

# The horizontal Y-shaped graft with respective graft tension angles in anatomical two-bundle medial patellofemoral ligament reconstruction

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Received: 8 December 2013 / Accepted: 9 April 2014 / Published online: 24 April 2014  
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## Abstract

**Purpose** Various techniques for medial patellofemoral ligament (MPFL) reconstruction have been described with two bundles of graft tensioned simultaneously. The present study was to introduce an anatomical reconstruction procedure using a horizontal Y-shaped graft with respective graft tension angles and report the preliminary results.

**Methods** A surgical technique for MPFL reconstruction using a horizontal Y-shaped semitendinosus tendon autograft with two bundles tensioned at 0° and 30° of knee flexion was described in detail. The patellar stability was evaluated with the apprehension test and an axial computed tomography (CT) scan at 30° of knee flexion. The knee function was evaluated using the Lysholm and Kujala scores.

**Results** No recurrent dislocation or subluxation was reported for 45 patients at a mean of 33.7-month follow-up. On CT images, congruence angle, patellar tilt angle, lateral patellar angle and lateral displacement were restored to the normal range. At the last follow-up, the mean Lysholm score improved from  $51.8 \pm 6.2$  to  $91.7 \pm 4.1$  and mean Kujala score was from  $53.4 \pm 5.3$  to  $90.9 \pm 6.6$  ( $P < 0.01$ ).

**Conclusions** The present anatomical MPFL reconstruction technique with a horizontal Y-shaped two-bundle graft tensioned at respective knee flexion angles could not only recreate the fan-shape of MPFL but also mimic the function bundles of native ligament. Clinical follow-up

confirms the good restoration of the patellar stability and significant improvement of knee function without special complications.

**Level of evidence** Therapeutic, Level IV.

**Keywords** Medial patellofemoral ligament · Anatomical reconstruction · Double-bundle · Recurrent patellar dislocation

## Introduction

Over the last decades, interest in the passive soft tissue restraints of the knee to patellar stability has resulted in consensus on the reconstruction of medial patellofemoral ligament (MPFL), which provides 57–63 % of the medial soft tissue restraints, to treat recurrent patellar dislocation or instability [11, 20].

Various techniques for MPFL reconstruction have been described, including tendon transfers [3, 6, 22] and ligament reconstruction with free tendon grafts [12, 15, 18, 19]. However, the graft tension angle remains controversial. Different knee flexion angles have been described in previous techniques such as 20°, 30°, 45°, 60° and 70° and so on [2, 4, 9, 10, 15, 21].

In recent anatomical studies, two functional bundles of the MPFL have been demonstrated that the superior-oblique bundle serves as dynamic maintenance of patella stability combined with the vastus medialis obliquus (VMO), and the inferior-straight bundle acts as main static soft tissue restraints [1, 8]. In traditional two-bundle reconstructions, the fan-shaped morphology of the MPFL could be recreated. However, the functional bundles would not be differentiated with two bundles of graft fixed at a certain angle of knee flexion simultaneously.

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Therefore, an anatomical two-bundle MPFL reconstruction technique using a horizontal Y-shaped graft with respective graft tension angles was developed to mimic the function bundles of native ligament. The purpose of the present study was to describe our new technique and present its preliminary results. The hypothesis was that our new technique would achieve the good restoration of patellar stability and significant improvement of knee function.

## Materials and methods

The symptomatic recurrent patellar dislocation or instability is defined as the condition where patellar dislocation has occurred at least twice, or patellar instability following initial dislocation had persisted for more than three months after the conservative treatment.

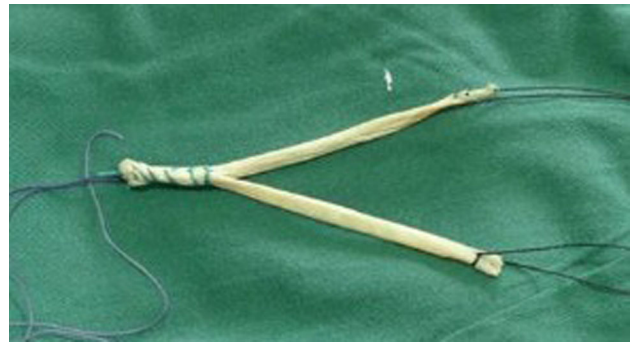
Based on medical history, physical examination, radiographs, computed tomography (CT), magnetic resonance imaging (MRI) scans, the exclusion criteria were as follows: (1) previous surgery on the injured knee, (2) a Q-angle  $>20^\circ$  in female patients and  $>17^\circ$  in males, (3) the trochlear angle  $>145^\circ$ , (4) the tibial tuberosity to trochlear groove (TT–TG) distance  $>20$  mm, (5) patella alta (Insall–Salvati index  $>1.2$ ), (6) patellar dysplasia grade IV and V according to the Wiberg classification, (7) articular cartilage erosion of severer than grade II, according to the Outerbridge classification and (8) meniscal- or tibial-femoral ligament injury requiring repair or reconstruction.

The study was approved by the Institutional Review Board of Shijiazhuang No. 1 Hospital, and all patients provided written informed consent. From June 2009 to June 2011, total 60 patients of symptomatic patellar dislocation or instability were underwent MPFL reconstruction with the present technique.

### Surgical technique

The patient was operated under spinal anaesthesia in a supine position. Physical examination under anaesthesia was performed to evaluate the degree of instability. Arthroscopy was first carried out to evaluate patellar trajectory and address any possible chondral lesions and concomitant injuries. The semitendinosus tendon was harvested through a 2- to 3-cm vertical incision over the pes anserinus. The tendon was folded from the middle point and sutured using the whip-stitch technique with No. 2 nonresorbable suture about 25 mm in length. The graft was prepared to be horizontal Y-shape (Fig. 1).

For an anatomical femoral insertion of the graft, the medial epicondyle and adductor tubercle were palpated. A 1-cm longitudinal incision was made in this area, and a



**Fig. 1** The horizontal Y-shaped two-bundle graft

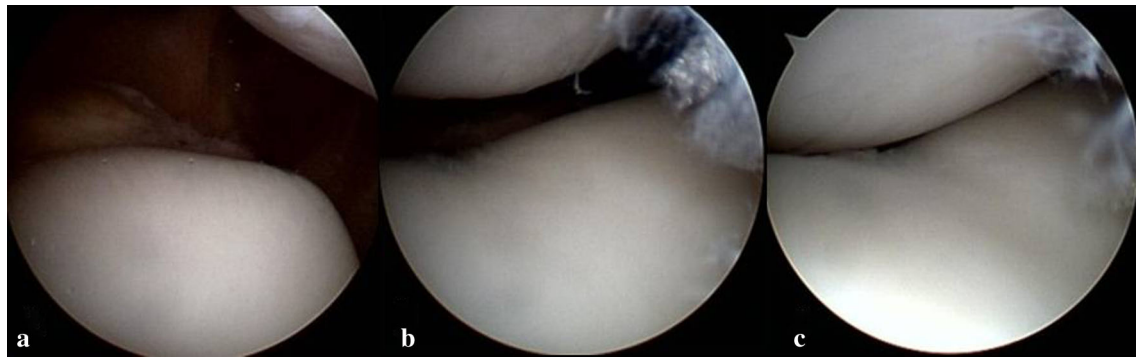
2-mm guide pin with an eyelet was placed slightly posterior to the mid-point of these two points [13]. A 7-mm bone tunnel was made with a guide drill along the guide pin to a depth of 25 mm. The folded end of graft was guided through the femoral tunnel and fixed with an interference screw.

Then, a 3 cm incision was made along the proximal medial border of the patella. Blunt dissection was carried out to create a soft tissue tunnel from the medial patellar border to the medial epicondyle, deep to the medial retinaculum but superficial to the synovium, and the two free ends were passed through the soft tissue tunnel to the medial patellar edge.

The inferior bundle graft was sutured to the mid-point of the medial patellar margin with the knee at complete extension firstly. The graft was inserted beneath the peripatellar retinaculum and out from the midline of the prepatellar fascia, and then sutured back to top of the graft with the whip-suture. Then, the superior bundle was fixed to the superior-medial corner at  $30^\circ$  of knee flexion since biomechanical studies have shown that the MPFL has its maximal restraint against patella lateralisation at  $30^\circ$  of knee flexion [1]. The patellar tracking was monitored under the arthroscopy (Fig. 2). In addition, the lower border of VMO was advanced 5–10 mm distally and laterally and sutured on the superior bundle graft about 20 mm in length (Fig. 3).

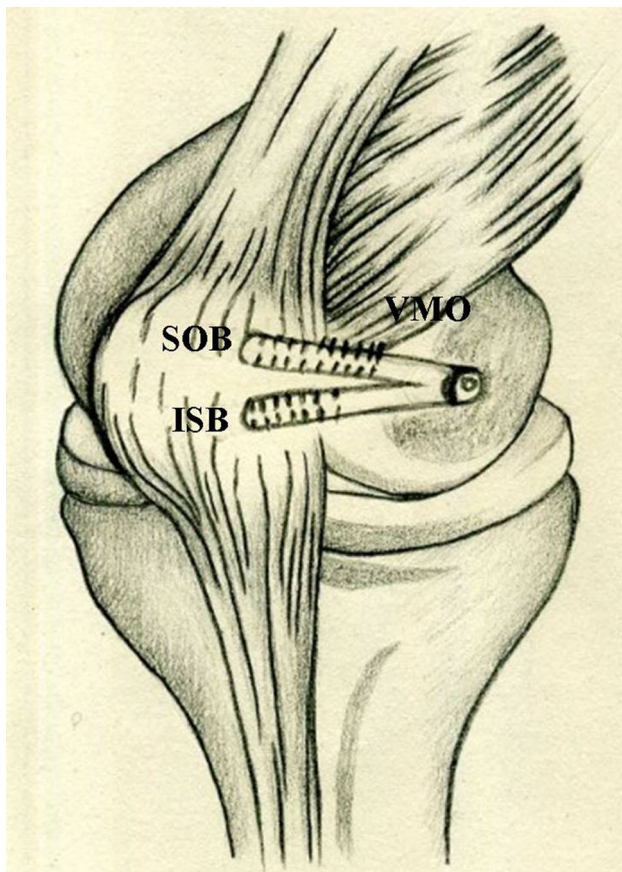
### Post-operative rehabilitation

Post-operative rehabilitation involved partial weight bearing permitted and gradually progressed on an as-tolerated basis in extension with a simple knee brace for 6 weeks. Range-of-motion exercise was not restricted. Functional activities including walking and running were allowed at 3 months, and normal sports activities were allowed at 6 months. During the follow-up, patellar stability was evaluated with the apprehension test and an axial CT scan at  $30^\circ$  of knee flexion [7]. The knee function was evaluated using the Lysholm and Kujala scores.



**Fig. 2** Arthroscopic patellar trajectory. **a** Patellar dislocation pre-operatively; **b** good congruence of patellofemoral joint when the inferior bundle graft was fixed with the knee at complete extension;

**c** patella was stabilised into the femoral groove with the superior bundle fixed at 30° of knee flexion



**Fig. 3** Illustration of anatomical MPFL reconstruction with a horizontal Y-shaped two-bundle graft. *SOB* the superior-oblique bundle of the graft, *ISB* the inferior-straight bundle of the graft, *VMO* the vastus medialis obliquus

#### Statistical analysis

The statistical analysis was conducted with SPSS 13.0 software (SPSS Inc., Chicago, IL, USA). The CT measurements and knee function scores were presented with

**Table 1** Patient characteristics

Demographic data	
<i>N</i> (patients)	45
Gender (F/M)	27/18
Side (L/R)	25/20
Age at operation in years	26.6 ± 5.8
Follow-up periods in months	33.7 ± 8.4
Q-angle (°)	13.4 ± 2.6
Insall–Salvati ratio	1.0 ± 0.1
Sulcus angle (°)	134.3 ± 5.7
TT–TG distance (mm)	14.4 ± 1.9

the mean (SD). The Kolmogorov–Smirnov test was used to test the normality of the variances. The *t* test was used for the parametric variances and the Mann–Whitney *U* test for nonparametric variances. Significance was set at  $P \leq 0.05$ .

#### Results

Among 60 patients, nine patients were excluded from the study for previous surgery on the injured knee (2 cases), the trochlear angle  $>145^\circ$  (2 cases), the TT–TG distance  $>20$  mm (3 cases) and articular cartilage erosion of grade IV (2 cases). Forty-five patients with a mean of 33.7-month follow-up were reported in the present study. The patient demographics and characteristics were shown in Table 1. There was no infection, chronic effusion or synovitis, patellar fracture and deep vein thrombosis reported at the time of follow-up. At the last follow-up, all patients restored full range of motion.

Immediately after operation, CT measurements of the congruence angle, lateral patellar angle, patellar tilt angle and lateral displacement significantly were restored to the normal range. At 24-month follow-up, the patella was

displaced and tilted laterally. However, significant improvement was still between pre-operative results and 24-month follow-up (Table 2).

Pre-operative lateral patellar apprehension was positive in all patients, whereas none remained apprehensive after surgery and at the last follow-up. No patients suffered from patellar redislocation or subluxation. The Lysholm score improved significantly from  $51.8 \pm 6.2$  to  $91.7 \pm 4.1$ , and the Kujala score improved significantly from  $53.4 \pm 5.3$  to  $90.9 \pm 6.6$ .

## Discussion

The most important finding of the present study is that anatomical two-bundle MPFL reconstruction with a horizontal Y-shaped semitendinosus autograft tensioned at different knee flexion angles, which can not only recreate the fan-shape of MPFL but also mimic function bundles of the native ligament, is an effective and safe technique to treat patients with symptomatic patellar instability.

In the lecture, many surgical techniques have been published for the MPFL reconstruction, but the graft tension angle during surgery remains controversial. The MPFL has been the primary soft tissue restraint against lateral patellar translation. The restraining force was associated with the knee flexion angle, 53 % of the total force in full extension, 60 % at 20°, and 50 % at 30° of knee flexion [27]. So the patella has the lowest ability to resist lateral force at 20–30° of knee flexion, which is the usual knee flexion angle where patella dislocates clinically. Recently, Yoo et al. [28] demonstrated that the best angle for graft fixation would be near 30° of knee flexion in the MPFL reconstruction based on the high-resolution CT analysis.

For native broad patellar attachment of the MPFL, the two-bundle procedure was considered to be the anatomical reconstruction. However, all the surgical fashion was that the two bundles of graft were fixed at the patellar insertion

firstly and then tensioned simultaneously by femoral fixation with knee flexion at a certain angle in the lecture. To some extent, these procedures could be interpreted as a single-bundle reconstruction with a wider graft. The fan-shaped morphology of MPFL would be recreated. However, the functional bundles can not be differentiated. Single-bundle reconstruction did not restore normal patellar tracking at any flexion angle [16]. Therefore, we introduced present anatomical procedure with two graft tension angles to mimic the double function bundles of the native ligament and reached the real anatomical reconstruction.

The anatomy is one of the major keys to the success of MPFL reconstruction. Recent anatomical studies have demonstrated two functional bands of MPFL: inferior-straight bundle and superior-oblique bundle, with different function to control the normal patellar tracking [1, 8]. From the anatomical view, the inferior-straight bundle was fixed at 0° of knee flexion to maintain the static restraints and the superior-oblique bundle was fixed at 30° of knee flexion with the VMO advancement to dynamic the restraints.

The isometry was also considered in the MPFL reconstruction. Some authors reported the most isometric portion was from the inferior patellar insertion to the superior femoral origin with an average change of 1.1 mm in length [23], whereas others discovered that the superior bundle of MPFL exhibited isometric behaviour and the inferior bundle slackened in flexion [14]. Therefore, the whole native MPFL is non isometric. For a reconstructed MPFL, the length change pattern depends critically on the femoral tunnel site. Thauat describes a technique that positioning the femoral insertion distally to its supposed anatomic position allows a decreasing length of the graft as the knee flexes resulting in a favourable anisometry [25]. With two bundles of graft fixed separately, the present technique can mimic the function bundles of the native ligament and complete the non isometric behaviour of the MPFL.

Comparing MPFL intact and resected patella kinematics, a biomechanical study has revealed statistical lateral translation in early flexion, with a significant effect of flexion angle at 0°, 10° and 30°, and significantly reduced medial joint contact pressure but increased lateral contact pressure, with the strongest effect near knee extension [24]. Therefore, patellar stability at 0° and 30° of knee flexion was required to be considered simultaneously in the MPFL reconstruction.

Various techniques for MPFL reconstruction have been described, and to date, no technique is considered to represent the ‘gold standard’. Besides the surgical details in graft choice, femoral tunnel position and patellar fixation method [5], the knee flexion angle for the graft tension has been one of the most important controversial issues. Some

**Table 2** Patellofemoral morphology on CT measurements

	Pre-operative	Post-operative	24-month follow-up	<i>P</i> value
Congruence angle (°)	$20.0 \pm 7.1$	$-9.0 \pm 5.9$	$-5.2 \pm 5.1$	<0.01
Patellar tilt angle (°)	$24.7 \pm 6.0$	$10.2 \pm 4.0$	$14.4 \pm 4.5$	<0.01
Lateral patellar angle (°)	$-7.5 \pm 5.4$	$8.0 \pm 3.0$	$5.3 \pm 2.6$	<0.01
Lateral patellar displacement (mm)	$13.8 \pm 6.2$	$-4.2 \pm 3.5$	$2.5 \pm 1.4$	<0.01



**Table 3** Summaries of the MPFL reconstruction outcomes in order of the graft tension angle

Trial	Surgical procedure(s)			No. Patients/ knees	Follow-up (Range if available)	Post-operative outcome	Subjective outcomes
	Tension angle	Graft type	Patellar fixation				
Ronga et al. [17]	20	Hamstring	2 transverse parallel tunnels	Interference screw	28	3.1 (2.5–4) years	3 with a new dislocation Cincinnati score: 52–89
Matthews and Schranz [10]	20	Hamstring	'Banana shaped' longitudinal tunnel	Interference screw	21	31 (3–87) months	No Kujala score: 45–83 Kujala score: ?–87 Tegner activity score: 3–4.4
Panni et al. [15]	20	Semitendinosus	Divergent 2-tunnel	Interference screw	45/48	33 (24–54) months	No Kujala score: 56.7–86.8 Larsen score: 12.4–17.1 Lysholm score: 57.6–88.1 Fulkerson score: 59.2–90.1 Kujala score: 64–94.5
Deie et al. [2]	30	Semitendinosus	Sutured at the patellar medial ridge and periosteum	Bone plug	29/31	3.2 (2–45) years	No Kujala score: ?–96
Toritsuka et al. [26]	45	Semitendinosus	2 patellar tunnels fixed with endo-button	Endo-button	20	30 months	No
Kita et al. [9]	45	Semitendinosus	2 patellar tunnels fixed with endo-button	Endo-button	24/25	13.2 (6–26) months	3 with positive apprehension without dislocation Kujala score: 73–95
Han et al. [4]	60	Hamstring	2 transverse parallel tunnels	Interference screw	52	5.7 (3.1–7.1) years	6 with an occasional unstable feeling without redislocation Kujala score: 41.4–82.6 Cincinnati scores: 50.6–88.7
Smith [21]	70	Hamstring	2 parallel tunnels	Interference screw	30	12 months	No Kujala score: 65.3–85.1 IKDC: 52.3–77.7 Lysholm score: 70–92
Watanane [27]	70	Hamstring	Sutured beneath the prepatellar fascia	Endo button	29	4.3 (1.5–8.1) years	No
Present study	0 and 30	Semitendinosus	Sutured beneath the prepatellar fascia	Interference screw	45	33.7 (24–50) months	No Lysholm score: 51.8–91.7 Kujala score: 53.4–90.9

authors chose to tension the ligament at 20° of flexion where the greatest length of MPFL is required to avoid over-tensioning [10, 15, 17], and 30° of flexion with the patella centred within the trochlea to avoid inadvertent medial subluxation [2]. Forty-five degree of knee flexion was recommended to be a suitable angle because the patellae locate on the femoral groove and are stabilised [9, 26]. As the MPFL generally becomes lax with knee flexion, the 60° and 70°, where the patella is more fully captured by the trochlea were also present in literature [4, 21, 27]. The clinical results of MPFL reconstruction were summarised in order of the graft tension angle in Table 3. All of the lectures were with a traditional single tension angle, which were comparable to the present technique in the redislocations rate and subjective outcomes.

To date, there is no clinical or biomechanical evidence that the two graft tension angle technique is superior to a traditional single tension angle technique. However, due to more close restoration of the anatomical and biomechanical properties of functional bundles of the MPFL, dynamic patellar kinematics with higher stability and better matching in the patellofemoral joint during flexion-extension movement could be restored. The academic superiority and encouraging results confirm the application of present technique in the day-by-day clinical work.

The present study has some limitations. First, it is only a clinical follow-up, and biomechanical analysis of the lateral shift and contact pressure in the patellofemoral joint after the two tension angle technique is needed to reveal the patellar tracking. Second, it is only a retrospective case series without a control group, and a prospective, randomised design may be better to show its effectiveness and superiority.

## Conclusions

The present study describes an anatomical MPFL reconstruction technique with a horizontal Y-shaped two-bundle graft tensioned at respective knee flexion angles, not only to recreate the fan-shape of the MPFL but also mimic the function bundles of the native ligament. The inferior bundle graft was fixed at 0° of knee flexion to maintain the static restraints, and the superior bundle was at 30° of knee flexion with the VMO advancement to dynamic its restraints. Clinical follow-up confirmed good restoration of patellar stability and significant improvement of knee function without special complications.

**Conflict of interest** All authors have read and contributed to the submitted manuscript and there is no conflict of interest among the authors.

**Ethical standards** This material has not been published and is not under consideration elsewhere. This study receives no financial support.

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