Double-Tunnel Technique Was Similar to Single-Tunnel Technique in Clinical, Imaging and Functional Outcomes for Medial Patellofemoral Ligament Reconstruction: A Randomized Clinical Trial

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Purpose: This study aimed to compare the clinical, functional, and imaging outcomes of single-tunnel (ST) and double-tunnel (DT) techniques for medial patellofemoral ligament (MPFL) reconstruction. **Methods:** Ninety-four patients with recurrent patellar instability were randomly divided into 2 groups, receiving either ST or DT MPFL reconstruction. Lateral reticulum release (LRR) and tibial tuberosity (TT) transfer were performed as combined procedures when necessary. Preoperative and postoperative clinical characteristics (symptoms and episodes of redislocation), functional outcomes (Kujala, Lysholm, Tegner, IKDC, and KOOS score), and radiological measurements (congruence angle, patellar tilt angle, lateral patellar angle, and lateral patellar translation) were analyzed. **Results:** The analysis included data from 90 patients with 48 patients in the ST group and 42 patients in the DT group. Patients were followed up for a mean period of 37.8 (range: 27-50) months in the ST group and 38.6 (range: 25-53) months in the DT group. Forty-three patients in the ST group and 40 patients in the DT group received combined TT transfer, and all patients underwent LRR. At the latest follow-up, 1 patient in ST group experienced redislocation, while no patient in the DT group sustained clinical failure ($P = .347$). Imaging measurements decreased significantly to the normal range postoperatively. No significant difference was noted between the postoperative radiological results of the 2 groups. All clinical scores significantly improved postoperatively, and no significant difference was observed between the 2 groups except for the higher Lysholm score ($P = .031$), KOOS symptoms score ($P = .021$) and KOOS knee-related quality of life score ($P = .043$) in the DT group. **Conclusion:** Both techniques could equally mitigate the patellar lateral translation or redislocation. Our results demonstrate several significant differences in functional outcomes that favored DT MPFL reconstruction but no difference in clinical failure rates and radiological results between ST and DT MPFL reconstruction. **Level of Evidence:** Level I, randomized clinical trial.

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Introduction

Recurrent patellar dislocation is a relatively common knee disorder associated with various pathological factors, such as patella alta, genu valgum and trochlear dysplasia.[1-4] Among all the predisposing etiologies, medial patellofemoral ligament (MPFL) injury or laxity plays a crucial role since MPFL is the major passive restraint preventing lateral patella translation. With the absence or loosening of MPFL, patellar tracking is remarkably affected by the lateral force. Therefore, MPFL reconstruction (MPFLR) has been proven as an effective procedure[5] that offers excellent

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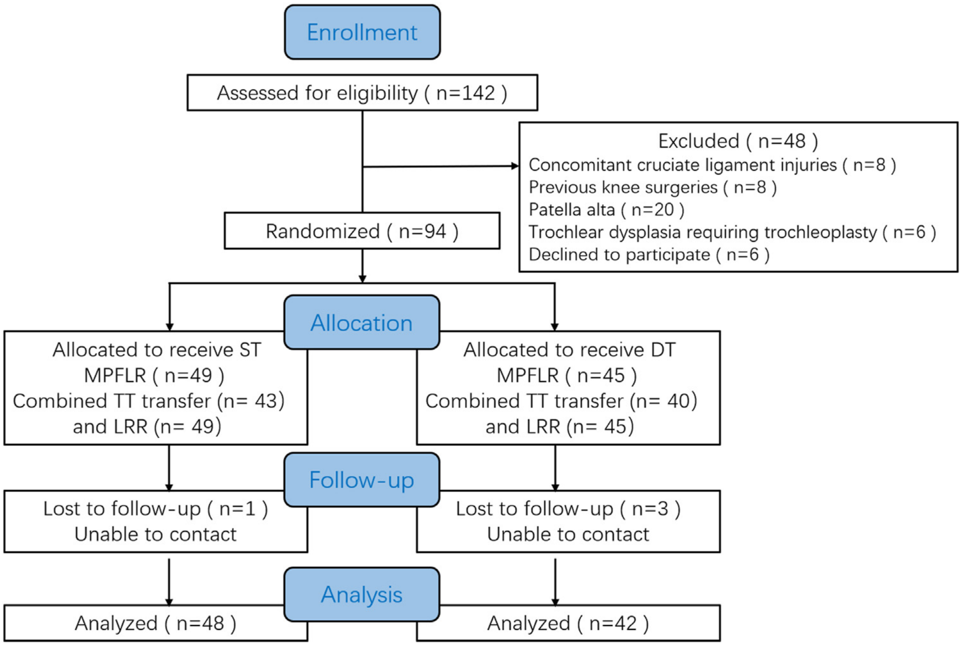

Fig 1. CONSORT (Consolidated Standards of Reporting Trials) flow diagram. DT, double-tunnel; LRR, lateral reticulum release; MPFLR, medial patellofemoral ligament reconstruction; ST, single-tunnel; TT, tibial tuberosity.

subjective and functional outcomes with a low incidence of patellar redislocation.[6]

As a sail-like structure routing from patella to femur, the patellar insertion point of MPFL is more flexible than the femoral insertion point, and functioned as a fan-shaped attachment over an extremely wide range.[7] Although numerous techniques for MPFL reconstruction have been described in the literature, there is still insufficient evidence to support the superiority of one technique over another.[8-10] With the increased understanding of the biomechanics and anatomy of the MPFL, tunnel reconstruction is favored due to its better outcomes than other techniques.[11] However, the existing literature comparing the single-tunnel (ST) and double-tunnel (DT) techniques for MPFL reconstruction is relatively sparse.[12] This study aimed to compare the clinical, functional, and imaging outcomes of ST and DT techniques for MPFL reconstruction. It was hypothesized that MPFLR with DT would result in superior clinical and functional outcomes, but equivalent radiological examination.

Methods

Study Design

This was a randomized controlled clinical trial. Institutional review board approval was obtained from the Ethics Committee of Shanghai Sixth People's Hospital (approval number 2017-008-[1]) and was registered in the Chinese Clinical Trial Registry (ChiCTR-IOR17010738) in February 2017. Patients were approached if they had 1) closed epiphysis, 2) more than 2 episodes of dislocation or 1 episode of dislocation plus multiple episodes of instability (lateral excursion of the patella), 3) unilateral symptoms, and 4) active level before injury. The exclusion criteria were as follows: 1) concomitant ligament injuries (except MPFL), 2) previous knee surgeries, 3) patella alta (Insall-Salvati index >1.2), 4) femoral trochlear dysplasia requiring trochleoplasty (type D by Dejour's classification with a supratrochlear spur more than 5 mm[13]), 5) associated with cardiovascular or other systemic diseases, 6) drug or alcohol abuse, 7) pregnant or breastfeeding female, and 8) lower limb malalignment (>5° varus or valgus deformities). From March 2017 to November 2019, after screening the eligibility of 142 subjects, 94 patients were enrolled and randomly assigned to undergo double-tunnel or single-tunnel MPFL reconstruction via randomized number processed by Excel (Microsoft). The patients were followed up at 1.5, 3, 6, 12, and 24 months after operation. After 2 years, there was no fixed time point for further consultation. The minimum follow-up for inclusion was 2 years. Ninety patients completed the final follow-up, while 4 patients lost to follow-up due to broken contact. All patients provided written informed consent, and baseline demographic data were collected. The flowchart of patient selection is demonstrated in Fig 1.

Surgical Techniques

A single experienced surgeon (J.Z.) in our institution conducted the surgical procedures from March 2017 to November 2019. All procedures were performed under general anesthesia in the supine position.

Single-Tunnel MPFL Reconstruction

The anterior half of the peroneus longus tendon (AHPLT) was harvested and braided with nonabsorbable

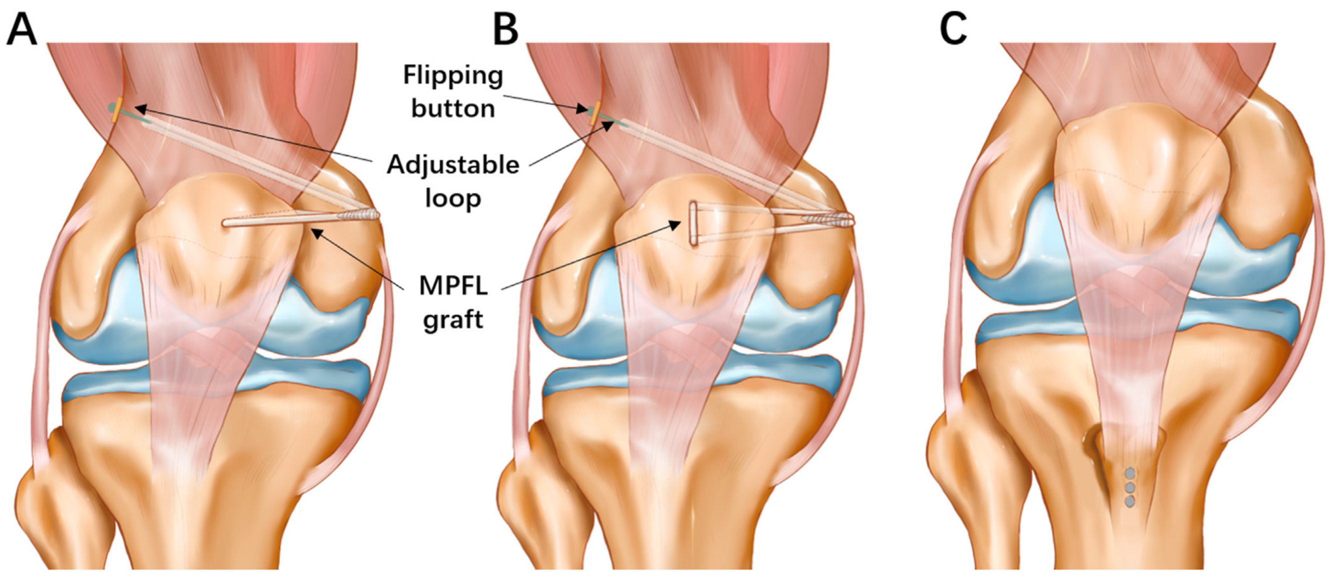

Fig 2. Diagrams of surgical procedures from the frontal view (right knee). (A) Single-tunnel MPFL reconstruction: the tunnel was drilled from the medial edge of the patella to the midline of the anterior surface of the patella, at level of the MPJ. (B) Double-tunnel MPFL reconstruction: two tunnels were drilled from the medial edge of the patella to the midline of the anterior surface of the patella, at levels respectively 5 mm proximal and distal to the MPJ. A cortical suspensory fixation device was used in both techniques to fix at the femoral side. (C) Tibial tuberosity osteotomy. MPJ, middle-proximal junction; MPFLR, medial patellofemoral ligament reconstruction.

sutures.[14] The level of the junction of the middle and proximal one third of the patella, which usually corresponds to the widest part of the patella, was identified. The point on the medial edge of the patella at this level was defined as middle-proximal junction (MPJ). A 1-cm longitudinal, medial incision was made over the MPJ. A single tunnel was drilled from the medial edge of the patella to the midline of the anterior surface of the patella, at the level of the MPJ.

To determine the femoral tunnel, a 2-3-cm longitudinal medial incision was made to define the medial femoral epicondyle, the adductor tubercle and the gastrocnemius tubercle.[15,16] The femoral tunnel was created at the midpoint among these three tubercles medially in a slight proximal and anterior deviation across the lateral cortex of the femur. The graft tendon was passed through the patellar tunnel and pulled back over the anterior surface of the patella. The arthroscope was placed in through the anteromedial portal, and the radiofrequency probe is placed in through the anterolateral portal with the knee in full extension. Lateral retinaculum release (LRR) was performed with tissue scissors by pulling the patella medially with the graft in the space between the vastus lateralis and the iliotibial band from the level of the anterolateral portal to the tendon-muscle junction of the vastus lateralis.[14,17] A cortical suspensory fixation device with an adjustable loop (Arthrex, Naples, FL) was used to introduce the graft into the femoral tunnel. Both graft ends were tied to the adjustable loop, and the cortical fixation device was pulled through the femoral tunnel till the graft ends were pulled into the tunnel with the knee in 90° of flexion. The adjustable loop was tightened until the flipping button was pulled back against the lateral orifice of the femoral tunnel (Fig 2A). An interference screw was used on the medial femoral side. Graft tension and patellar tracking with flexion-extension movements were checked during the procedure.

Double-Tunnel MPFL Reconstruction

As in the reconstruction with a ST, the same single incision and approach were used[14] (Fig 2B). Two tunnels were created from the medial edge of the patella to the midline of the anterior surface of the patella, at levels 5 mm proximal and distal, respectively, to the MPJ. The graft was passed through the double tunnel in a looped fashion. LRR was performed. The fixation on the femoral side was the same way as in ST reconstruction. Graft tension and patellar tracking with flexion-extension movements were checked in the same fashion of single-tunnel MPFLR.

Combined Procedure

Eighty-three patients received tibial tubercle medialization, as tibial tubercle-trochlear groove (TT-TG) was greater than 15 mm. The procedure of TT transfer[18] is a modification of Fulkerson's osteotomy (Fig 2C). Briefly, a 4-cm longitudinal incision was made along the lateral edge of the tibial tuberosity. Through this movable skin window, tibial tubercle osteotomy was performed along

Table 1. Baseline Demographic of the 2 Groups

Characteristic	ST Group ($n = 48$)	DT Group ($n = 42$)	P Value
Male/Female	16 / 32	15 / 27	.813
Age (years)	23.8 (15-39)	21.4 (14-41)	.063
Body mass index (kg/m^2)	22.4(17.7-38.8)	23.3(15.5-34.6)	.402
Left/Right side	26 / 22	20 / 22	.535
Patella height	0.9 ± 0.2	0.9 ± 0.2	.665
Articular cartilage status (Lesion/Normal)	15 / 33	14 / 28	.833
Number of dislocations	4.3 (1-17)	4.7 (1-15)	.484
Duration of symptoms (month)	24.7 (1-108)	20.3 (1-48)	.581
Follow-up period (month)	37.8 (27-50)	38.6 (25-53)	.194

Data are presented as n or means ± standard deviation, mean (range). The independent-sample t-test was employed to compare continuous variables and the chi-square test was used to compare nominal variables.

a plane from the medial edge of the tibial tubercle and the posterolateral ridge of the proximal tibia, creating a 6-8-cm bone fragment with a tapering distal end. The proximal part of the bone fragment was transferred anteromedially, with the distal tapering end left in place or, in some cases, rotated laterally along the osteotomy surface. The magnitude of the medialization of the proximal end of the tibial tubercle was measured and adjusted as needed. The purpose was to mitigate the TT-TG distance to 5-10 mm. The transferred tibial tubercle was fixed with K-wires in the desired position.

Rehabilitation Protocol

Patients were allowed to bear weight and walk with a brace locked in extension immediately after operation. Calf raise training were started on the first day after surgery. Range-of-motion exercises began immediately, but the knee flexion angle was restricted to 45°, 90°, and 120° in the 1st, 2nd, and 3rd 2-week periods following the operation, respectively. The brace was removed at 6 weeks after surgery. Proprioception training began 6 weeks following the operation; running and agility training started 3 months after operation. All sports were gradually resumed after 6 months.

Outcome Measurements

Primary Outcome

Clinical failure of MPFLR,[18] as primary outcome, was determined by patellar redislocation or multiple episodes of patellar instability. The physical examination of patients was conducted by two sports medicine fellowship-trained orthopedic surgeons independent of the surgical team in a blind fashion.

Secondary Outcomes

Secondary outcomes consisted of patient-reported outcome measures (PROM), including the Kujala score,[19] Knee Injury and Osteoarthritis Outcome (KOOS) score,[20] Tegner Score,[21] International Knee Documentation Committee (IKDC) subjective score,[22,23] and Lysholm score.[24] As a statistically significant outcome may not be clinically relevant,[25] frequencies of patients with overall change scores exceeding minimal clinically important difference (MCID) or similar threshold as minimal detectable change (MDC) were calculated to determine clinical relevance and improvement. MCID in Kujala score of 12 points,[26] KOOS of 10 points,[27] IKDC of 11.5 points,[28] and MDC in Lysholm score of 8.9 points,[25] Tegner of 1 point,[25] were used. In addition, computed tomography scans (CT) were taken for radiological outcome measurements. Lateral patellar angle (LPA), congruence angle (CA), patellar tilt angle (PTA), lateral patellar translation (LPT) and TT-TG distance were assessed on CT, according to the previous methods.[18,29] All imaging parameters were measured by two sports medicine fellowship-trained orthopedic surgeons independent of the surgical team in a blind fashion. Intra-class correlation coefficients (ICC) were calculated for inter-rater reliabilities of the measurements.

Adverse Events and Complications

All possible adverse events and complications related to the surgical procedures were recorded, such as poor wound healing, nonunion of the osteotomy area, knee joint dysfunction (anterior knee pain and stiffness), and patellar fracture.

Sample Size Calculation and Power Analysis

The estimated sample size was calculated with a priori power test on G power software (version 3.1). A clinical failure rate of 4.54% and 26.9% in previous research,[30] and an α of 0.05 and power of 0.80 was employed, resulting in a minimum 32 patients in each group. Assuming a dropout rate of 10%, the minimal sample size was set to 36 in each group.

Statistical Analysis

Analyses of the data obtained in the study were performed with SPSS (26.0; IBM). After testing the distribution of data for normality, the independent-sample t-test was employed to compare variables with a normal distribution, otherwise the Mann-Whitney

Table 2. Comparison of Functional Scores Between the 2 Groups

	ST Group	DT Group	*P* Value
Kujala score			
Preoperative	70.4 ± 20.2	68.7 ± 19.1	.730
Final follow-up	84.5 ± 14.7	88.9 ± 14.4	.156
	$P = .002$	$P < .001$	
Lysholm score			
Preoperative	64.9 ± 15.0	72.0 ± 15.4	.074
Final follow-up	83.7 ± 13.5	89.5 ± 11.4	**.031**
	$P = .001$	$P < .001$	
Tegner score			
Preoperative	2.52 ± 1.04	2.65 ± 1.03	.671
Final follow-up	3.89 ± 1.18	4.32 ± 1.29	.113
	$P = .004$	$P < .001$	
IKDC score			
Preoperative	65.7 ± 16.5	62.0 ± 17.1	.366
Final follow-up	74.3 ± 12.5	77.3 ± 12.3	.254
	$P = .005$	$P < .001$	
KOOS Scores			
Pain			
Preoperative	84.3 ± 12.5	84.6 ± 13.6	.909
Final follow-up	92.7 ± 7.5	95.7 ± 7.2	.057
	$P = .002$	$P < .001$	
Symptoms			
Preoperative	66.9 ± 14.0	69.6 ± 15.7	.451
Final follow-up	74.7 ± 12.1	81.2 ± 14.1	**.021**
	$P = .003$	$P = .001$	
Function in daily living activities			
Preoperative	85.5 ± 15.6	88.1 ± 13.1	.454
Final follow-up	96.1 ± 5.3	97.5 ± 4.8	.172
	$P < .001$	$P < .001$	
Function in sports and recreation			
Preoperative	56.9 ± 31.4	52.3 ± 28.8	.542
Final follow-up	80.0 ± 18.5	84.3 ± 20.6	.302
	$P < .001$	$P < .001$	
Knee-related quality of life			
Preoperative	47.0 ± 23.2	52.9 ± 24.5	.312
Final follow-up	61.8 ± 22.2	71.1 ± 20.3	**.043**
	$P = .006$	$P = .009$	

Data are presented as means ± standard deviation. The independent-sample *t*-test was employed to compare the scores between the 2 groups and the matched *t*-test was used to compare the preoperative and postoperative scores. Significant *P* values for comparison between two groups at final follow-up are bolded. IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score.

U-test was used. The chi-square test was used to compare nominal variables. Statistical significance was set to $P < .05$.

Results

General Demographics

Total 94 patients (49 patients in ST group and 45 patients in DT group) were included in this study, and 90 patients completed the final follow-up, while 4 patients were lost to follow-up due to broken contact (Fig 1). The overall mean follow-up duration was 37.8 (range: 27-50) and 38.6 (range: 25-53) months for the ST and DT groups, respectively. Forty-three patients in ST group and 40 patients in DT group received combined TT transfer, and all patients received LRR. The baseline demographic characteristics of the patients are provided in Table 1.

Primary Outcome

Clinical Failure

The rate of clinical failure was 2.1% (1 of 48) in the ST group, while no patient in the DT group experienced clinical failure. There was no significant difference between the two groups ($P = .347$). The patient with patellar redislocation in the ST group was successfully managed with a revision surgery for MPFLR.

Secondary Outcomes

Functional Outcomes

Results of the clinical scores (Kujala, Lysholm, Tegner, IKDC, and five KOOS subscales) for ST and DT groups are displayed in Table 2. No significant difference was detected between the two groups preoperatively. At the final follow-up, significant improvements were observed in both groups (all $P < .05$). When

Table 3. Computed Tomography Assessment Comparison Between the 2 Groups

	ST Group	DT Group	*P* Value
TT-TG distance			
Preoperative	20.0 ± 4.1	20.4 ± 4.6	.619
Final follow-up	10.2 ± 4.5	11.3 ± 4.0	.233
	$P = .020$	$P = .005$	
Congruence angle			
Preoperative	44.6 ± 20.0	41.1 ± 23.1	.445
Final follow-up	−23.2 ± 36.8	−13.4 ± 39.5	.230
	$P < .001$	$P < .001$	
Patellar tilt angle			
Preoperative	29.5 ± 9.0	31.6 ± 10.2	.301
Final follow-up	7.6 ± 10.4	11.4 ± 8.6	.062
	$P < .001$	$P < .001$	
Lateral patellar angle			
Preoperative	12.9 ± 9.6	13.4 ± 13.9	.849
Final follow-up	−9.1 ± 10.0	−6.1 ± 8.3	.137
	$P < .001$	$P < .001$	
Lateral patellar translation			
Preoperative	13.4 ± 6.9	16.2 ± 13.5	.200
Final follow-up	1.4 ± 4.8	2.3 ± 5.1	.408
	$P < .001$	$P < .001$	

Data are presented as means ± standard deviation. The independent-sample *t*-test was employed to compare the variables between the 2 groups and the matched *t*-test was used to compare the preoperative and postoperative variables. TT-TG, tibial tubercle-trochlear groove.

comparing clinical outcomes between two technique groups postoperatively, the DT group had a higher Lysholm score (83.7 ± 13.5 vs 89.5 ± 11.4; $P = .031$), KOOS symptoms score (74.7 ± 12.1 vs 81.2 ± 14.1; $P = .021$) and KOOS knee-related quality of life score (61.8 ± 22.2 vs 71.1 ± 20.3; $P = .043$). No significant difference was noted for other scores between the groups. As for clinically significant differences, MCIDs or MDCs for all PROMs were exceeded by mean overall improvement scores except IKDC score, KOOS pain and symptom scores in ST group, and KOOS activities of daily living score in DT group. A total of 40 patients (83%) in the ST group and 37 patients (88%) in the DT group had a clinically relevant improvement of Kujala score, 39 patients (81%) in the ST group and 35 patients (83%) in the DT group of Lysholm, 38 patients (79%) in the ST group and 35 patients (83%) in the DT group of IKDC, a median of 40 patients (83%) in the ST group and 35 patients (83%) in the DT group of KOOS, and 41 patients (85%) in the ST group and 36 patients (86%) in the DT group of Tegner. No significant difference was found between the percentage of two groups.

Radiological Outcomes

Results of the measurements for TT-TG, CA, PTA, LPA, and LPT are provided in Table 3. The measured radiological parameters showed excellent agreement with ICCs > 0.85. Preoperative results were similar between the groups. At the final follow-up, the parameters in both groups returned to the normal ranges and were statistically significant ($P < .001$) compared with preoperative findings. No significant difference was detected between the groups postoperatively.

Complications and Adverse Events

Four patients (8.3%) in the ST group complained of mild anterior knee pain, compared with 2 patients (4.8%) in the DT group ($P = .498$). 5 patients (10.4%) in the ST group and 4 in the DT group (9.5%) experienced mild knee range-of-motion (ROM) limitation (could not flex beyond 110°), such as deep squat ($P = .888$). The mean postoperative ROM for ST group was 125 ± 8° with 127 ± 9° for DT group. No complications, including donor-site morbidity, patellar fracture, infection, or chronic effusion, have been reported. The overall rate of complications and adverse events showed no significant differences between the two groups.

Discussion

The most important finding of this study was that the DT MPFLR could result in more favorable functional outcomes but could also result in an equivalent clinical failure rate and radiological parameters to ST MPFLR.

Of all MPFLR procedures, transpatellar tunnel technique became a more preferrable procedure due to its stronger fixation force than the suture anchor both biomechanically and clinically.[31-33] Furthermore, tunnel reconstruction allows for the similar strength of native MPFL[32] with no use of extra fixation devices[34] and a favorable environment for bone-tendon healing, as there are no implants between the graft and bone.[35] So far, various drilling techniques have been developed.[11,36] However, the tunnel number or size remains controversial. As the major passive restraint preventing lateral patella translation, numerous research articles have elaborated on the anatomy of MPFL, from a sail-like,[7] or complex polygon-shaped structure[37] to the concept of functional bundles.[38] Nevertheless, the insertion point on the patellar side was rather flexible and covered an extremely wide range. Hence, double-bundle (DB) MPFL reconstruction, rather than single-bundle (SB), has been popular and has achieved good outcomes[30,38,39] from an anatomic perspective. In addition, DB reconstruction has an angular synergy effect biomechanically, which grants a greater resistance to patellar dislocation at a smaller flexion angle.[40] The DT technique, as a type of DB reconstruction, fixed the graft at the patellar side through two transpatellar tunnels. Hence, DT MPFL reconstruction, theoretically, is one procedure that combines the advantage of transpatellar tunnel technique and DB MPFL reconstruction, as the separate tunnels could simulate the MPFL wide footprint on the patella.

In the present study, the DT MPFLR group had relatively better functional outcomes, but similar clinical failure rate compared with ST group. DT group has a higher Lysholm score, KOOS symptoms, and knee-related quality of life score than ST group, whereas other outcomes, such as Kujala score, were similar between the 2 groups. As for clinically significant differences, MCIDs or MDCs for all PROMs were exceeded by mean overall improvement scores except IKDC score, KOOS pain and symptom scores in ST group, and KOOS activities of daily living score in DT group. These findings are mostly consistent with previous research by Li et al.[41]. Li et al.[41] noted that the double-anchor group showed a higher functional outcome than the traditional ST group with no significant difference in patellar re-dislocation between the 2 groups. The main reason for better functional outcome in the DT group than in the ST group might be the same with DB over SB, that DT reconstruction could simulate the native MPFL wide footprint on the patella, and restore the anatomy of MPFL better as stated in biomechanical studies by Placella et al.[42] and Wang et al.[40] Anatomical reconstruction of MPFL is important as demonstrated that incorrect graft placement could increase medial patellofemoral contact pressures by over 50% in biomechanical research.[43] As for the primary outcome, there was no significant difference between two groups due to the possible reasons, as follows. First, no significant difference was indicated between the maximum load for the 2 techniques,[42] and they could both provide the fixation force strong enough to effectively prevent the lateral translation of the patella. Second, in addition to MPFLR, most patients also received LRR and tibial tubercle transfer in the present study, thus resulting in better restoration of anatomy and malalignment correction of patellofemoral joint. These combined procedures could all help reduce the clinical failure rate. Additionally, the AHPLT was used as the graft for MPFLR in the present study. It locates superficially in the distal leg and permits easy harvesting in 5-10 minutes with strength similar to that of the semitendinosus tendon.[44] Furthermore, the selection of AHPLT could avoid multiple incisions or a long incision around the TT when TT transfer is required. Our results suggested that DT MPFLR with AHPLT was effective and safe. Moreover, it might have some advantages in functional outcomes over ST technique and could be considered in clinical practice.

Regarding radiological outcomes, the measurements showed no significance between two groups postoperatively. Both techniques could effectively correct the patellar alignment and rotation. Li et al.[41] demonstrated similar results in comparison between ST technique and double-anchor technique, except for the patellar tilt angle. The double-anchor group showed smaller patellar tilt angle. However, in line with our results, Ercan et al.[34] demonstrated the similar outcomes in ST and DT group.

In the present study, no significant difference was found in complications between the 2 techniques. One of the major complications with the transpatellar technique was patellar fracture.[45-48] The DT technique was considered to have a greater risk than ST technique due to the additional tunnel, but both the current study and Mohammed et al.'s[49] research noted no case of such complication in both groups. Additionally, Christiansen et al.[50] noted that the transverse holes violating the anterior patellar cortex was the main reason for patellar fracture in their study. Deasey et al.[51] indicated that oblique tunnels with an anterior patellar exit was a safe technique with only 1 out of 215 knees encountering a fracture. By using shorter tunnels with smaller diameters and maintaining a sufficient bone bridge in DT reconstruction, the risk of patellar fracture could be minimized. Previous studies by Deasey et al.[51], Niu et al.[52] and Toritsuka et al.[53] also indicated that DT technique is a safe procedure of MPFLR without significantly increasing the risk of patellar fracture. Furthermore, compared with the ST technique, the DT technique still has several disadvantages due to the additional tunnel, including the risk of articular surface violation and the need for a longer graft.[51,54] The other frequently reported problems were knee stiffness and patellofemoral pain,[55,56] which also appeared in the present study. The loss of knee flexion was successfully managed with maneuver release and progressive physical therapy. The pain is usually associated with preoperative patellar or trochlear cartilage lesions, and thus occurs regardless of which technique is employed to reconstruct the MPFL.[49,57] As for the complication rates, the overall mean rate (16.7%) was mainly within the range reported by Desai et al.[11] (0%-28%) for bone socket technique. The rate of patellar fracture (0%) was the same with the most studies included in the research of Desai et al.,[11] and the overall value was reported by Kang et al.[57] (0.1%).

As for the surgical procedures, LRR and TT transfers were performed in addition to MPFLR. Whether TT transfer plays the major role in improving the outcomes remains unknown. TT transfer has been proven as an effective bony procedure to treat patients with patella alta.[58] For patients with a normal patellar height, TT transfer was usually considered with MPFLR in case of a lateral positioned tuberosity (TT-TG $>$ 15 or 20 mm), and usually provides a good outcome.[56] However, isolated MPFLR has also been reported to achieve a satisfactory result regardless of the TT-TG distance.[59,60] Additionally, Kim et al.[61] indicated that MPFLR with and without TT transfer yielded similar outcomes in patients with patellar instability with a TT-TG distance of 15 to 25 mm. The influence of TT transfer in the present study awaits investigation.

Limitations

Several limitations should be considered in the present study. First, the enrolled patients were mainly young and female. Despite its consistency with the population distribution of recurrent patellar dislocation, bias may still exist. Additionally, patients with certain abnormalities, such as patella alta, severe trochlear dysplasia, or lower limb malalignment were not included. Secondly, since LRR and TT transfers were performed in addition to MPFLR, which exact procedure had the greatest effect on improving clinical failure remains unknown. Furthermore, not all patients received a combined TT transfer, which could add heterogeneity. Third, the duration of follow-up was relatively short and potential degenerative changes, such as the development of patellofemoral osteoarthritis, were difficult to detect at 2-year follow-up, and they were not evaluated in the present study. Additionally, the present study might have been underpowered as the sample size calculation was based on a large effect size, and all the functional scores were higher for the DT group, suggesting that there might have been a beta error.

Conclusion

Both techniques could equally mitigate the patellar lateral translation or redislocation. Our results demonstrate several significant differences in functional outcomes that favored DT MPFL reconstruction but no difference in clinical failure rates and radiological results between ST and DT MPFL reconstruction.

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