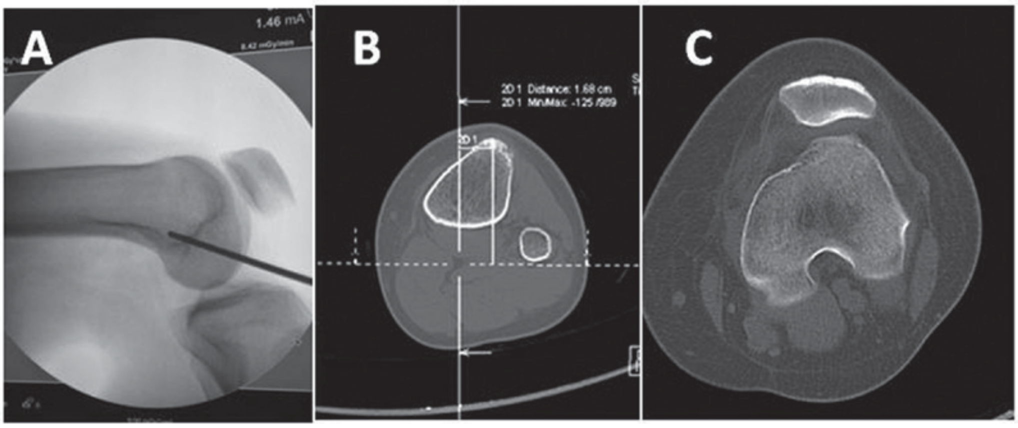

Figure 3. (A) Intraoperative isometric positioning of the C-arm X-ray probe. (B) The tibial tuberosity trochlear groove values on pre-operative computed tomography. (C) The patella leans outward (patellar tilt angle >20˚).

exercises while wearing knee braces were gradually introduced following another week, as were weight-bearing walking and flexion and extension exercises while in bed. Within 2 weeks of surgery, ≥90˚ of movement was attained. After 6 weeks, full weight-bearing-supported walking and progressive resistance training were introduced, and, after 12 weeks, the knee joint restraints were removed, and knee joint activity and muscle strength training were commenced. Simple uniform motion was permitted after 6 months and full resumption of sporting activities after 1 year.

Follow-up and statistical analysis. All patients were followed up in the orthopaedic clinic of the Hospital of Traditional Chinese Medicine of Xinjiang Medical University at 1, 3, 6 and 12 months after surgery, and then via telephone or in the clinic every 6 months thereafter. Each follow-up evaluation explored symptom improvement, included physical and radiological examinations, and evaluated the International Knee Documentation Committee (IKDC), Lysholm Knee Function and Tegner Knee Movement scores (23). Data were analyzed using SPSS 19.0 (IBM Corp., Armonk, NY, USA). Pre- and post-operative data were compared using the paired t-test. $P<0.05$ was considered to indicate a statistically significant difference.

Results

All patients were followed up for 1-40 months (21±6.24 months). No patellar dislocation or fracture occurred during follow-up. The fear test was negative and the patellar tilt was essentially symmetrical. CA, AC and LPE at the last follow-up differed significantly from the pre-operative values. The IKDC and Lysholm scores also improved significantly following surgery (Table I). As presented in post-operative X-rays of the knee joint (Fig. 4A and B) and CT of the lateral knee joint (Fig. 4C), the anchor position was good, the tunnel was located at the isometric point and the patellar position was appropriate.

Discussion

The typical patellar dislocation case is a diminutive young female exhibiting poor patellar alignment and ligament relaxation (1). Acute dislocation is triggered principally by direct trauma; dislocation develops during the application of knee torsion stress over the line of abnormality. The majority of patellar dislocations are lateral (24,25). The MPFL is the most important ligament in terms of medial patellar strength (50-60% of all the strength that is imparted) (26-28). The MPFL maintains the patellar trajectory and minimizes dislocation. Therefore, MPLF reconstruction is essential to restore patellofemoral joint stability.

The treatment success rate when recurrent patellar dislocations are supported by only simple lateral support bands is 68% and most scholars do not advocate that recurrent dislocations should be treated by simply loosening the lateral supports (2). Lind *et al* (29) previously demonstrated that reconstruction of the medial patellar ligament afforded significantly improved results than simple repair. Schöttle *et al* (30) recommended the use of double anchors to fix the patellar tendon, double-beam MPFL reconstruction and placement of interfacial extruded screws on the femoral side. Typically, the femoral condyle is located visually, and the adductor node and internal condyle serve as anatomical landmarks during MPFL reconstruction. In 2 of the present patients, the use of this approach was associated with larger internal condylar incisions in the femoral shaft and increased trauma. The optimal location may be affected by the position of the internal adductor node and extent of development of the internal femoral condyle. Schöttle *et al* (19) suggested that the knee be viewed laterally and that the medial and lateral femoral condyles should be overlapped by reference to the inflection points of the femoral condyle, the posterior cortex, and the final extension of the Blumensaat line. A perpendicular should be drawn to the tangential extension of the posterior femoral cortex, 1.3 mm in front of the cortex, distal to the end of the femoral condyle and 2.5 mm toward the back of the cortex. The proximal 3-mm position of the Blumensaat line at the end of the vertical point thus created defines the length of the MPFL. Prior to 2013, patients with recurrent patellar dislocations at our hospital were treated via open, descending, medial patellar ligament overlap suturing, lateral patellar thigh support, and MPFL loosening or reconstruction. The 'saddle zone' between the proximal femur and the femoral condyle was used to reconstruct the femoral MPFL. After surgery, X-rays revealed the MPFL at the femoral side of the tunnel. During follow-up,

Table I. Radiographic and function assessment prior to and following surgical protocols.

Index	Pre-operative	Post-operative	T-value	P-value
CA	9.67˚±6.93˚	0.22˚±4.23˚	10.15	<0.001
AC	-0.40˚±6.65˚	3.44˚±1.30˚	-4.09	<0.001
LPE	0.70±0.28	0.36±0.14	7.49	<0.001
IKDC score	56.98±5.72	87.84±3.74	-33.24	<0.001
Lysholm score	47.88±7.78	87.48±3.35	-33.69	<0.001

Data are presented as the mean ± standard deviation (n=52). CA, congruence angle; AC, patellofemoral angle; LPE, patellar removal rate; IKDC, International Knee Documentation Committee.

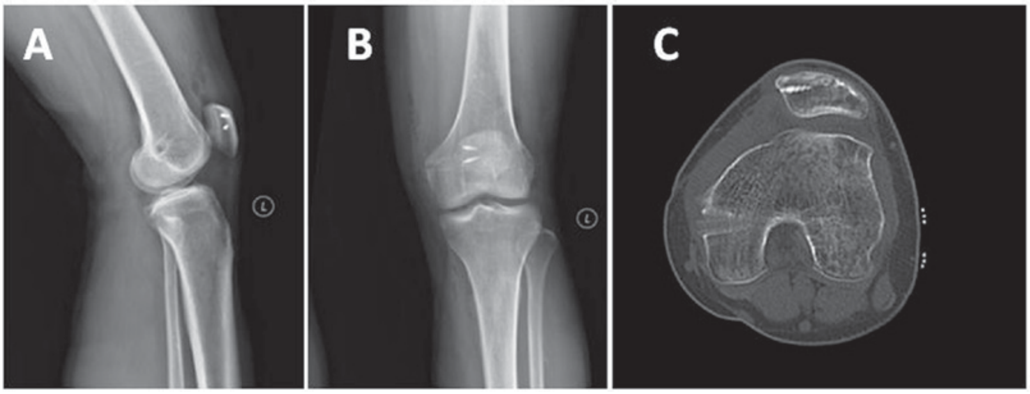

Figure 4. Post-operative imaging tests of the knee joint. The anchor position is good, the tunnel is located at the isometric point, and the patellar position is appropriate. (A) Lateral and (B) front X-ray view of the knee joint. (C) Axial CT view of the knee joint.

no instances of patellar re-dislocation were observed, but in many cases the MPFL was observed to relax, which is associated with patellar instability. Medial patellar support was required to treat tenderness and other manifestations. More recently, developments in sports medicine have encouraged the treatment of recurrent dislocations via arthroscopic exploration and cleaning, loosening of the lateral support bands, C-arm fluoroscopy to locate the femoral condyle and other long points, autogenous half-tendon muscle double-beam reconstruction of the MPFL, pre-operative positioning of the knee joint in the lateral position, axial patellar positioning at 30˚ and 45˚ during fully erect standing, and the use of knee CT and magnetic resonance imaging to determine whether anatomical abnormalities are evident (with or without injury to the articular cartilage or formation of free bodies, and with or without merger of other ligaments and meniscal injury). After surgery, data obtained in the lateral position and the patellar axis, and knee CT data were reviewed. Arthroscopy was useful to define the trajectory of patellar activity, to clear inflamed synovial tissue, to detect injuries to the anterior and posterior cruciate ligaments and the menisci, to clear the articular cavity of free bodies, and to assess damage to the articular surface. Radiofrequency catheter ablation and/or microfracture treatments were performed depending on the extent of contracture of the lateral support band both before and during the operation; the support was relieved via appropriate arthroscopy. The choice between an open operation and arthroscopic loosening remains controversial. Either treatment should permit maximal loosening, avoiding residual contracture stress that may trigger symptoms of patellofemoral arthritis. The use of hamstring muscle to restore tensile strength to the MPFL ligament afforded a strength ~10-fold that of the normal MPFL, significantly affecting the patellofemoral joint. In addition, in patients with basic anatomical abnormalities, simple lateral support combined with loosening and medial MPFL reconstruction may not completely eliminate degenerative patellar joint degeneration. Furthermore, distal rearrangement may be required. At present, Elmslie-Trillat surgery (31) and Fulkerson osteotomy (21,22) are used widely. TT-TG >20 mm and Q angle >20˚ indicates that distal rearrangement is required. Fulkerson osteotomy is typically used to treat non-professional athletes exhibiting severe patellofemoral degeneration (22). The recent cadaveric study by Tanaka *et al* (32) demonstrated that the MPFL was structurally large and narrow-sided on the patellar side, and that the MPFL patellar side-stop was typically located proximal to the end of the patellar four-headed muscle. The patella occupied ~66% of the relevant area and the four-headed muscle segment occupied ~33%. Double anchoring and the placement of patellar stops restricting transplanted tendon movement to ~2.0 cm ensure effective femoral tendon bone healing, approximating anatomical reconstruction of the MPFL. The C-arm perspective of the femoral side ensures good patellar trajectory and avoids the 'rubber band' MPFL effect after reconstruction, mitigating the risk of patellofemoral arthritis. The medial femoral incision length was ~1 cm in length, the lateral support band was relieved by arthroscopy and the incisional length was only ~0.5 cm in the bilateral genus eye. Therefore, the procedure was less invasive than open surgery. Two-beam anatomical reconstruction of the MPFL via autogenous half-tendon anastomosis is facilitated when the patellar tunnel method (accompanied by double-anchor nail fixation) is employed, associated with (at least) enhanced short-term curative effects (30). The long-term effects require further study.

In conclusion, in the short term, recurrent patellar dislocation treatment via knee arthroscopy combined with C-arm fluoroscopy and reconstruction of the medial patellofemoral ligament was effective. The procedure benefits the patients by reducing pain and recovery time. This surgery may provide a new direction for future clinical treatment of recurrent patellar dislocation.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author

Authors' contributions

LL and HW operated on patients. YH, YS and HZ completed the patient follow-up. XW analyzed the relevant data. LL, HW and YH were major contributors in writing the manuscript and all authors read and approved the final manuscript.

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of the Hospital of Traditional Chinese Medicine of Xinjiang Medical University (Urumqi, China) and all patients provided written, informed consent prior to their inclusion.

Consent for publication

All patients provided written, informed consent prior to their inclusion.

Competing interests

The authors declare that they have no competing interests.

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