Effectiveness and limitations of reconstruction of the medial patellofemoral ligament using a titanium interference screw in single patellar and femoral bone tunnels

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Abstract

No standard surgical procedure for medial patellofemoral ligament (MPFL) reconstruction exists. The purpose of this study was to evaluate the clinical effectiveness and limitation of the reconstructions of the MPFL in single patellar and femoral bone tunnels. The methods used a hamstring tendon and titanium interference screws in patients with recurrent patellar dislocation. Nineteen knees in 17 patients were studied. Subjects underwent MPFL reconstruction with or without lateral release using interference screws in single patellar and femoral tunnels. Patients were evaluated using preoperative and postoperative physical and radiographic examinations, including apprehension testing, assessment of tilting and congruence angles, medial and lateral shift ratios under stress X-ray imaging, and Kujala and Lysholm scores. Average follow-up was 22 months (12–71 months). None experienced recurrent postoperative episodes of dislocation or subluxation. By the final follow-up, patellar apprehension had disappeared in all patients except for one with generalized joint laxity. In addition, patients showed significant improvement in the following areas: tilting angle (from 14.4° ± 5.6° to 6.4° ± 4.6°, p < 0.0001), congruence angle (0.5° ± 16° to −9.2° ± 6.9°, p < 0.001), lateral shift ratio (23.8 ± 11.3% to 11.6 ± 13.4%, p < 0.001), Kujala score (74.0 ± 7.8 points to 95.7 ± 4.4 points, p < 0.0001), and Lysholm score (71.0 ± 10 points to 95.5 ± 5.3 points, p < 0.0001). MPFL reconstruction methods, using titanium interference screws in single patellar and femoral tunnels provide acceptable short-term results for the treatment of recurrent patellar dislocations.

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Background

Patellar dislocation is common among young female athletes. Repeated episodes of patellar dislocation result in patellofemoral pain, degenerative arthritis, and impairment of the activities of daily living.

Controversy persists as to whether first-line treatment of acute patellar dislocations should be conservative or surgical. Some authors have reported a 50% recurrence rate of patellar dislocation associated with conservative treatment, leading to their recommending surgical management of acute patellofemoral dislocation of the patella, especially in patients with femoral avulsion of the medial patellofemoral ligament (MPFL). On the other hand, the only prospective and randomized study to our knowledge (Nikku et al.) showed that surgical treatment did not show a demonstrable improvement in medium-term (7-year) outcomes over conservative treatment.

Recently cadaveric studies have clarified the anatomy and biomechanics of MPFL and documented the importance of MPFL reconstruction to patellar lateral stability. The MPFL is a primary soft-tissue restraint on lateral displacement of the patella, and its contribution is reported to be 53% when the knee is flexed between 0° to 30°. Based on recent studies
examining the function of the MPFL, numerous techniques of MPFL reconstruction for patellar instability have been published, reporting good clinical results in general.\textsuperscript{1,5,11–22} However, no single gold standard procedure, superior to all other procedures, has emerged because multiple factors have been identified as causing patellar instability, including Q angle, generalized joint laxity, and trochlear groove development.

In 1997, Tanaka described a tendon junction technique using a titanium interference screw and found it an effective reconstruction procedure in cases of Gamekeeper’s thumb.\textsuperscript{23} Furthermore, Takao reported on anatomical reconstruction using the gracilis tendon to treat anterior tibiofibular ligament (ATFL) injury that employed an anchoring fit titanium interference system, and clinical results were excellent.\textsuperscript{24}

The hypothesis behind our study, then, is that an anchoring fit titanium interference system, which is an inside-out technique for graft fixation in the bone tunnel that needs only a small skin incision, is an effective reconstruction procedure in cases of recurrent dislocation of the patella. The aim of our study was to evaluate the early clinical results and limitations of using an anchoring fit titanium interference system in patients with recurrent patellar dislocation under tension control.

Materials and methods

Patients

The subjects of this retrospective study included patients with recurrent patellar dislocation: 17 patients and 19 patellae with closure of the epiphyseal line (3 males and 14 females, 8 right and 11 left sides). All patients received treatment at our hospitals between 2003 and 2008. Mean age at the time of surgery was 20 years (range: 14–38 years). Mean duration from first dislocation to surgery was 48 months (range: 4–121 months). Eleven patients had suffered two dislocations, five had suffered three dislocations, two had suffered five dislocations, and the remaining one had suffered more than 10 dislocations. All patients experienced apprehension and recurrent subluxation after their first dislocation. The mean postoperative follow-up period was 22 months (range: 12–71 months). Inclusion criteria for this study were that the patients had experienced recurrent dislocation of the patella, and had not responded to conservative treatment including bracing and physical therapy for longer than 3 months. Patients with acute, habitual, or permanent dislocation of the patella were excluded from the study.

Surgical technique

All patients were treated by the same surgeon. Surgery was conducted under lumbar anesthesia or femoral and sciatic nerve block in a prone position. Before MPFL surgery, arthroscopy was conducted to examine the locations of the patella. Two 21 gauge needles were inserted, one located two finger breadths proximal to the patellar superior pole and the second at the patellar superior pole. Lateral retinacular release was selectively performed between the two 21-gauge needles under arthroscopy with hook-type radiofrequency (ArthroCare\textsuperscript{®}) in cases where there was no medial instability by preoperative stress Xp view\textsuperscript{25} (indicated for cases less than −20%; only one patient had a medial stress −45%, Fig. 3A).

Our MPFL reconstruction procedure was performed as follows (Fig. 1). After arthroscopy, a pneumatic tourniquet was applied to the thigh and inflated as an Esmarch bandage. After the semitendinosus tendon was identified, it was harvested from the affected side with an open tendon stripper. The harvested semitendinosus tendon was folded in two (to form a double-stranded graft), such that the graft was approximately 8 cm long (inserted length of patella bone tunnel—1 cm; MPFL length—approximately 5 cm, exact length varying with each individual; inserted length of femur bone tunnel—2 cm), and 1-0 braided nylon suture material was passed through each end (Surgilon; Tyco Healthcare, Norwalk, CN) to fit it into the bone tunnels that would later be formed. Both ends were sutured five times with 1-0 Surgilon.

Three-cm and 2-cm skin incisions were made longitudinally over the proximal third of the patella and at the origin of the adductor muscle, respectively. The extensor retinaculum and remaining MPFL were incised in a rectangular shape carefully in order to avoid cutting the capsule. Femoral and patellar sides exposed only the bony attachment of the MPFL, and the reconstruction route was created by blunt dissection with a long pair of forceps between the second layer and third layer. Two 1.6-mm guide pins were inserted into the point of the patellar tunnel, proximal third of the patella and middle of the patellar facet parallel to the ground, and the femoral tunnel just distal to the adductor tuberosity of the femur, and superoposterior to the medial collateral ligament. These are reported to be the anatomical position of the MPFL\textsuperscript{8,13} as seen from anteroposterior and lateral views under an image intensifier.

Next, a 6.5-mm diameter by 1-cm long bone tunnel was carefully created by core reaming into the side of the patella where the guide pin had been initially placed, so as not to penetrate the cartilage (Fig. 1A). The bone tunnel on the patellar side was made as short as possible so as not to fracture or break the chondral surface or the anterior cortex. The bone chip obtained in the core reamer was cut into two pieces, preparation for later placement between the interference screw and the graft so as not to injure the ligament. Looped 1-0 Surgilon attached to the end of the 1.6-mm guide pin was passed laterally through the patellar tunnel (Fig. 1A). The other end of the looped Surgilon was passed through the guide pin in the head of the femur. Tensioning was obtained by keeping the Surgilon lateral to the patella, using mosquito forceps (Fig. 1A).

The tracking course from almost full extension to full flexion under the tensioning was confirmed to be satisfactory in anteroposterior and axial views in the image intensifier. When the patella was rotated or moved to the medial side, if the position of the guide wire on the femoral side was incorrect, it was changed in each case. The tension was adjusted to become slightly tight when the knee was fully extended, while endeavoring to avoid exerting excessive tension. When appropriate placement was achieved, the length of the femoral and patellar tunnels (measured by using a tape measure inserted
from the entry point of the patellar tunnel and femoral tunnel) was individually measured in full knee extension in each case. MPFL length has been reported to be the longest in full extension. The prepared graft then was cut and finished.

At the folded end of the graft, 1-0 Surgilon was passed into the eye of the loop and the loop 1-0 surgilon was pulled laterally (Fig. 1B). The reconstructed tendon was inserted into the 1.0-cm-long patellar bone tunnel and the two prepared bone chip pieces were inserted. Fixation onto the patella was achieved using a 5.0 mm diameter by 9.0 mm long titanium interference screw (tendon-junction screw; Meira, Nagoya, Japan) inferiorly to the reconstructed ligament pulled into the hole by lateral tension on the braided nylon suture (Fig. 1C). The long guide pin on the femoral side was carefully passed again in the initial position under intensified lateral and axial views, being careful not to penetrate the joint (Fig. 1C).

A 6.5-mm diameter by 3-cm long femoral bone tunnel was created by core reaming (Fig. 1C), and the bone chip was preserved for later use in bone grafting. The bone tunnel on the femoral side was 1 cm longer than the inserted femoral graft to allow for adjustment of MPFL tensioning just before fixation with the interference screw. The looped suture was passed through the end of the long guide wire (Fig. 1C). The suture loop from the free end of the reconstructed ligament was passed through the suture attached to the femoral guide wire (Fig. 1C), which was pulled out laterally from the femur.

Subsequently, the braided nylon suture attached to the end of the graft was pulled out laterally and the 2 cm reconstructed graft
was inserted into the femoral bone tunnel (Fig. 1D). The tension was adjusted again by pulling the Surgilon laterally such that it became slightly tight and the length change was within 5 mm when the knee was fully extended without limiting flexion. Furthermore, a good patellar tracking course was confirmed both by the image intensifier and by arthroscopy.

We fixed the femoral side with an interference screw at the other end of the reconstructed ligament at a 30° flexion angle because the patella began to stabilize into the patellar groove. We further stabilized it by pulling the Surgilon laterally and adding gentle force to the patella medially by thumb pressure to adjust the same line between the lateral patellar line and the edge of the lateral femoral condyle (Fig. 1E). The extensor retinaculum flap was sutured to the reconstructed tendon like a wider fan-like insertion with the core suture, using a side-locking loop technique with USP 2-0-sized braided polyblend suture thread (Fiberwire®, Arthrex, Naples, Florida).

**Postoperative management**

A knee brace with a 30° extension limit was placed postoperatively not to stretch the graft. Range-of-motion exercises were started at 1 week. Partial weight-bearing was started 2 weeks postoperatively, and full weight-bearing was permitted.
at 4 weeks. The knee brace was removed 3 months postoperatively and jogging started at the same time. Six months postoperatively, the patients were allowed to resume sports activity.

**Evaluation**

During physical examination, the Carter test along with range of motion and apprehension tests were conducted. Tilting, congruence, and sulcus angles were determined from plain axial view X-ray images at 45° of knee flexion (Fig. 2C). The lateral view was used to measure the patellar height as described by Insall and Salvati. All knees were examined by CT or magnetic resonance imaging (MRI) every 6 months during the follow-up period. Clinical results were evaluated using Kujala and Lysholm scores. Physical examination, X-ray findings, and clinical scores were evaluated preoperatively and at final follow-up.

Complications (patellar fracture, irritation from an interference screw, redislocation, allergic reaction, infection, hemarthrosis, and deep venous thrombosis) were also investigated at final follow-up.

**Statistical analysis**

The Wilcoxon signed-rank test was used to determine differences between preoperative and postoperative values (StatView 5.0, Abacus Concepts, Berkeley, CA, USA). Differences were considered significant when \( p < 0.05 \).

**Results**

Results are presented as mean values ± standard deviation, as summarized in Tables 1 and 2. No postoperative loss of flexion or extension limitations were observed. Apprehension test results were all positive preoperatively, and all were negative postoperatively except for one patient, who was a 22-year-old female with generalized joint laxity (Fig. 3). She had dislocated initially 10 years ago and underwent an Elmslie-Trillat procedure at another hospital 8 years ago. However, she had suffered more than 10 additional dislocations before the MPFL reconstruction. She underwent MPFL reconstruction in our hospital without lateral release because her medial stress ratio was −45% (patellar height before operation: 1.1; sulcus angle: 145°). Radiographic observations demonstrated significant improvement postoperatively in the following parameters: tilting angle (\( p < 0.0001 \)), congruence angle (\( p < 0.001 \)), and lateral shift ratio (\( p < 0.001 \)). The medial shift ratio did not improve (\( p = 0.79 \)). Kujala and Lysholm scores also significantly improved following surgery, from 74 ± 7.8 points to 95.7 ± 4.4 points (\( p < 0.0001 \)) and from 71 ± 10 points to 95.5 ± 5.3 points (\( p < 0.0001 \)), respectively.

Only one complication was observed during the entire follow-up period: a 19-year-old female patient developed irritation from an interference screw on the femoral side 19 months after surgery and the screw had to be removed 2 months later. X-ray images showed that the interference screw position was virtually unchanged from its position after the initial operation. The screw was easily removed; MPFL tension on the capsule remained good under arthroscopy and the irritation disappeared completely after removal of the screw. No patellar dislocation or discomfort has been identified subsequently.

**Discussion**

Improved clinical results were observed during a minimum 1-year follow-up period after the MPFL reconstruction of recurrent patellar dislocation using a titanium interference fit anchoring system. Good postoperative patellar stability was seen using the 2 kg stress view (Table 2). Approximately the mean two years following the operation, the medial and lateral shift ratio was approximately 10% (absolute value). These findings indicate that pre-evaluation of medial and lateral instability, which means the medial and lateral shift ratio under stress Xp view, is important for MPFL reconstruction, with or without lateral retinacular release, and that this consideration could lead to an increase in patella stability and clinical scores.

Several surgical procedures for MPFL reconstruction using interference screws have been reported. In 2007, LeGrand et al. reported good clinical results with MPFL reconstruction using the semitendinosus tendon by shuttling the graft through bone tunnels in the patella and securing the two free graft ends to the femur using a bioabsorbable interference screw. In 2008, Christiansen et al. described MPFL reconstruction using a gracilis tendon autograft looped through two transverse 4.5 mm drill holes in the patella and fixed to the medial femoral condyle with a bio-absorbable interference screw.

**Table 2**

Pre- and postoperative measurements of X-ray image findings.

<table>
<thead>
<tr>
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<th>Pre-operation</th>
<th>Post-operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulcus angle ()</td>
<td>140.1 ± 13.4</td>
<td>1.1 ± 0.0</td>
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<tr>
<td>Insall-Salvati</td>
<td>1.2 ± 0.1</td>
<td>6.4 ± 4.6**</td>
</tr>
<tr>
<td>Congruence angle (°)</td>
<td>14.4 ± 5.6***</td>
<td>6.4 ± 4.6***</td>
</tr>
<tr>
<td>Lateral shift ratio (%)</td>
<td>23.8 ± 11.2**</td>
<td>11.6 ± 13.4**</td>
</tr>
<tr>
<td>Medial shift ratio (%)</td>
<td>9.8 ± 17.6</td>
<td>11.6 ± 4.8</td>
</tr>
</tbody>
</table>

**p < 0.001,** **"p < 0.0001.**

**Table 1**

Pre- and postoperative physical findings.

<table>
<thead>
<tr>
<th></th>
<th>Pre-operation</th>
<th>Post-operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carter test</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Range of motion:</td>
<td></td>
<td></td>
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<tr>
<td>Extension (°)</td>
<td>2.3 ± 5.1</td>
<td>0.5 ± 1.6</td>
</tr>
<tr>
<td>Flexion (°)</td>
<td>131 ± 15.8</td>
<td>139 ± 3.0</td>
</tr>
<tr>
<td>Apprehension test</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Patella compression pain</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Patella compression retropatella crepitus</td>
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<td>2</td>
</tr>
<tr>
<td>Quadriceps muscle atrophy</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

Mean values ± SD are given.
described MPFL reconstruction using the semitendinosus tendon with Bio-Tenodesis screw fixation of the femur and a docking technique for fixation of the patella.\textsuperscript{22} Our clinical results were similar to those reported in these published series of studies; our use of a titanium interference screw in patients with recurrent patellar dislocations is the first such use in MPFL reconstruction that has been reported, to our knowledge. On the other hand, one patient who had generalized joint laxity and a shallow femoral sulcus remained apprehensive (Fig. 3). In that case, it took 10 years to reconstruct the MPFL after her first dislocation. This might be the limitation of single patellar and femoral bone tunnels. Perhaps other techniques might have been used, or the patient should have the MPFL reconstruction at the same time as the Elmslie-Trillat procedure.

Surgery using double tunnels in the patellar side and a single femoral tunnel in MPFL reconstruction has been reported. Toritsuka reported the dual tunnel MPFL reconstruction for patients with patellar dislocation using a semitendinosus tendon autograft, and showed a 96-point of the average Kujala’s score, although one patient remained slightly positive apprehension.\textsuperscript{33} Panni reported MPFL reconstruction with a divergent patellar transverse two-tunnel technique using a semitendinosus tendon autograft. They reported good clinical scores, and 29 of the 45 patients returned to the same type of sports at the same level.\textsuperscript{34} The original MPFL at the patellar insertion site resembles a fan and these procedures can mimic the original MPFL better than the single socket on the patellar side as in our current study of MPFL reconstruction. However, this procedure requires dual tunnels and the risk of patellar fracture is higher than for single-socket reconstruction. In fact, Panni reported one patellar fracture from direct trauma 4 months after surgery.\textsuperscript{34} Furthermore, the tension and length pattern could be slightly different between the proximal and distal fibers, which would influence the angle and force of graft fixation. From these findings, we reconstructed the MPFL using a single patellar tunnel in this series, and achieved good clinical results without any patellar fractures. We sutured the single reconstructed graft to the rectangular shaped retinaculum with the MPFL remnant and mimicked the fan-like lesion.

Mountney et al. published a biomechanical study in which they measured tensile strength for different methods of MPFL reconstruction.\textsuperscript{35} Cossey and Paterson described MPFL reconstruction with a strip of medial retinaculum using a 0 PDS suturing method\textsuperscript{11}; according to the Mountney study, the suture repair probably has a tensile strength of around 37 N.\textsuperscript{35} On the other hand, the Mountney study reported a tensile strength of 126 N for the bioabsorbable interference screw method, which is similar to our method, a value that indicates that this method provided a much stronger repair than the sutured attachment method. However, the repair still had a tensile strength weaker than the 208 N tensile strength of native MPFL,\textsuperscript{35} which is much higher than that of the reconstructed graft during weight bearing in activities of daily living. Because of these results for bioabsorbable interference screws, we decided to routinely fit our patients for 3 months after surgery with a knee brace that limited extension to 30°, so as not to prematurely stretch the graft during normal daily activities before it had the opportunity to become established. Our clinical results were good with almost no limitations of range of motion at final follow-up (Table 1).

We encountered only one complication in a single patient (1/19, 5%) that resulted in reoperation, in which we removed an irritating interference screw from the femoral side. Christiansen et al. reported that 3 of 44 patients needed bioabsorbable interference screw removal because of screw protrusion or pain.\textsuperscript{32} Steiner et al. reported that 10% of patients needed cancellous lag screw removal because of a prominent or painful screw on the femoral side.\textsuperscript{20} In our patient who suffered the complication, the screw initially projected out slightly from the cortex but failed to shift medially over time. Since then, we have carefully checked the position of the interference screws using an image intensifier, especially in the axial view, and have encountered no further cases requiring screw removal.

On the other hand, patellar fracture is one of the most common complications associated with the method we employ to make bone tunnels. Mikashima et al. reported two cases of patellar fractures in 24 patients after MPFL reconstruction using the endobutton technique on the femoral side to create a 4.5-mm oblique hole in the patella.\textsuperscript{19} Christiansen et al. reported one patient with a transverse patellar fracture associated with their making two 4.5-mm patellar drill holes.\textsuperscript{32} We have created a single patellar bone tunnel only 1 cm long by 6.5 mm in diameter, which is the smallest size we are capable of producing. The femoral bone tunnels we make are longer than the patellar bone tunnels because of the greater mass of bone on the femoral side. We have not had any fractures on either the patellar or the femoral side in our series thus far.

Our study has several limitations, including a relatively short follow-up period and a relatively small number of study subjects. Future studies should include a longer follow-up period and more patients. Furthermore, although our results were excellent except for one case among patients meeting our criteria, we do not know the clear indications for this technique. We will attempt to use our technique with a broader set of indications in the future in order to better identify the operative indications for employing the interference screw method. Lastly, there was no control group in this study, so that a further study is needed to compare with the MPFL reconstruction without interference screw fixation to clarify the true usefulness of fixation method.

In conclusion, MPFL reconstruction using titanium interference screws in single patellar and femoral bone tunnels is one of the most promising procedures for treating recurrent patellar dislocation with acceptable short-term results. Only one patient who had generalized joint laxity, a shallow femoral sulcus and suffered more than 10 dislocations before MPFL reconstruction did not have a positive outcome.

**Author contributions**

YU conceived of the surgery and helped to draft the manuscript.

NK participated in the surgeries and drafted the manuscript.

SK participated in the surgeries and helped to draft the manuscript.
TI participated in the surgeries and helped to draft the manuscript.
All authors read and approved the final manuscript.

Conflicts of interest
The authors declare that they have no financial or non-financial conflicts of interest related to the subject matter or materials discussed in the manuscript.

References