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Single- and double-bundle medial patellofemoral ligament reconstruction procedures result in similar recurrent dislocation rates and improvements in knee function: a systematic review

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Abstract

Purpose To evaluate medial patellofemoral ligament (MPFL) reconstruction using hamstring tendon autografts using single-bundle (SB) and double-bundle (DB) techniques, and compare the clinical outcomes including the Kujala score, postoperative apprehension, recurrent subluxation or dislocation, and complications.

Methods The PubMed, Embase, and Cochrane Library databases were searched for relevant literature using the terms ''medial patellofemoral ligament'' and ''MPFL''. The pooled mean values of improvement in the Kujala score were calculated by random effects meta-analysis. Unweighted estimates for the rates of postoperative apprehension, recurrent subluxation or dislocation, and complications were determined by dividing the total number of occurrences by the total number of knees.

Results Thirty-one articles were included, involving 1063 patients (1116 knees). Two hundred and forty-four patients (254 knees) underwent SB reconstruction, while 819 patients (862 knees) underwent DB reconstruction. The pooled mean values of Kujala score improvement were similar in the SB group (30.1; 95% CI 26.6–33.6) and DB group (30.7; 95% CI 27.7–33.7). The SB group had a significantly greater rate of postoperative apprehension (7.9%) than the DB group (4.1%; $P = 0.014$). There were no significant differences between the two groups in the rates of recurrent subluxation or dislocation (1.2 and 1.6%) and complications (10.6 and 7.7%).

Conclusion With variability in patient populations and surgical techniques, the DB procedure for isolated MPFL reconstruction demonstrates similar outcomes to the SB technique regarding improvement of knee function, recurrent subluxation or dislocation, and complications. The SB technique may have a greater risk of postoperative apprehension, whereas the DB technique may cause more stiffness.

Level of evidence IV.

Keywords MPFL reconstruction · Medial patellofemoral ligament · Double-bundle · Single-bundle · Patellar dislocation

Introduction

Recurrent patellar dislocation is a particularly challenging clinical problem because of its multifactorial etiology. The medial patellofemoral ligament (MPFL) is regarded as the primary stabilizing soft tissue restraint to lateral patellar translation [17], providing about 50–60% of the innate medial passive resistance during early knee flexion [6, 9, 13]. The MPFL is ruptured in up to 94% of patients with acute patellar dislocation [33], and conservative treatment results in recurrent patellar dislocation due to the torn or attenuated MPFL in 44% of patients [39]. Therefore, MPFL reconstruction is an established surgical procedure for recurrent patellar dislocation, and is implemented on a large scale both in isolation and in combination with bony procedures.

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In current clinical practice, MPFL reconstruction is performed either via a single-bundle (SB) or double-bundle (DB) procedure. Gomes first reported good clinical results for MPFL reconstruction as a "single-bundle structure" to connect the patella and the medial femoral epicondyle [7]. In 2010, Kang et al. proposed the concept of "double functional bundles" based on their anatomical research [16]; the DB MPFL reconstruction has since increased in popularity due to its decreased rates of failure and complications compared with SB reconstruction [34, 38]. However, the superiority of the DB technique over the SB procedure is still debatable, and the few clinical studies published on this topic have had controversial results [2, 25, 41]. Furthermore, most studies investigating MPFL reconstruction are clinical follow-up case series with relatively small sample sizes. Therefore, there is a need for a systematic review that compares the clinical outcomes of the SB and DB techniques in isolated MPFL reconstruction for recurrent patellar dislocation.

The purpose of the current systematic review was to compare the clinical outcomes of isolated MPFL reconstruction using the SB and DB techniques, including postoperative improvements in Kujala score, postoperative apprehension, recurrent subluxation or dislocation, and complications. It was hypothesized that the two techniques would have similar outcomes.

Materials and methods

Two authors independently performed comprehensive online literature searches in the PubMed, Embase, and Cochrane Library databases on July 31, 2017 using the terms ''(medial patellofemoral ligament [Title]) OR MPFL [Title]''. The purpose was to identify publications reporting the clinical results of isolated MPFL reconstruction. Reference lists of relevant studies and review articles were also checked.

Two reviewers screened the titles and abstracts of the retrieved papers, and selected relevant studies for further thorough review on the basis of the following inclusion and exclusion criteria. The inclusion criteria were: (1) studies that reported the results of MPFL reconstruction for chronic/recurrent patellar dislocation with or without minor secondary soft tissue surgery (e.g., release of the lateral retinaculum or advancement of the vastus medialis); (2) MPFL reconstruction was performed using hamstring tendon autografts, and femoral fixation was performed using a tunnel and screw; (3) studies with a cohort of 10 or more knees; (4) minimum mean follow-up of 24 months; (5) minimum mean or median group age of 18 years; (6) articles available in English. The exclusion criteria were: (1) studies that investigated acute patellar dislocation or MPFL repair; (2) studies that described the various techniques of tendon transfer for MPFL reconstruction; (3) concomitant surgical procedure(s), including trochleoplasty, tibial tubercle osteotomy, medial patellotibial ligament reconstruction, and anterior cruciate ligament reconstruction; (4) animal or cadaveric studies; (5) case reports, abstracts, technical notes, editorials, or reviews. The literature search process is summarized in Fig. 1.

The screening process was completed by two independent reviewers. The level of evidence in accordance with the guidelines of the Centre for Evidence-Based Medicine was used to evaluate the quality of each study. The modified Coleman score was used to evaluate the methodological quality (Online Appendix 1); each study was assessed for each of the 10 criteria, resulting in a final score ranging from 0 to 100. In cases of disagreement, the two authors debated the controversial score until a consensus was reached.

The data were extracted using a predefined form, and the general characteristics, surgical techniques, and clinical results of each study were recorded. General characteristics included the name of the first author, publication year, level of evidence, sample size, and demographic factors. Surgical techniques including graft type, patellar and femoral fixation methods, and fixation angle. When the study had two separate groups that both met the inclusion criteria, these two groups were included separately in the final analysis [14, 22, 42].

To enable meaningful comparisons to be made, we broadly categorized the subjects into the SB or DB reconstruction groups in accordance with the patellar fixation configuration that was performed. SB reconstruction was defined as a MPFL reconstruction in which one limb of the graft was fixed to the patellar insertion, while DB reconstruction was defined as a MPFL reconstruction in which two limbs of the graft were attached to the patellar insertion, regardless of the fixation technique.

The primary outcome measures in the present review were the improvements in the Kujala score, and the incidences of postoperative apprehension, recurrent subluxation or dislocation, and complications. The improvement in the Kujala score was defined as the change in the Kujala score from preoperative evaluation to final follow-up. The secondary outcome analysis was the type of complications that occurred after each of the two techniques.

Statistical analysis

Pooled mean values of improvement in the Kujala score were calculated by a random-effects meta-analysis using Open-Meta Analyst (Centre for Evidence-Based Medicine). The unweighted estimates for the rates of postoperative apprehension, recurrent subluxation or dislocation, and complications were determined by dividing the raw data of the total number of occurrences by the total number of knees.

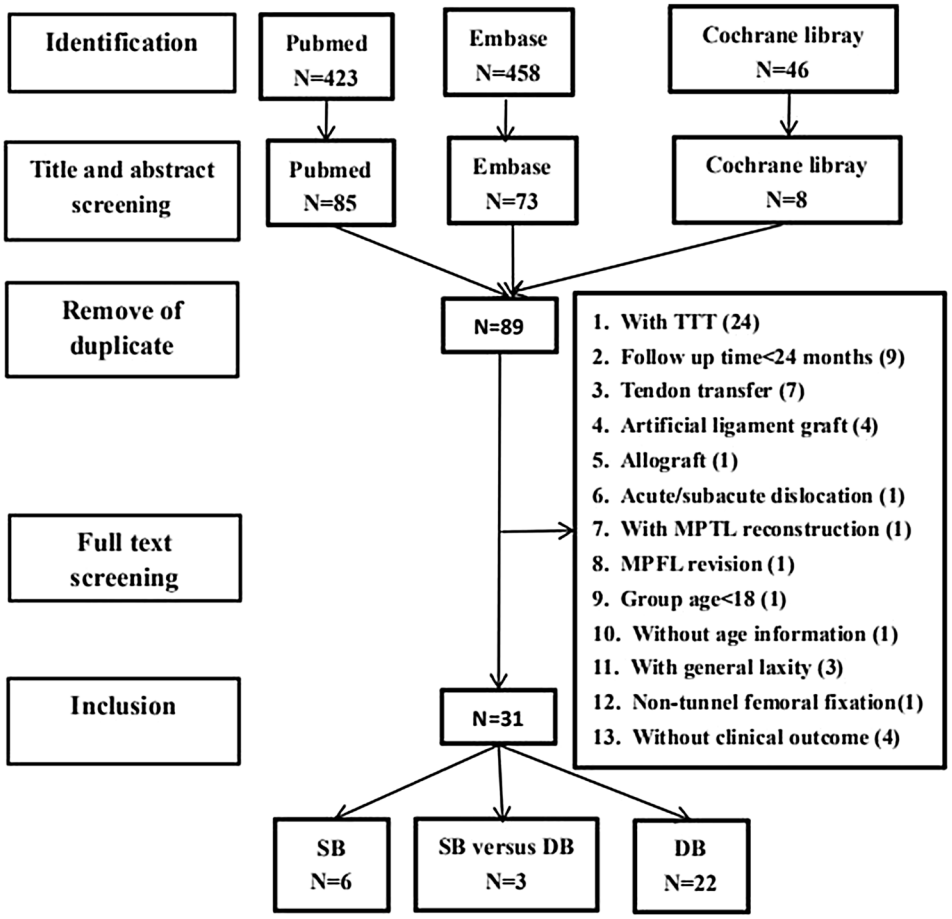

Fig. 1 Flowchart of the literature search process. *TTT* tibial tubercle transfer, *MPFL* medial patellofemoral ligament, *MPTL* medial patellotibial ligament

The categorical variables were assessed using the Pearson χ^2 test. $P < 0.05$ was considered statistically significant.

Results

The initial literature search identified 927 relevant articles. After screening of the titles and abstracts, 838 articles were excluded because they were not related to the topic of the present study. After thorough review of the full text of the remaining 89 articles, 58 articles were excluded, and 31 articles were finally included for analysis; the included articles comprised six studies that evaluated SB reconstruction, 22 studies that evaluated DB reconstruction, and three studies that directly compared the two surgical procedures [2, 25, 41]. The flow diagram of the study selection process is shown in Fig. 1. The levels of evidence assigned to the included studies were level 2 for four studies, level 3 for 10 studies, and level 4 for 17 studies. The average modified Coleman methodology score of the articles was 69.8 ± 8.0.

A total of 1063 patients (1116 knees) were included in the present review, comprising 244 patients (254 knees) who underwent SB reconstruction (Table 1), and 819 patients (862 knees) who underwent DB reconstruction (Table 2). The weighted mean age of the patients was 25.6 years, and the weighted mean duration of follow-up was 43.2 months.

The included studies evaluated a wide variety of patient populations. Surgical indications were recurrent or chronic patellar dislocation with a minimum of two [3, 19, 37] or three [29, 32] episodes of patellar dislocation, and failure of nonsurgical treatment after at least 3 [14, 25, 32] or 6 [2, 29] months of physical therapy. Specific anatomic features were assessed, such as the *Q* angle, tibial tuberosity–trochlear groove distance, trochlear angle, and Insall–Salvati index (Table 3).

In all included studies, hamstring tendon autografts were fixed into the femoral tunnel by a screw for MPFL reconstruction. However, there were great variations between studies in the patellar fixation method. In the SB group, the bone tunnel was commonly located in the upper 1/3 of the medial border, and ran in the medial–lateral [2, 8, 19, 30] or medial-anterior direction [25, 28, 42], with a graft loop with the tunnel [25, 28], or suture with the lateral retinaculum [8] or the anterior patellar aponeurosis [42], or fixation with an endobutton [2, 19]. In the DB group, two tunnels were applied in a transverse parallel [18, 32] or laterally diverging

Table 1 Studies included for single-bundle MPFL reconstruction

General information							Surgical technique				Clinical results				
Author	Year	Level of evidence	No. of patients	No. of knees	Mean age	Follow-up	Graft	Patellar fixation	Femoral fixation	Fixation angle	Mean Kujala score		Functional failure		Complications
											Pre	Post	App	Sub/Dis	
Astur [2]	2015	II	30	30	31.06	60	GR	BT	BT	30–45	N/A	82.1 ± 14.4	0	0	5
Ellera Gomes [8]	2004	IV	15	16	26.7	60	ST	BT	OT	60	N/A	N/A	1	0	1
Krishna Kumar [19]	2014	IV	30	30	18	25	GR	BT	BT	45	47.5	87.3	3	0	7
Mikashima [25]	2006	III	12	12	22.3	41.0	ST	BT	BT	45	N/A	N/A	1	0	2
Nomura [28]	2006	IV	12	12	24.8	50.4	ST	BT	SCREW	60	56.3 ± 15.6	96.0 ± 5.2	0	0	5
Pinheiro Junior [30]	2015	III	26	30	25.8	24.3	ST	BT	BT	30–45	N/A	88.37 ± 11.16	0	0	0
Wang [41]	2013	III	21	26	23	48	ST	SA	BT	30	57.35 ± 7.14	80.46 ± 3.59	7	3	1
Wang-A [42]	2010	III	28	28	29	42	ST	BT	BT	30	51.3 ± 4.5	79.9 ± 6.2	0	0	2
Wang-B [42]	2010	III	41	41	31	42	ST	BT	BT	30	53.7 ± 5.2	83.9 ± 6.5	0	0	4
Watanabe [46]	2008	III	29	29	19	51.6	HA	SU	BT	70	N/A	N/A	8	0	0

GR graciis, *ST* semitendinosus, *HA* hamstrings, *BT* bone tunnel, *SU* suture, *SA* suture anchor, *OT* osteoperistal tunnel, *N/A* not available, *Pre* preoperative, *Post* postoperative, *App* apprehension, *Sub/Dis* subluxation/dislocation

Table 2 Studies included for double-bundle MPFL reconstruction

General information							Surgical technique				Clinical results				
Author	Year	Level of evidence	No. of patients	No. of knees	Mean age	Follow-up	Graft	Patellar fixation	Femoral fixation	Fixation angle	Mean Kujala score		Functional failure		Complication
											Pre	Post	App	Sub/Dis	
Ambrozic [1]	2016	IV	29	31	26.2	76.8	GR	SA	BT	30	75 ± 10	95 ± 10	1	0	0
Astur [2]	2015	II	28	28	28.32	60	GR	SA	BT	30–45	N/A	87.0 ± 12.6	0	0	1
Becher [3]	2014	III	15	15	21.3	26	GR	SA	BT	30	N/A	82 ± 17	0	0	4
Csintalan [4]	2014	IV	49	56	24	51.6	ST	BT	BT	N/A	N/A	N/A	7	6	5
Deie [5]	2011	IV	29	31	22.2	38.4	ST	SU	BT	30	64	94.5	1	0	0
Feller [10]	2014	III	31	31	23.9	37.2	HA	BT	BT	20	N/A	N/A	0	0	0
Goncalves [11]	2011	IV	22	22	28.6	26.1	ST	BT	BT	60	59.81	83.54	0	0	0
Han [12]	2011	IV	52	59	24.3	68.4	ST	BT	BT	60	41.4	82.6	7	0	3
Kang-A [14]	2013	II	40	40	28.3	32.0	ST	SU	BT	0 and 30	53.5 ± 5.6	95.9 ± 4.7	0	0	0
Kang-B [14]	2013	II	42	42	29.4	33.9	ST	TS	BT	30	52.5 ± 5.5	91.3 ± 9.7	0	0	0
Kang [15]	2014	IV	45	45	26.6	33.7	ST	SU	BT	0 and 30	53.4 ± 5.3	90.9 ± 6.6	0	0	0
Kita [18]	2015	III	42	44	25.4	38.4	ST	BT	BT	45	66.6 ± 8.9	93.6 ± 4.4	8	2	12
Lobner [20]	2017	III	17	17	23.8	25.4	GR	TS	BT	30	N/A	84	0	1	8
Ma [21]	2013	II	32	32	28.4	40	ST	SA	BT	N/A	55	87	0	0	5
Matsushita-A [22]	2014	III	19	21	22.1	44	ST	SA	BT	20–30	75.5 ± 18.5	92.3 ± 11.7	4	1	3
Matsushita-B [22]	2014	III	15	18	23.5	38	ST	SA	BT	20–30	67.8 ± 19.0	92.1 ± 6.3	1	0	0
Matsushita [23]	2017	IV	46	54	22.8	63.6	ST	SA	BT	20–30	64.0 ± 22.1	84.9 ± 11.5	3	0	0
Matthews [24]	2010	IV	21	21	24	31	HA	TS	BT	20	N/A	87	0	0	7
Mikashima [25]	2006	III	12	12	24	41.0	ST	SU	BT	45	N/A	N/A	0	0	0
Niu [27]	2016	II	22	22	27.46	48	HA	SA	BT	30	61.73 ± 4.88	92.46 ± 2.25	0	0	0
Panni [29]	2011	IV	48	51	28	33	ST	BT	BT	20	56.7 ± 17.7	86.8 ± 14.4	0	0	11
Ronga [32]	2009	IV	28	28	32.5	37.2	GR	BT	BT	20	45 ± 17	83 ± 14	0	3	5
Song [37]	2014	IV	20	20	21	34.5	ST	SA	BT	30–45	52.6 ± 12.4	90.9 ± 4.5	0	0	0
Valkering [40]	2016	IV	31	31	23.9	37.2	GR	SA	BT	60–70	53.3 ± 19.3	80.9 ± 6.1	0	1	1
Wang [41]	2013	III	37	44	26	48	ST	SA	BT	30	61.00 ± 5.17	92.86 ± 2.47	2	0	1
Wang [43]	2016	IV	26	26	26.3	38.2	GR	SA	BT	30	53.2 ± 8.3	89.4 ± 7.6	0	0	0
Wang [44]	2012	IV	21	21	23	37.5	ST	TS	BT	45	53.9 ± 5.02	84.1 ± 3.72	1	0	0

GR graciis, *ST* semitendinosus, *HA* hamstrings, *SA* suture anchor, *BT* bone tunnel, *SU* suture, *TS* transosseous suture, *N/A* not available, *Pre* preoperative, *Post* postoperative, *App* apprehension, *Sub/Dis* subluxation/dislocation

Table 3 The exclusion criteria of bony risk factors for isolated MPFL reconstruction

Bony factor	Exclusion criteria
Q angle	Q angle greater than 20° in female and 17° in male [14, 15, 29, 43]
	Q angle greater than 20° [8, 27, 28, 32, 41, 42]
Valgus angle	Genu valgus angle greater than 7° [3, 21, 29, 32] or 10° [8]
Anterversion angle	Femoral anterversion angle greater than 35° [21]
Sulcus angle	Sulcus angle greater than 145° [14, 15, 29, 32] or 150° [21, 41, 42]
Trochlear dysplasia	Severe trochlear dysplasia (Dejour type B or C [24, 29] or D [3, 12, 29, 43])
TT–TG distance	TT–TG distance greater than 15 mm [21, 24, 27, 41, 42] or 20 mm [3, 11, 14, 15, 19, 29, 43]
Patellar dysplasia	Patellar dysplasia grade IV and V [14, 15, 29, 32, 42, 43]
Patellar alta	Insall–Salvati index greater than 1.2 [14, 15, 27–29, 32, 41–43] or C-D index greater than 1.3 [3]
Cartilage lesion	Articular cartilage defects above Outerbridge II [14, 15, 42] or III [3, 24, 27, 41, 43]

shape [12, 29], either in the medial–lateral direction [12, 18, 29, 32] or exiting anteriorly [4, 10, 11]. Patellar fixation was commonly performed using two suture anchors [1–3, 21–24, 27, 37, 40, 41, 43].

The postoperative improvement in the Kujala score in four cohorts who underwent SB MPFL reconstruction was 30.1 (95% CI 26.6–33.6), while that in 16 cohorts who underwent DB reconstruction was 30.7 (95% CI 27.7–33.7) (Fig. 2). The SB group had a significantly greater rate of postoperative apprehension (7.9%) than the DB group (4.1%) ($P = 0.014$). There were no significant differences between the two groups in the rates of recurrent subluxation or dislocation (1.2 and 1.6%, P = n.s.) and complications (10.6 and 7.7%, P = n.s.).

The overall complication rate after MPFL reconstruction was 8.3% (93/1,116). The most common complications were knee stiffness (3.0%, 33/1,116) and persistent pain (2.8%, 31/1,116). Regarding the types of complications that

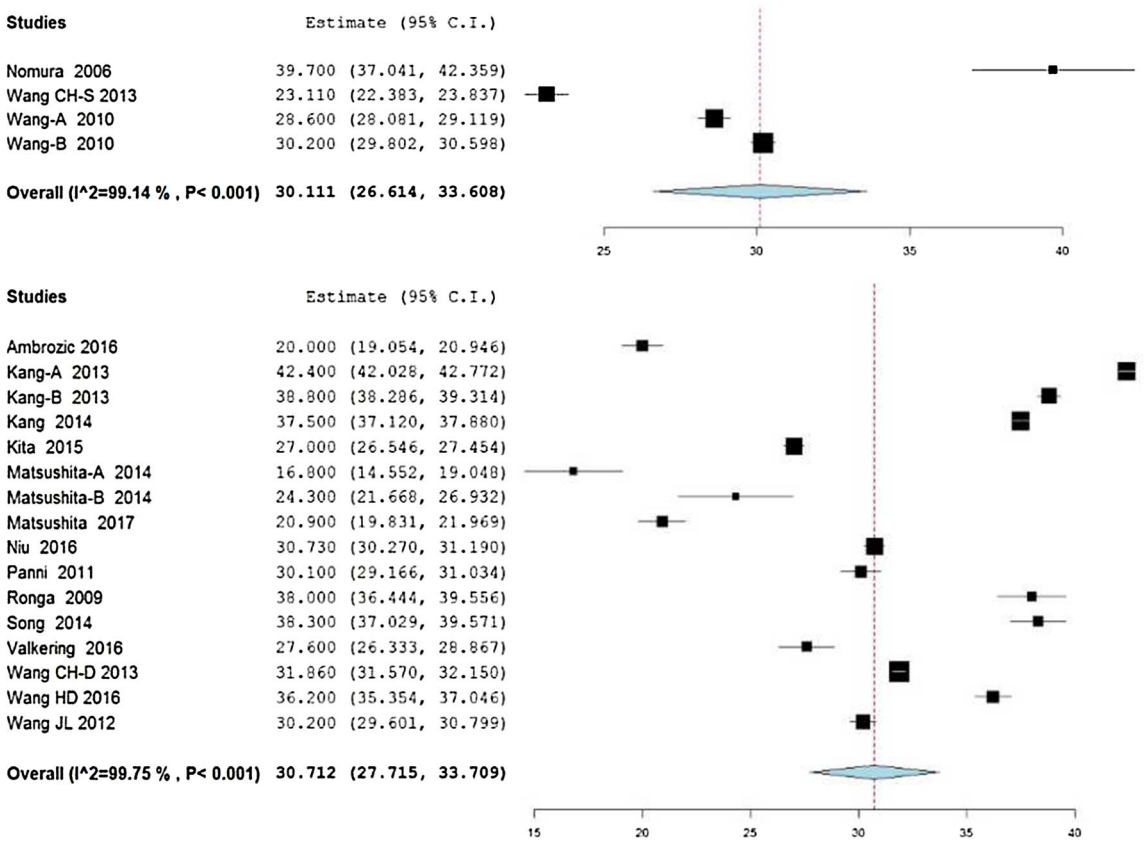

Fig. 2 The pooled mean values of improvement in the Kujala score for the single-bundle and double-bundle groups

occurred after each surgical technique, knee stiffness was the most common complication in the DB group (3.5%), while the incidence of knee stiffness in the SB group was only 1.2%. Persistent pain was the most common complication in the SB group (5.1%), and the second-most common complication in the DB group (2.1%). Patellar fracture occurred in 1.2% of patients in the SB group, and 0.5% of patients in the DB group (Table 4).

Discussion

The most important finding of the present study was that the DB procedure and the SB technique for isolated MPFL reconstruction demonstrated similar outcomes in the improvement of knee function, and the incidences of postoperative recurrent subluxation or dislocation and complications. Regarding the types of complications, the SB technique may have a greater risk of postoperative apprehension, whereas the DB technique may cause more stiffness.

Patellar stability is the main goal of MPFL reconstruction, and this was evaluated by assessing the postoperative apprehension and recurrent subluxation/dislocation rates. In the present study, apprehension included a patient-reported feeling of instability or apprehension, and the clinicians' observations of apprehension during physical examination. Our findings showed that the SB technique resulted in a significantly greater rate of postoperative apprehension than the DB technique. A previous study reported that the incidence of patellar instability was significantly greater in the SB group (26.9%) than in the DB group (4.54%) at 48 months postoperatively [41]. From a biomechanical viewpoint, the DB technique has an angular synergy effect that simulates the broad footprint of the MPFL in the patella, enabling a greater capacity to resist patellar dislocation at the early knee flexion angle [45]; moreover, the two-point fixation at the patella means that less patellar rotation and greater stability can be achieved during flexion–extension movement [12, 26, 31]. However, SB and DB grafts in MPFL reconstruction have similar degrees of stiffness and ultimate load [31], and similar strengths to restore the patellar stability [45]; hence, the rate of postoperative recurrent subluxation or dislocation was lower than 2% for both techniques, and did not significantly differ between the two groups.

The present review of subjective scores for knee function revealed that the SB group showed similar improvements in the Kujala score to the DB group. Similarly, a previous study did not show any significant difference between the SB and DB groups in postoperative Kujala, Fulkerson, and SF-36 questionnaire scores at 2–10 years postoperatively [2]. This indicates that both the SB and DB techniques result in equivalent improvement of knee function after MPFL reconstruction.

The overall complication rate for isolated MPFL reconstruction in the present study was 8.3%. In contrast, a previous study reported a much higher complication rate of 26.1% (164 complications in 629 knees) due to the complexity of additional procedures performed during MPFL reconstruction, including lateral retinacular release, retinacular plication, vastus medialis obliquus advancement, tibial tubercle transfer, and trochleoplasty [35]. The risk of complications may be mitigated by careful evaluation of patient and radiographic factors to identify optimal candidates for isolated MPFL reconstruction. The present study found no significant difference in the rate of complications after isolated MPFL reconstruction performed using the SB technique versus the DB technique.

Although there was no difference between the two groups in the overall rate of complications, the most common type of complication differed in accordance with the type of MPFL reconstruction procedure. Postoperative stiffness was the most frequent complication in the DB group (3.5%), while it only occurred in 1.2% of patients in the SB group. Similarly, a previous systematic review reported that

Table 4 Complication profile in SB versus DB MPFL reconstruction

	Single-bundle	Double-bundle
Rate of complication	10.6% (27/254)	7.7% (66/862)
Complication in detail	13 Persistent pain	30 Stiffness
	3 Stiffness	18 Persistent pain
	3 Patellar fracture	4 Patellar fracture
	3 Extensor lag or weakness	3 Extensor lag or weakness
	3 Painful hardware	3 Superficial infection
	1 Superficial infection	2 Painful hardware
	1 Dissatisfied outcome	2 Persistent swelling
		1 Deep infection
		1 Neuroma
		1 Hypoesthesia
		1 Severe crepitation

the most frequent complication after MPFL reconstruction apart from recurrent apprehension is the loss of knee flexion [35]. Furthermore, Singhal et al. [36] reported an overall complications rate of 12.5%, with knee stiffness being the most common complication in those who underwent DB MPFL reconstruction with patellar fixation via mediolateral patellar tunnels. A biomechanical study has shown that the DB technique has an angular synergy effect that results in a greater capacity to resist patellar dislocation and cause more restraints to the normal mobility of the patella than the SB technique [45], which explains the increased stiffness after DB compared with SB MPFL reconstruction. The most common complication in the SB group was persistent pain, which was also commonly reported in the DB group. This pain is associated with preoperative cartilage lesions of the patella or trochlea in those with recurrent patellar dislocation, and hence this occurs irrespective of whether the MPFL reconstruction is done via the SB or the DB technique.

The present study has some limitations. The main limitation is the variability among studies in terms of the patient populations and surgical techniques. Although all patients in included studies underwent isolated MPFL reconstruction without any additional bony procedures (such as tibial tubercle transfer and trochleoplasty), there was no exclusion of subjects with bony risk factors such as an increased tibial tuberosity–trochlear groove distance, trochlear dysplasia, and patellar alta. Furthermore, although the included studies all used hamstring tendon autografts, there were still many variations in fixation method, fixation angle, and graft tension, apart from the differences in the SB and DB configurations. Additionally, most included studies were case series with relatively small sample sizes; further high-quality studies are needed to confirm our results.

To date, it remains unclear whether the DB technique is superior to the SB technique in MPFL reconstruction. The present study revealed that these two techniques had similar rates of recurrent patellar subluxation or dislocation and similar degrees of knee function improvement. The two techniques also had similar overall complication rates; however, the SB technique had a significantly greater incidence of postoperative apprehension, whereas the DB technique caused more stiffness. These factors should be considered when selecting the SB or DB procedure for isolated MPFL reconstruction in clinical practice.

Conclusions

With variability between included studies in patient populations and surgical techniques, the DB procedure for isolated MPFL reconstruction demonstrated similar outcomes to the SB technique in the improvement of knee function, postoperative recurrent subluxation or dislocation, and complications. The SB technique may have a greater risk of postoperative apprehension, as this technique cannot restore the broad patellar footprint; whereas the DB technique may cause more stiffness due to its angular synergy effect to resist patellar dislocation. These factors should be considered when selecting a SB or DB procedure for isolated MPFL reconstruction.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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