



The modified semi-tunnel bone bridge technique achieved statistically better knee function than the suture anchor technique

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Abstract

Purpose The purpose of this study was to evaluate and compare the clinical outcomes of two different fixation techniques for anatomic medial patellofemoral ligament (MPFL) reconstruction.

Methods A retrospective study was undertaken between 2012 and 2018 of 60 cases of patellar dislocation who underwent surgical reconstruction between 2007 and 2010: 30 patients were treated with modified semi-tunnel bone bridge fixation (group A) and 30 patients with suture anchor fixation (group B). All patients had computed tomography scans available to review the patellar tilt angle and lateral patellar angle (LPA). In addition, a physical examination was performed, and the patellar apprehension sign and patellar stability were evaluated. Knee function was also evaluated using the Kujala score and Lysholm score.

Results At a minimum 5-year follow-up, the patellar tilt angle and LPA were restored to the normal range, and a significant difference was observed between the groups. There was a significant improvement in knee function in the Kujala and Lysholm scores after surgery in both groups. At the final follow-up, the mean Kujala and Lysholm scores in groups A and B were significantly different.

Conclusion Both the semi-tunnel bone bridge and suture anchor fixation for double-bundle anatomic reconstruction of the MPFL can effectively restore patellar stability and improve knee function. The semi-tunnel bone bridge technique achieved statistically better knee function than the suture anchor technique at a minimum 5-year follow-up.

Level of evidence III.

Keywords Patellar dislocation · Semi-tunnel bone bridge fixation · Suture anchor fixation · Medial patellofemoral ligament · Anatomic reconstruction

Introduction

The patellofemoral (PF) joint is considered one of the most complex joints in the human body from a biomechanical perspective owing to its unique bony anatomy and the numerous capsuloligamentous structures and muscles that act statically and dynamically on the patella [30]. In recent years, reconstruction of the medial patellofemoral ligament (MPFL) has become increasingly popular because it is the main passive restraint to lateral patellar translation at 0°–30° of knee flexion and contributes about 53–60% of the total medial restraining force as a distinct restraining structure in the second layer of the medial soft tissues [2, 4, 29]. Various techniques for reconstruction of the MPFL have been reported to treat recurrent patellar instability.

The MPFL is a condensation of capsular fibres, and originates at the medial femoral condyle. It runs transversely

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and inserts on the medial edge of the patella [19, 20, 26]. The latest anatomic studies have confirmed that from the femoral origination point, fibres of the MPFL form two relatively concentrated fibre bundles: the inferior-straight bundle, which is the main static soft tissue restraint, and the superior-oblique bundle, which is associated with the vastus medialis obliquus (VMO) and serves as the main dynamic soft tissue restraint [10]. Clinically, to restore the fan-shaped insertion of the MPFL, multiple double-bundle reconstruction procedures have been described. The patellar graft fixation is a key procedure during MPFL reconstruction. There are various methods for patellar graft fixation, such as bone tunnels [16, 20] and suture anchors [23, 25]. However, these methods have some disadvantages, as patellar fractures through the bone tunnel have been reported by several authors, especially when drilling the transverse tunnel through the patella [1, 5, 13]. Although the suture anchor technique can lead to good clinical outcomes, a biomechanical study showed that the strength of the MPFL following suture or suture anchor fixation is obviously weaker than the native MPFL [22].

Based on our clinical experience, the tunnel technique was modified, which is easy to perform and led to no patellar fractures at short-term follow-up [8]. The purpose of this study was to report and compare clinical outcomes of the modified semi-tunnel bone bridge and suture anchor techniques at a minimum 5-year follow-up. The hypothesis was that the semi-tunnel bone bridge technique will achieve statistically better knee function than the suture anchor technique at a minimum 5-year follow-up.

Materials and methods

All of the methods herein described were approved by the local ethics committee, and all patients provided their informed consent to be included in the study. From 2007 to 2010, 68 patients with symptomatic chronic patellar dislocations were operated on using one of these two techniques. The exclusion criteria were as follows: (1) Q angle greater than 20° with previous surgery on the injured knee, (2) trochlear angle greater than 145° and patellar dysplasia grades IV and V according to the Wiberg classification [17], (3) tibial tuberosity–trochlear groove (TT–TG) distance > 20 mm, (4) patella alta (Insall–Salvati index > 1.2), (5) articular cartilage erosion more severe than grade II on the outerbridge classification, (6) a meniscal or tibiofemoral ligament injury requiring repair or reconstruction, and (7) previous surgery on the injured knee. According to the exclusion criteria, eight patients were excluded from the study; two patients had a Q angle greater than 20° , one patient had medial collateral ligament injury that was treated operatively, three patients had a TT–TG distance greater

than 20 mm, and two patients had patella alta. All patients suffered trochlear dysplasia (Dejour II, III), however, there is no difference between the two groups. Finally, there were 30 patients in the modified semi-tunnel bone bridge fixation group (group A) and 30 patients in the suture anchor fixation group (group B) (Table 1). The patient demographic characteristics are displayed in Table 1, with no statistical difference between the two groups.

All patients had symptomatic chronic patellar dislocation, which was defined by Nomura [15]. All patients underwent the patellar apprehension test [9]; with the knee in 30° of flexion with the quadriceps relaxed, a direct lateral force was placed on the patella, lateral translation grade was determined (translation to one-fourth, one-half, three-fourths, and one of the patellar width was documented as grade I, II, III, and IV, respectively; lateral translation greater than the whole patellar width was documented as grade V; lateral translation grade greater than III was considered abnormal), and the senior author evaluated the soft versus firm end points to lateral patellar translation. Radiographs and computed tomography (CT) scans were performed in all patients. The patellar height was evaluated on radiographs according to the Insall–Salvati index [7]. The patellar tilt angle (PTA) and the lateral patellar angle (LPA) were evaluated on CT scans.

Our measurement methods had an accuracy of 0.1 mm and 0.1° . All measurements were taken by one blinded observer. To determine test–retest reliability, 30 knees were randomly selected from both the groups ($n = 60$). This group measured patellar tilt angle by the same examiner with an interval of 2 weeks between measurements. The study was approved by the Medical Ethical Committee of the Third Hospital of Hebei Medical University (Ke-2011-K-086).

Surgical technique

All surgeries were performed by the same senior surgeon. The patient was examined under anaesthesia to confirm the diagnosis of a lateral patellar dislocation according to the quadripartite method. Arthroscopic surgery was first carried out to assess and address any possible chondral lesions and concomitant pathology. Arthroscopic lateral retinacular release (LRR) was performed to decrease the tensile strength of the lateral retinaculum where there was a medial shift

Table 1 Patients' characteristics

	Group A	Group B	<i>p</i> value
Sex (M/F)	12/18	10/20	n.s
Side (L/R)	16/14	13/17	n.s
Age (years)	23.4 ± 3.6	23.3 ± 3.8	n.s

of the patella less than one-fourth the width of the patella, which indicated excessive tension of the lateral retinaculum.

The semitendinosus tendon autograft was harvested using a closed-end tendon stripper (the length of the graft was about 20 cm), and then the graft was shaped to a “Y”. The folded end was whipstitched about 2.5 cm with No. 1 Ethicon non-absorbable suture. A No. 2 absorbable suture was used to pull the folded end into the femoral tunnel. The two free ends were not disposed temporarily.

We made two incisions (a 4-cm longitudinal incision along the proximal medial border of the patella, and a 2-cm incision above the MPFL femoral insertion). The femoral origin of the MPFL resided in the saddle between the adductor tubercle and the medial epicondyle [28, 29]. A 7-mm reamer was used to drill a tunnel over the guide pin to a depth of 25 mm, and the folded end of the graft was fixed with an interference screw. The patellar fixation was performed separately as follows:

In group A, a 2.4-mm guide pin with an eyelet was transversely inserted from the medial edge of the patella to the lateral border and a 4.5-mm cannulated reamer was used to drill a tunnel over the guide pin to a depth of 20 mm. A No. 10 non-absorbable suture was then pulled out through the patellar tunnel by the guide pin. The 2.4-mm guide pin was inserted into the superomedial corner of the patellar border with a patellar longitudinal axis at a 60° angle and drilled to the lateral edge, and a 4.5-mm cannulated reamer was used to drill a tunnel over the guide pin to a depth of 20 mm. For the inferior bundle, a No. 10 non-absorbable suture was pulled out through the patellar tunnel by the guide pin. For fitting in the patellar tunnel, both free ends were folded about 20 mm and were sutured with No. 1 Ethicon non-absorbable suture. Two No. 2 Fiberwire non-absorbable sutures were used to pull the two free ends into the patellar tunnels and tied together for fixation. No. 10 non-absorbable suture was used to pull the No. 2 Fiberwire non-absorbable suture through the transverse tunnel and clamped the suture temporarily. The graft tension and patellar tracking were evaluated by arthroscopy with the knee flexed at 0°–60°.

We were able to adjust the tension and patellar tracking by changing the folded ends. For the superior bundle, the procedures were performed the same way. Finally, the two No. 2 Fiberwire sutures over the lateral bone bridge were fastened for fixation whilst tensing the free ends of the graft and the vastus medialis obliquus was sutured to the superior bundle at about 30° of knee flexion (Fig. 1).

In group B, two points were chose at the medial edge of the patella, the centre and the superomedial corner. Then two suture anchors [3.5-mm titanium suture anchors (TwinFix; Smith & Nephew, Andover, MA, USA)] were inserted into the patella. The two free ends were passed through the soft tissue tunnel to the medial patellar edge. The graft tension was adjusted before fixation. The inferior bundle was sutured first in the centre of the patellar medial edge, and then the superior bundle was fixed to the superomedial corner with the knee flexed at about 30°. Finally, the vastus medialis obliquus was sutured to the superior bundle of the MPFL at about 30° of knee flexion (Fig. 2).

Post-operative rehabilitation and assessment

After MPFL reconstruction, all patients followed the same rehabilitation protocol. We encouraged patients to perform quadriceps setting and straight leg raise exercises to strengthen the muscle starting the day after surgery. Walking with partial weight bearing was permitted on two crutches and activities involving knee flexion were also encouraged and gradually progressed as tolerated. After 2 days, all of the patients started knee flexion exercises, and within 4 weeks flexion gradually increased to 90°. After 3 months, they could return to normal functional activities such as walking, running, and jogging. After 6 months, the patients resumed normal sports activities.

The mean follow-up period was 86 months (60–95 months). The apprehension test was evaluated and patients were divided into three groups based on this: stable, subluxated, and re-dislocated. The lateral translation grade was divided into four grades (grades I and II with a hard

Fig. 1 The modified semi-tunnel bone bridge fixation

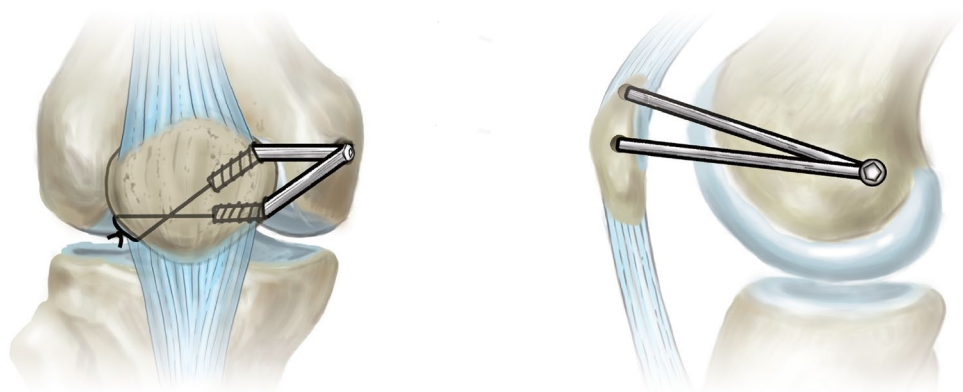


Fig. 2 The suture anchors fixation

end point were considered stable, grade III with a hard end point was considered subluxated, and grade III with a soft end point and a grade greater than III was considered re-dislocated). Radiographically, lateral patellar angle (LPA) and the patella tilt angle (PTA) were evaluated on a CT scan with knee flexion at 30°. The Kujala score and Lysholm score were used for subjective knee function.

Statistical analysis

SPSS 13.0 software (SPSS Inc, Chicago, IL, USA) was used for data processing. The Kolmogorov–Smirnov test was used to test the normality of the variances. The *t* test was used for parametric variances, and the Mann–Whitney *U* test and χ^2 test were used for non-parametric variances. A $p < 0.05$ was defined as a significant difference.

Results

The mean follow-up period was 86 months (60–95 months). There were two re-dislocations in group A and four re-dislocations in group B that underwent revision surgeries (n.s.). There was a significant difference between the two groups. The mean Kujala score for groups A and B was 89.9 ± 3.7 and 85.5 ± 5.0 , respectively ($p < 0.01$). The mean post-operative Lysholm score for groups A and B was 90.7 ± 4.1 and 86.4 ± 4.8 , respectively ($p < 0.01$) (Table 2). On CT scans, a significant difference was seen between the two groups (Table 3).

At surgery, arthroscopic cartilage lesions on the patellofemoral joint were observed in 46.7% of patients in the modified semi-tunnel bone bridge fixation group and 50% in the suture anchor fixation group, with no significant difference between the groups. All of the cartilage lesions were outerbridge grade I or II. No loose osteochondral fragments were found (Table 4). Arthroscopic LRR was performed in 40% of patients in the modified semi-tunnel bone bridge

Table 2 Results of knee function at follow-up

	Group A	Group B	<i>p</i> value
Kujala score			
Pre-operative	52.7 ± 3.7	51.1 ± 3.2	n.s
Final follow-up	89.9 ± 3.7	85.5 ± 5.0	0.0005
	$p = 0.0000^*$	$p = 0.0000^*$	
Lysholm score			
Pre-operative	50.2 ± 3.7	49.3 ± 3.4	n.s
Final follow-up	90.7 ± 4.1	86.4 ± 4.8	0.0004
	$p = 0.0000^*$	$p = 0.0000^*$	

*Comparative results between pre-operative and final follow-up

Table 3 Patellofemoral measurements on computed tomography

	Group A	Group B	<i>p</i> value
Patella tilt angle (°)			
Pre-operative	23.2 ± 2.3	23.7 ± 2.3	n.s
Final follow-up	11.5 ± 1.6	14.9 ± 1.7	0.0001
	$p = 0.0001^*$	$p = 0.0001^*$	
Lateral patellar angle (°)			
Pre-operative	-7.4 ± 1.4	-6.8 ± 1.5	n.s
Final follow-up	5.1 ± 1.2	3.7 ± 1.1	0.0003
	$p = 0.0001^*$	$p = 0.0001^*$	

*Comparative results between pre-operative and final follow-up

Table 4 Osteochondral fragments between two groups

	Group A	Group B	<i>p</i> value
Arthroscopic LRR			n.s
Applied	12	10	
Not applied	18	20	
Arthroscopic cartilage lesions			n.s
Patellar facet	5	3	
Femoral facet	3	4	
Both patellar and femoral facets	6	8	
None observed	16	15	

fixation group and 33.3% in the suture anchor fixation group, without a significant difference between the groups.

Discussion

The most important finding of the present study was that the modified semi-tunnel bone bridge technique achieved significantly better knee function and radiologic results than the suture anchor technique at a minimum 5-year follow-up.

Over the past century, although multiple techniques for patellar fixation in MPFL reconstruction have been described, the best method remains controversial. In a human cadaveric model, Russ et al. [21] compared the biomechanical properties of two commonly used methods for patellar graft fixation—suture anchor fixation and interference screw fixation—and concluded that interference screw fixation to the medial patella was significantly stronger than suture anchor fixation. However, they also reported that suture anchors may provide adequate strength of fixation and are less invasive than interference screws in bone tunnels. In a porcine model, Lenschow et al. [12] demonstrated a lower load to failure in the bone bridge group when compared with the suture anchor, interference screw, and transosseous suture groups. However, Russo et al. [6] reported substantially different results. In their study, the transosseous technique demonstrated higher yield loads than the groups utilizing implants. In the clinical studies, although good outcomes with multiple different fixation techniques have been demonstrated, these studies are limited by small numbers and short follow-ups. In the present study, we demonstrated a modified semi-tunnel bone bridge technique without transosseous tunnels and implants, which may avoid the potential complication of patellar fracture. The most important part of this study was to demonstrate minimum 5-year follow-up results comparing the suture anchor technique, which is a commonly used method for patellar graft fixation. During this procedure, the graft must be placed with either femoral or patellar fixation during surgery. Usually, the femoral fixation is with a tunnel and an interference screw. However, various procedures have been reported for patellar fixation, including the semi-tunnel technique and the suture anchor technique. To our knowledge, no published works have revealed the effect of patellar fixation on clinical outcomes. Thus, in our study, the surgical procedure was classified into two types according to the patellar fixation of the graft. The comparisons between the two techniques are summarised in Table 4.

The patella begins to contact the femoral trochlea at approximately 20° of knee flexion [18]. With knee flexion, the VMO starts to contract; the superior oblique bundle is not only a static structure but also serves as a dynamic preserver of patellar stability combined with the VMO,

and the inferior-straight bundle acts as the main static soft tissue restraint [10]. Biomechanical and clinical studies [18, 27] have reported that the anatomic double-bundle technique should be the recommended procedure for MPFL reconstruction, as the single-bundle technique did not restore normal patellar tracking at any flexion angle. At the final follow-up, in our semi-tunnel bone bridge fixation group, good clinical results were obtained. All of the clinical outcome results were significantly higher than before surgery. These results are comparable to those of recent clinical studies. Deie et al. [3] reported that in their double-bundle reconstruction study, they evaluated 31 patients and there were no patellar re-dislocations. Thirty patients had good clinical results, and the mean Kujala score was significantly different, improving from 64 points to 94.5 after 3.2 years. One patient felt medial instability with a Kujala score of 79. Kita et al. [11] reported on their double-bundle reconstruction technique with EndoButton fixation on the femoral side. Their evaluation was with second-look arthroscopic surgery 1 year after the initial surgery. There were no patellar re-dislocations. In 25 patients, 16 patients' patellar tracking was slightly laterally shifted after reconstruction and 3 patients still had positive apprehension signs. The median Kujala score improved significantly from 73 points to 95 points, similar to our semi-tunnel bone bridge technique.

Based on the present data, at final follow-up, the mean Lysholm score for groups A and B was significantly different. Radiographically, a significant difference was seen between the two groups. This result may be comparable to Simon's biomechanical study that compared the fixation strength of five different techniques for graft fixation at the patella [12]. When two suture anchors were used to fix the graft to the patella, the initial stiffness of the graft fixation showed no significant difference with the interference screw fixation, medial bone bridge, or transpatellar tunnel techniques, but an elongation of the graft fixation/bone complex of 3.7 ± 1.6 mm occurred, which was significantly higher than in the other groups after 1000 cycles. Though anatomic double-bundle reconstruction of the MPFL was achieved in this technique, the fixation strength when suture anchors were used was 68% of the native MPFL [14]. Schottle et al. reported that in the suture anchor fixation group, there was loosening of the graft, and they found that secure graft to bone healing cannot be achieved in every patient, and loosening of the graft could occur with suture anchor fixation [24]. Whilst in the semi-tunnel bone bridge group, the graft was fixed into the patellar tunnels by lateral cortical suspension, this avoided hardware at the patella, reducing the risk of intra- or post-operative implant-related complications [8]. The modified semi-tunnel bone bridge technique not only had a dependable initial stiffness of graft fixation, but also had good graft-to-bone healing.

This study had some limitations: (1) the patellar rotation which may better reveal patellar tracking after MPFL reconstruction was unable to be evaluated; and (2) the sample size was small, and additional studies with larger sample sizes are needed to make more precise conclusions.

The present study indicated that the bone–tendon healing got good outcomes compared to the anchor fixation.

Conclusion

Both the semi-tunnel bone bridge and suture anchor fixation techniques for double-bundle anatomic reconstruction of the MPFL can effectively restore patellar stability and improve knee function. The modified semi-tunnel bone bridge technique for anatomic double-bundle MPFL reconstruction achieved statistically better knee function than the suture anchor procedure at a minimum 5-year follow-up.

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Compliance with ethical standards

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

Ethical approval The study was approved by the Medical Ethical Committee of the Third Hospital of Hebei Medical University (Ke-2011-K-086).

Informed consent Informed consent was obtained from all individual participants included in the study.

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