

Anatomical transverse patella double tunnel reconstruction of medial patellofemoral ligament with a hamstring tendon autograft for recurrent patellar dislocation

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Abstract

Introduction The purpose of this study was to describe our transverse patella double tunnel technique to reconstruct the medial patellofemoral ligament (MPFL) with a hamstring tendon autograft in patients who suffered recurrent dislocation of the patella, and to evaluate the intermediate-term outcomes of reconstruction treatment.

Materials and methods Fifty-nine consecutive knees (52 patients) with recurrent dislocation of the patella without marked predisposing anatomic abnormalities and radiographically documented moderate/severe osteochondral lesions were included in the study. Outcomes were assessed with physical and radiographic examination, the Kujala and the modified Cincinnati scores preoperatively and postoperatively at 3, 6, 12, 36, 60 and 84 months.

Results There were 19 male and 33 female patients with up to 7.1-year follow-up (mean 5.7 years). The mean age was 24.3 years. A comparison of preoperative scores with those obtained at most recent follow-up revealed a significant improvement for all outcomes measured: range of motion ($30 \pm 2^\circ$ vs. $125 \pm 5^\circ$, $P < 0.01$), the mean Kujala scores (41.4 vs. 82.6, $P < 0.001$), the mean modified Cincinnati scores (50.6 vs. 88.7, $P < 0.01$), the mean congruence angle (12.2° vs. -2.4° , $P < 0.01$) and the mean tilt angle (11.4° vs. 8.4° , $P < 0.05$). No recurrent episodes of dislocation or subluxation were postoperatively reported, although there were seven knees with an occasional unstable feeling without redislocation.

Conclusions MPFL reconstruction with the double-transverse tunnels technique is safe and effective in patients of all ages, without marked predisposing anatomic abnormalities and moderate/severe osteochondral lesions, who suffered recurrent dislocation of the patella.

Keywords Patella · Recurrent dislocation · Medial patellofemoral ligament · Reconstruction · Hamstring tendon

Introduction

Recurrent dislocation of the patella is a relatively common orthopedic condition. It is clear from a review of the biomechanics of the patellofemoral joint that there usually are three principal factors at the knee that contribute to patellar stability: articular geometry, muscle actions, and passive soft-tissue restraints [1]. In spite of these factors influencing patellar instability, in patients with normal patellofemoral morphologic features and lower-extremity alignment, patellar instability results from deficient soft-tissue stabilizers. The soft-tissue restraints contributing to patellofemoral stability consist of the vastus medialis obliquus (VMO) component of the quadriceps muscle, the medial retinaculum (the medial patellotibial/meniscal ligaments), and the medial patellofemoral ligament (MPFL) [2, 3].

The MPFL is a thin ligament that inserts at the proximal two-thirds of the medial border of the patella [4]. The origin of the MPFL, at the femur, is located in layer 2 of the medial knee. It begins with an arc of fibers continuous with the anterior edge of the superficial medial collateral ligament near the medial epicondyle with other fibers originating from the adductor tubercle or medial epicondyle or both, with individual variation [5, 6].

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During the past decade, the importance of the MPFL as a pivotal medial patellar stabilizer in lateral patellar dislocation has been clarified. Several biomechanical studies have shown that the MPFL acts as the major static restraint to resist forces that move the patella out of the sulcus, contributing an average of 50–60% of the total medial restraining force [1–3]. In a functional deficiency study, when the medial passive patellar restraints were ruptured, the force required to displace the patella 10 mm laterally was reduced by 49% [7]. This check-rein effect of the MPFL is remarkably conspicuous in early knee flexion. Accordingly, laxity or rupture of the MPFL may result in an increase in subluxation or dislocation of the patella.

On the basis of the aforementioned anatomic and functional considerations, many different surgical procedures have successfully been developed in order to reproduce its check-rein effect [8–13]. The reconstruction of the MPFL, which restores native length and stiffness of the medial soft tissue, must be the goal of a successful surgical intervention. Success rates of procedures which reconstruct the MPFL using different types of grafts and techniques ranges between 83 and 93%. However, the isolated repair of the MPFL has been proven to be insufficient to provide mechanical strength for adequate MPFL function and produce any significantly better functional outcomes [14]. Moreover, the length change pattern of a reconstruction of the MPFL relies mainly on the site of femoral attachment, with a proximal point leading to increasing distance to the patellar attachment as the knee flexes, and vice versa for a distal attachment [15]. This indicates that a double-bundle reconstruction of the MPFL reproducing a cyclical tightening–slackening pattern as the movements of the knee might be more reasonable. Meanwhile, this surgical design lessens horizontal rotation of the patella during flexion–extension movement that may occur during single-bundle reconstruction [16]. This study (1) describe a transverse patella double tunnel technique to reconstruct the MPFL using semitendinosus autograft, (2) chronologically evaluate our surgical method of MPFL reconstruction in patients of all ages who were treated for recurrent dislocation of the patella. To our knowledge, this is the first outcome report of a minimum 3.1-year clinical and radiological follow-up after an anatomical transverse patella double tunnel reconstruction of the MPFL, with a semitendinosus autograft in recurrent patellar dislocations.

Patients and methods

Between January 2003 and December 2006, a total of 83 knees in 75 patients with recurrent patellar dislocation were treated surgically by the senior author using a

semitendinosus autograft. When the amelioration of symptoms, such as giving-way, painful clicking and instability on activities of daily living (ADL) or sports activities, was not satisfactory for the patients even after 3 months of conservative treatment of isometric quadriceps contraction exercise, MPFL reconstruction was indicated. Of these patients, 59 knees (52 patients) were included in this study. Of the remaining 23 patients, 12 were excluded from the study because they could not be examined more than four times postoperatively at 3, 6, 12, 36, 60, or 84 months. Besides, 11 patients undergoing a previous injury to or surgery on the affected knee, moderate/severe osteochondral lesions visible on the roentgenograms, a high-grade trochlear dysplasia based on the criteria of Dejour [17] or malalignment were also excluded from the study. The average follow-up rate was 69.3%. There were 19 male and 33 female patients. The left knee was affected in 36 knees and the right knee in 23. Seven patients had bilateral involvement. The mean age of the patients at the time of surgery was 24.3 years (range 15–41 years). Average duration of symptoms before surgery was 3.8 years (range 0.4–22 years). The average follow-up time was 5.7 years (range 3.1–7.1 years). The medical ethical committee of our institution granted us permission to perform this study.

All surgeries were performed by the senior surgeon (X.YY). The patient was placed supine, with a tourniquet applied to the thigh, following the administration of prophylactic antibiotics. The leg is then prepped and draped in the standard surgical fashion, elevated, and the tourniquet is inflated. To avoid capturing the quadriceps with the tourniquet, the leg is fully flexed before tourniquet inflation. Skin preparation and sterile draping was performed in the usual fashion. The patient was examined under anesthesia to confirm the diagnosis of lateral patella instability and to evaluate the degree of patellar instability according to the quadripartite method [18]. The number of quadrants that the patella laterally translated was recorded. A lateral force was applied to the patella in full extension and 60° of flexion. Patients with a history of frank dislocations typically had an examination under anesthesia that allows the patella to dislocate (Fig. 1), whereas patients with history of subluxations may or may not have a patella that dislocates under anesthesia.

All patients underwent reconstruction of the MPFL using an ipsilateral hamstring tendon autograft. The semitendinosus tendon was our preferential choice. A 2- to 3-cm-long longitudinal skin incision was made at the medial side of the tibial tubercle, just at the midline between the posteromedial border of the tibia and the anterior tibial crest. Through blunt dissection, the insertion site of the pes anserinus was exposed, and the distal portion of the semitendinosus tendon was then palpated through the overlying sartorial fascia. The semitendinosus at its

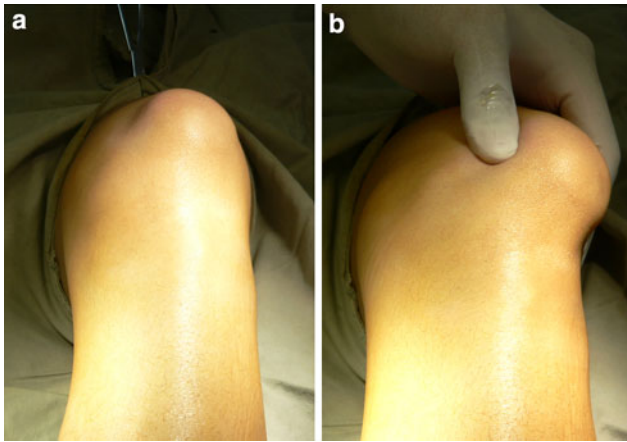


Fig. 1 Examination showing marked patella dislocation under anesthesia

myotendinous junction was detached using a tendon stripper, leaving it attached distally to the pes anserinus (Fig. 2). After removal of the muscular tissue and pruning, the tendon was then mounted to tendon manipulation tables for pre-tensioning with a force of 60–80 N until graft placement into the joint was performed. In eight patients, the semitendinosus tendon was impaired or insufficient in length or diameter and the gracilis tendon was therefore harvested and utilized to reconstruct the MPFL.

Diagnostic arthroscopy was routinely performed before reconstruction of the MPFL. Following traditional knee arthroscopy with inferolateral and inferomedial portals, an arthroscopy (4 mm in diameter; Stryker, USA) was performed to document cartilaginous changes to the trochlea and patella and visualize the amount of lateral patellar tilt and subluxation. The other compartments of the knee were visualized and chondral debridement was performed as needed and loose bodies were removed. A lateral release was routinely performed and may improve postoperative

range of motion (ROM), decreasing the tensile strength of the lateral retinaculum.

The patella was elevated to facilitate palpation of the medial and lateral borders of the patella. A 3-cm symmetric parapatellar incision was made along the medial and lateral borders of the patella, respectively. The exposure was facilitated by placing the knee in full extension. A 2.4-mm guide pin was placed into the superior third of the patella at the insertion point of the intact MPFL through medial parapatellar incision. One transverse tunnel was drilled over the guide pin to accommodate a diameter of single-strand semitendinosus tendon, exiting the symmetric lateral surface position of the patella. In this way, the second tunnel was drilled at the midpoint of the medial border of patella, parallel to the first one, separated approximately by a 1-cm bone bridge traversing the whole width of the patella. Each tunnel must also be directed to avoid lesions of patellar articular cartilage intra-articularly. After each pin was drilled, a finger can be used to palpate articular cartilage surface (Fig. 3).

Utilizing a guide pin with the eyelet, one free end of the single-strand semitendinosus tendon was shuttled through the two transverse parallel tunnels from medial to lateral, and then from lateral to medial so that the tendon formed a loop through the patellar double tunnels (Fig. 4). It was more convenient to advance the graft passing the pes anserinus end (thinner) preferentially. Medial epicondyle of the femur was palpated through the skin and exposed using a 2-cm incision. A curved blunt forceps was used to create a soft-tissue tunnel between the femoral incision and the medial parapatellar incision. The semitendinosus tendon was passed through the plane between these layers.

A guide pin was placed in the site of femoral origin of the MPFL at the medial epicondyle, proximal to the origin of the superficial medial collateral ligament. The guide pin was directed slightly anterior and superior to avoid



Fig. 2 Harvesting of the semitendinosus tendon using a tendon stripper



Fig. 3 Palpation of patellofemoral cartilage surface, following the drilling of double tunnels

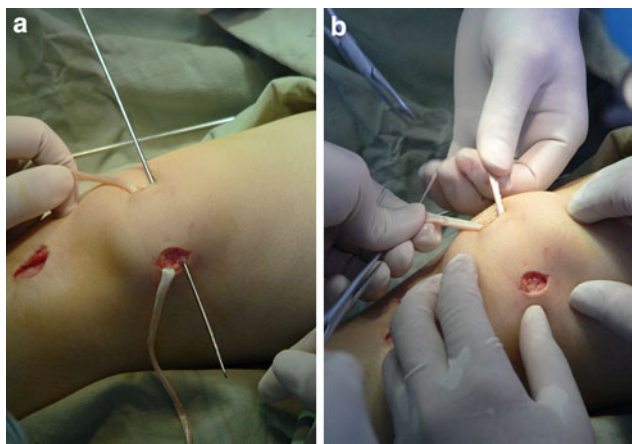


Fig. 4 **a** The graft was passed through the tunnels using a guide pin with the eyelet, from medial to lateral; **b** the tendon formed a loop through double patellar bony tunnels

posterior penetration of the condyle during tunnel reaming. Isometry was evaluated by flexing and extending the knee with the graft held over the guide pin and the patella reduced in the trochlear groove. Tendon excursion around the pin with flexion–extension of the knee allowed assessment of the isometry. If the graft was not isometric, the femoral guide pin was repositioned and the graft isometry reevaluated. This step was repeated until appropriate graft placement was obtained. A 7-mm tunnel was drilled over the guide pin to a depth of 25 mm (Fig. 5a). The free ends of the tendon was folded over and sutured together for 20 mm in a whipstitch style with No. 5 polyester suture (Fig. 5b). The diameter of the folded-over graft was then determined with sizing guides; this was typically 5 mm. Appropriate graft tension was obtained by holding the knee in 60° of flexion with the patella reduced in the trochlear groove while the graft was secured to the medial femoral epicondyle with an interference screw (7 × 25 mm, Depuy Mitek, Raynham, MA), 1 cm distal to the adductor tubercle, and proximal to the medial collateral ligament (Fig. 5c). The medial exposure to the medial epicondyle was facilitated by placing the knee in approximately 60° of flexion.

Our rehabilitation protocol began at the time of the initial diagnosis. In this period before surgery, patients participated in physical therapy to restore full knee ROM

and to eliminate anterior knee pain and knee swelling. After MPFL reconstruction, all patients were followed using the same rehabilitation protocol, which emphasized early restoration of full extension and strengthening training. Isometric quadriceps contraction was performed immediately. Continuous passive motion exercises began the day after surgery for 1 h thrice a day. Patients would start between 0° and 45° and increased 10° per day as tolerated to a maximum of 120°. Progression of partial to full weight-bearing activity in a knee brace was done on an as-tolerated basis, being guided by the presence and degree of pain and swelling. Closed kinetic chain exercises were initiated 4 weeks postoperatively. Proprioception activities were allowed 8 weeks postoperatively and extended through approximately 6 months. Functional activities including walking, jogging and running were introduced at 4 months postoperatively. Typically, 4–6 months were needed for patients to return to work or full athletic participation. Appropriate modifications to the ROM limits and weight-bearing status were made for concomitant arthroscopic chondral debridement and loose body removal.

Physical and radiographic assessments of the involved knee were performed preoperatively and postoperatively to obtain subjective and objective measures of the clinical outcomes of the MPFL reconstruction. Detailed history of dislocation and subluxation of the patella was recorded. All patients were evaluated by physical findings using Kujala's questionnaire [19], the modified Cincinnati rating system [20, 21], and radiography before reconstruction, and more than four time points at 3, 6, 12, 36, 60, or 84 months postoperatively. Radiographic examination consisted of the anterior–posterior view, lateral view at 30° of knee flexion, and Merchant's axial view. Lateral views at 30° of flexion were evaluated for the Insall–Salvati ratio and Blackburne–Peel ratio [22, 23]. In the Merchant's view, the sulcus angle, the congruence angle and the tilting angle were measured [24, 25].

Statistical analysis was performed with SPSS for Windows (version 12.0; SPSS, Chicago, IL) software package. Each score among the various periods was analyzed statistically by the Kruskal–Wallis procedure followed by Tukey's test for multiple comparisons with a significance level at $P < 0.05$. At each time point and for

Fig. 5 **a** Drilling a tunnel into the femoral attachment of the MPFL; **b** the free ends of the tendon was folded over and sutured together for 20 mm in a whipstitch style; **c** the graft was secured within the tunnel in the medial epicondyle using an interference screw



each patient, the evaluation was repeated three times, and the average was used for statistical analysis.

Results

We evaluated the 52 patients at a mean of 5.7 years (range 3.1–7.1 years) following the MPFL reconstruction. Patient demographics and characteristics are shown in Table 1. At each follow-up time point, the number of knees was as follows: 59 knees before surgery, 43 knees at 3 months after surgery, 46 knees at 6 months after surgery, 42 knees at 12 months after surgery, 39 knees at 36 months after surgery, 34 knees at 60 months after surgery, and 31 knees at 84 months after surgery.

Preoperative physical examination was positive for lateral patellar apprehension in all patients, whereas none remained apprehensive between surgery and the most recent follow-up. There were no reported recurrent episodes of dislocation or subluxation postoperatively, although 7 knees (6 patients) with an occasional unstable feeling without redislocation were found. Of the seven knees, one knee had mild patellar hypermobility without positive apprehension sign and one knee had moderate patellar hypermobility without positive apprehension sign.

Table 1 Characteristics and preoperative radiographic findings of study patients

Demographic data	
N (patients/knees)	52/59
Gender (F/M)	33/19
Side (L/R)	36/23
Age at operation in years (range)	24.3 (15–41)
Duration of symptoms before operation in years (range)	3.8 (0.4–22)
Follow-up periods in years (range)	5.7 (3.1–7.1)
Q-angle, ° (range)	13.2 (9.6–17.5)
Insall–Salvati ratio (range)	1.1 (0.8–1.4)
Blackburne–Peel ratio (range)	1.0 (0.7–1.5)
Sulcus angle, ° (range)	137.5 (120–146)
Congruence angle, ° (range)	12.2 ^a (15 ^b –27 ^a)
Tilt angle, ° (range)	11.4 (7–18)
Activity level	
Participation in highly competitive sports	3 (6%)
Well-trained and frequent participation in sporting activities	5 (10%)
Participation in some sporting activities	36 (69%)
No participation in sports	8 (15%)

^a Lateral

^b Medial

During examination under anesthesia, the lateral patella translation was greater than two quadrants (mean 3.2 quadrants) in all patients on application of medial-to-lateral manual pressure, and mean 1.4, 1.6, 1.4, 1.9, 1.8 and 1.6 quadrant remained at recorded six follow-up points postoperatively. The average preoperative Q-angle of patients who were included in this study was 13.2° (range 9.6°–17.5°). Six patients had patella alta (Insall–Salvati ratios > 1.2), and nine had patella alta (Blackburne–Peel ratios > 1.0), including the five patients with high Insall–Salvati ratios. The average range of motion was from 30 ± 2° preoperatively and 125 ± 5° postoperatively at most recent follow-up ($P < 0.01$). Knee stiffness developed postoperatively in three patients, but resolved after 6 months of consecutive physical therapy.

Intraoperatively, 14 patients (16 knees) had cartilage lesions of the patella (Table 2). Fissuring was observed in 12 knees (75%). Of the 12 knees, fissuring alone was seen in 2 knees (17%), and fissuring associated with fibrillation and/or defect was seen in 10 knees (83%). The most common location of fissuring was in the central dome of the patellar articular surface. The average number of fissuring in each knee (mainly longitudinal fissuring) was 2.4 (range 1–7). Marginal/radial fissuring in the periphery of fibrillation and/or defect, mainly in the medial facet, and interlaced fissuring were found in four knees. Fibrillation and/or defect were observed in 14 knees (88%). Of the 14 knees, 10 knees had concomitant fissuring (71%), and remaining 4 knees had not (29%). Fibrillation and/or defect mostly located in the medial dome. In the two knees, the subterraneous collapse of cartilage surface on the central dome was observed, along with tracking of patella. Additional arthroscopic findings included mild trochlear hypoplasia in nine knees. In seven of all knees, we found loose osteochondral fragments and removed these fragments. We debrided the exfoliated area where the fragment appeared to have originated, and performed micro-fracture surgery. We did not further perform trochleoplasty or osteochondral transplantation in the above patients.

Table 2 The findings of cartilage lesions of the patella at arthroscopy (16 knees)

Involved location	Fissuring (12 knees)	Fibrillation/defect (14 knees)
Medial facet	2 (17)	3 (21)
Medial dome	2 (17)	6 (43)
Central dome	7 (58)	4 (29)
Lateral dome	1 (8)	1 (7)
Lateral facet	0 (0)	0 (0)

Values in parentheses are given in percentage

There were significant differences between the mean preoperative Kujala scores and the postoperative scores (3, 6, 12, 36, 60, 84 months) in MPFL reconstruction ($P < 0.001$) (Fig. 6a). There were also significant differences between the mean preoperative modified Cincinnati scores and those at 12, 36, 60, and 84 months after surgery in MPFL reconstruction ($P < 0.01$) (Fig. 6b). There were no significant differences in all the above values between patients with and without cartilage lesions of the patella ($P \geq 0.08$), and between male and female patients ($P \geq 0.07$).

There were significant differences between the mean preoperative congruence angle and the postoperative scores (6, 12, 36, 84 months) after MPFL reconstruction ($P < 0.01$) (Fig. 7a). The mean congruence angle was 12.2° (range -15° to 27°) preoperatively and reverted to the

normal range postoperatively [24]. There were also significant differences between the mean preoperative tilt angle and those at 6 and 84 months after MPFL reconstruction ($P < 0.05$) (Fig. 7b). The mean patellar tilt decreased statistically significantly from 11.4° (range 7° – 18°) preoperatively to 7.9° (range 4° – 16°) at 6 months ($P < 0.03$) and 8.4° (range 3° – 16°) at 84 months ($P < 0.04$), remaining in the normal range after surgery [25].

Discussion

Many pathologic conditions such as trochlear dysplasia, patella alta, ligamentous laxity or muscular hypotonia caused by some inherited disorders such as Down's syndrome or Ehlers–Danlos syndrome, an over-increased

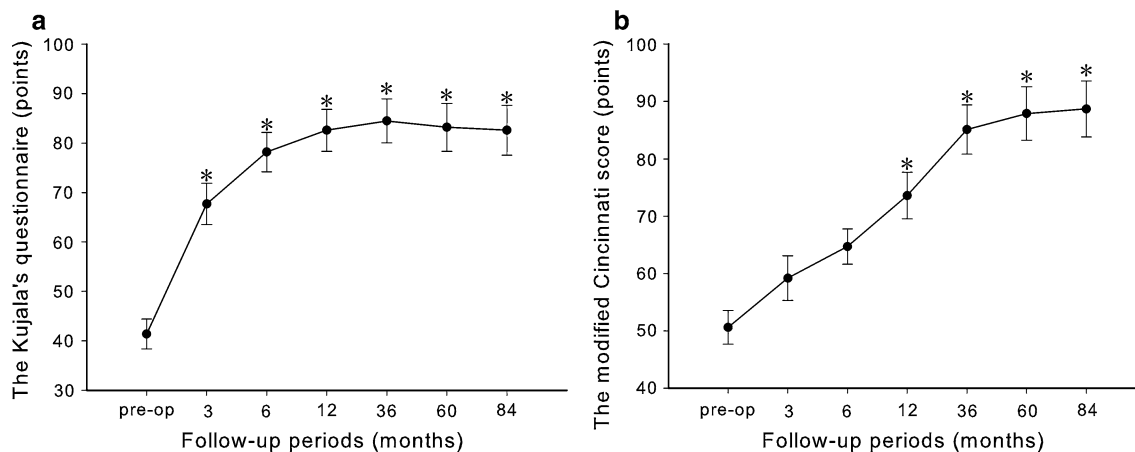


Fig. 6 a The mean Kujala scores. There were significant differences between the preoperative scores and the postoperative scores. **b** The mean modified Cincinnati scores. There were significant differences

between the preoperative scores and those at 12, 36, 60, and 84 months after surgery. * $P < 0.05$

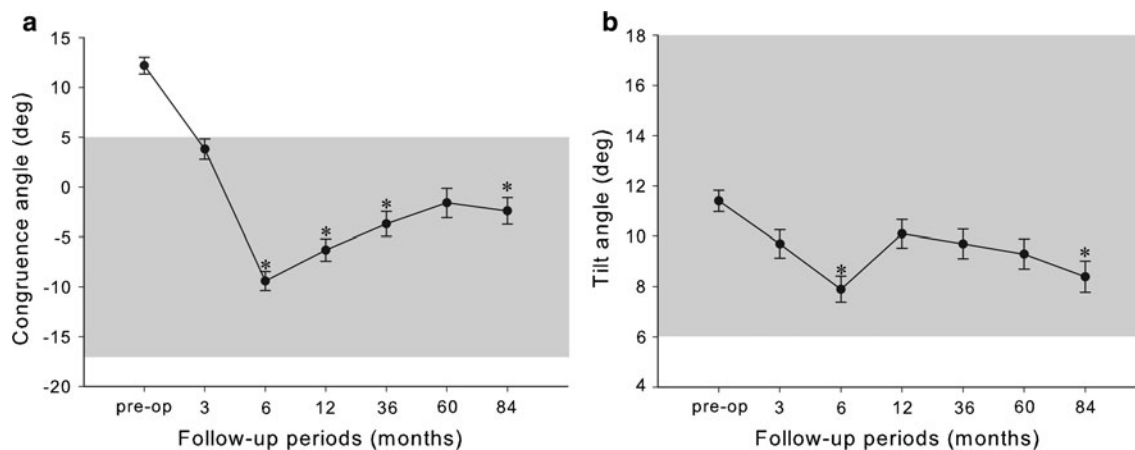


Fig. 7 a The mean congruence angle. There were significant differences between the congruence angle values before reconstruction and those at 6, 12, 36 and 84 months after reconstruction of the MPFL. **b** The mean tilt angle. The mean patellar tilt angle decreased

statistically significantly from 11.4° (range 7° – 18°) preoperatively to 7.9° (range 4° – 17°) at a 6-month follow-up interval, 8.4° (range 3° – 18°). The normal range was indicated by gray area, respectively. * $P < 0.05$

Q-angle resulting from a rotational malalignment of the tibiofemoral joint, and female gender can be closely correlated with recurrent patellar instability [26–33]. For the purpose of restoring lesioned biomechanics of the patellofemoral joint, the above conditions demands anatomical and functional rectification. Multiple series of surgical procedures have been characterized as proximal soft-tissue realignment, lateral retinacular release, all-inside arthroscopic techniques, distal realignment, and combined procedures [34–37]. The presence of abnormal geometry of osseous structures, including a shallow sulcus of femur, external rotation of tibia, hypoplasia of the lateral femoral condyle and malalignment of the lower extremity, are indications for osseous realignment procedures. These nonanatomic procedures, however, directly or indirectly alter the premorbid biomechanical properties of the patellofemoral joint, leading to some cacoethic outcomes, such as intermittent redislocation, anterior knee pain and degenerative arthritis, especially after distal realignment procedures [38–41].

Biomechanics studies have confirmed that the MPFL is the major soft-tissue stabilizer in preventing lateral dislocation or subluxation of the patella [1–3, 42]. Up till now, multiple surgical procedures have been developed to reconstruct the MPFL, demonstrating good early to mid-term results [8–13, 43]. However, there is presently no clear consensus on the most optimized method to reproduce intact biomechanical properties of the MPFL.

The objective of this study was to chronologically evaluate double tunnel method of MPFL reconstruction in patients of all ages without any severe osseous abnormalities. The high success rates (88.1%) and the absence of a tendency towards redislocation probably rely on selection criteria of patients in this study. In accordance with our speculation on clinical outcomes, Christiansen et al. [10] reported on 44 patients with 12–32 months of follow-up, and there were higher scores in patients without trochlear dysplasia and treated with isolated MPFL reconstruction compared with patients who underwent tibial tuberosity transfer with MPFL reconstruction for a marked trochlear dysplasia. Nevertheless, Schöttle et al. [9] reported on 12 patients with 24–70 months of follow-up, and there were no difference with respect to clinical and radiological outcome between with or without trochlear dysplasia. Therefore, a comparative investigation needs to be further performed.

An isometry of the MPFL is critical to the success of the reconstruction [5, 44]. In a computational analysis, with the simulation of physiological knee function from 30° to 90° flexion, it was emphasized that anatomical reconstructed graft was similar to the native MPFL, and that small errors in graft length and position can dramatically increase the force and pressure applied to medial patellofemoral

cartilage, which could lead to pain and degenerative arthrosis [44]. Just as seen in the clinic cases, as Thauant and Erasmus [45] presented, pain and loss of flexion could occur due to overtight reconstructed MPFL. In our cases, the anatomic structure of the patellar insertion was kept to, with the duplication of the concept of the functional bundles of the MPFL. Approximately from the femur origination, the fibers of the MPFL become wider as fan-sharp, forming two relatively concentrated fiber bundles: the inferior-straight bundle and the superior-oblique bundle [15]. Although these two bundles run on the patellar MPFL inferiorly and superiorly, respectively, by the free ends of the tendon whipstitched, the two bundles are not entirely separated, which make the graft mimicking the intact MPFL as far as possible. However, the functional significance, if any, of this two-band structure remains unknown. The assumption about the function of each bundle needs to be further confirmed.

We fixed the graft to the femur with the knee flexed to 60° because maximal graft length has been reported at this knee flexion degree [5]. This angle therefore avoids over-tightening of the graft. Furthermore, at this angle, the patella assumes its reproducible and normal position because of passive tension of the quadriceps and the patellofemoral articulation. For this reason, medial–lateral position of the patella is not a subjective determination by the surgeon. Our technique also allows evaluation of graft isometry before commitment to tunnel location on the femur.

Before this, a few of anchoring techniques have been described in great detail with good to excellent clinical results. In a cadaveric study, the researchers compared the tensile strength of different fixation techniques. The MPFL failed at a mean tensile strength of 208 N. The strengths of the other techniques were: sutures alone, 37 N; bone anchors plus sutures, 142 N; blind-tunnel tendon graft, 126 N; and through-tunnel tendon graft, 195 N [42]. There were no significant differences in strength between the native MPFL and through-tunnel reconstructions. Furthermore, the strength and stiffness of two equally tensioned semitendinosus strands has been verified for MPFL reconstruction as the load to failure of the graft is approximately tenfold greater than the native MPFL [46], thus indicating that an adequate tensile strength for MPFL reconstruction is guaranteed.

In the present study, the clinical outcomes have been relatively good. Although there were seven knees (6 patients) with an occasional unstable feeling, no reported recurrent episodes of dislocation or subluxation postoperatively were found. Of the seven knees, one knee had mild patellar and one knee had moderate patellar hypermobility. In addition, none remained apprehensive between surgery and the most recent follow-up. The mean Kujala score and

the mean modified Cincinnati score have both remained high since the MPFL reconstruction, and the patients' scores after surgery have been significantly higher than their preoperative scores (Fig. 6). On the other hand, in the radiological evaluation, the mean values of the congruence angle and the tilt angle were demonstrated to be within the normal range (Fig. 7) [24, 25]. The effect of the MPFL reconstruction on these parameters has also been maintained after surgery. Interestingly, there appeared to be similar degrees of the mean Kujala score improvement in those with more than 5 years of follow-up compared with those with less than 5 years of follow-up. This suggests that the effects of the procedure may endure beyond the 5-year timeline.

Intraoperatively, the thin guide pins allow significant control when drilling through the patella, thus reducing the risk of iatrogenic lesions of the articular surface of the patella. In order to analyze cartilage changes of the patella in recurrent patellar dislocation, an arthroscopic examination was routinely performed. The cartilage changes of the involved recurrent dislocated patella were far more complicated than cartilage damage of acute patellar dislocation (Table 2) [47]. This could be due to the site, condition (osteochondral fissuring; fibrillation/defect), severity of the lesions, with or without repeated trauma, and time period following acute phase. Because the medial patellar stabilizer is highly flabby when dislocation continues, it is considered that the force of injury to patellar cartilage decreases. Therefore, the number of fissuring in involved knees may not be significantly different. If dislocation continues, fibrillation and/or defect (erosion) can tend to deterioration. In addition, we did not record any case of patellar fracture intraoperatively and postoperatively as reported by other studies [10, 48, 49], probably due to the small size of the pins.

Several drawbacks of this study should be noted. As a retrospective follow-up report, the clinical evaluations were not blinded and there was the lack of a control group. A direct prospective comparison with simple continued nonoperative management or other surgical procedures, such as the Elmslie–Trillat osteotomy, would be interesting but is beyond the scope of this article. Another limitation could be perceived to be the lack of routine, more sophisticated radiological evaluation of limb-length alignment and the rotational and angular profile of the lower extremity and knee. Tracing it to its cause as to overinvestigating these patients was considered inappropriate once an appropriate clinical examination was carried out and routine radiographs were taken.

All patients returned to preoperative levels of function and athletic participation. We did not encounter any marked complications postoperatively. We therefore conclude that MPFL reconstruction with the double-transverse

tunnel technique is safe (given that we observed no complications) and effective (because no postoperative dislocations or subluxations were observed) in patients of all ages without any predisposing anatomic abnormalities.

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Conflict of interest The authors report no conflict of interest.

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