Technical Note

Arthroscopically Assisted Double-Bundle Medial Patellofemoral Ligament Augmentation With Physeal-Sparing Suture Fixation for Recurrent Patellar Dislocation in Skeletally Immature Patients

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Abstract: Recurrent patellar dislocation is a common patellofemoral disease that affects active adolescents. The optimal surgical treatment of recurrent patellar dislocation in skeletally immature patients remains controversial. This Technical Note describes an arthroscopically assisted double-bundle medial patellofemoral ligament (MPFL) augmentation. Orthocord suture, with ideal strength and partial bioabsorbable characteristics, is used as the stabilizer to augment and protect the native MPFL during its biological healing. Under an arthroscope, patellar tunnels are created with Kirshner wire at the upper third point of the medial articular margin and the midpoint of the proximal articular margin. A physeal-sparing transosseous suture fixation technique is applied at the femoral attachment. Two femoral tunnels are made with half-circle cutting needle, which is pierced into the femoral origin of the MPFL and exits the posterior femoral cortex. After dynamic assessments of knee range of motion and patellofemoral congruence, free ends of the Orthocord suture bundle are tied together at the external opening of the femoral tunnel. Transosseous suture fixation balances the requirements of anatomic restoration, reliable fixation, and physeal preservation, and thus may provide a promising alternative to current algorithm of addressing recurrent patellar dislocation in pediatric population.

Patellar dislocation is a multifactorial disorder that primarily affects young, active patients.[1] There is a wide consensus that surgical interventions are necessary for recurrent dislocations.[2] Despite various procedures being reported, including medial reefing, medial retinacular plasty, lateral release, medial patellofemoral ligament reconstruction (MPFL-R) using adductor-transfer or pedicled quadriceps tendon, and fluoroscopy-guided autograft MPFL-R, the optimal surgical treatment of recurrent patellar dislocation for pediatric population remains a debated issue.[3-6]

With all skeletally immature patients, an integral part of the surgical plan centers on preserving the femoral physis.[7] Adductor transfer, adductor sling, and medial collateral ligament sling have been described as physeal-sparing techniques.[3,8] However, these techniques fail to reproduce the anatomy of the native MPFL, which would possibly lead to altered isometry and abnormal kinematic changes of the reconstructed ligament.[9,10] Growing attention has been drawn to fluoroscopy-guided MPFL-R with autograft, which has demonstrated satisfactory efficiency for adolescents.[2,11,12] Nevertheless, the main concern arises from the risk of physeal injury. The distance from the MPFL origin to the distal femoral physis varies from 3.7 mm proximal to 10.0 mm distal in skeletally immature specimens.[13] The concave posteromedial femoral physis dips distal to the MPFL femoral attachment, whereas its convex anteromedial portion lies proximal to the footprint.[14] These variabilities lead to a dilemma in choosing between perfect isometry and physeal preservation during MPFL-R in certain cases.[13,15]

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The use of autograft tendons has also raised continuous concern regarding donor-site morbidity.[6,16]

Under this background, MPFL augmentation may provide a reasonable alternative. Augmentation refers to a technique that reproduces the structure of soft-tissue stabilizers by using suture tape or bioactive material as an "artificial ligament."[16-18] The tape is supposed to act as a secondary stabilizer and to protect the native ligament during its biological healing by preventing increased patellar lateralization.[16,18] A recent biomechanical study confirmed similar contact pressures and joint kinematics between MPFL augmentation and MPFL-R using tendon grafts in almost all degrees of knee flexion.[16] To avoid injury of the epiphyseal plate, osseous femoral fixation during MPFL augmentation for adults should not be mechanically transplanted to young patients.

The purpose of this Technical Note is to describe a novel technique of arthroscopically assisted double-bundle MPFL augmentation for recurrent patellar dislocation in skeletally immature patients. The transosseous suture fixation at femoral side balances the requirements of anatomic restoration, reliable fixation, and physeal preservation, and thus may provide a promising alternative to current algorithm of addressing patellar instability in pediatric population.

Surgical Technique (With Video Illustration)

This work was approved by the ethics committee of Peking University Third Hospital (Project Number: M2021404).

Anesthesia and Patient Positioning

The patient is placed supine on a standard operating table. Subarachnoid anesthesia is administered. If young patients cannot cooperate, general anesthesia is used as an alternative. The head and body prominences are padded. The lower extremity is prepped and draped in the usual sterile fashion. A sterile tourniquet is placed on the ipsilateral thigh.

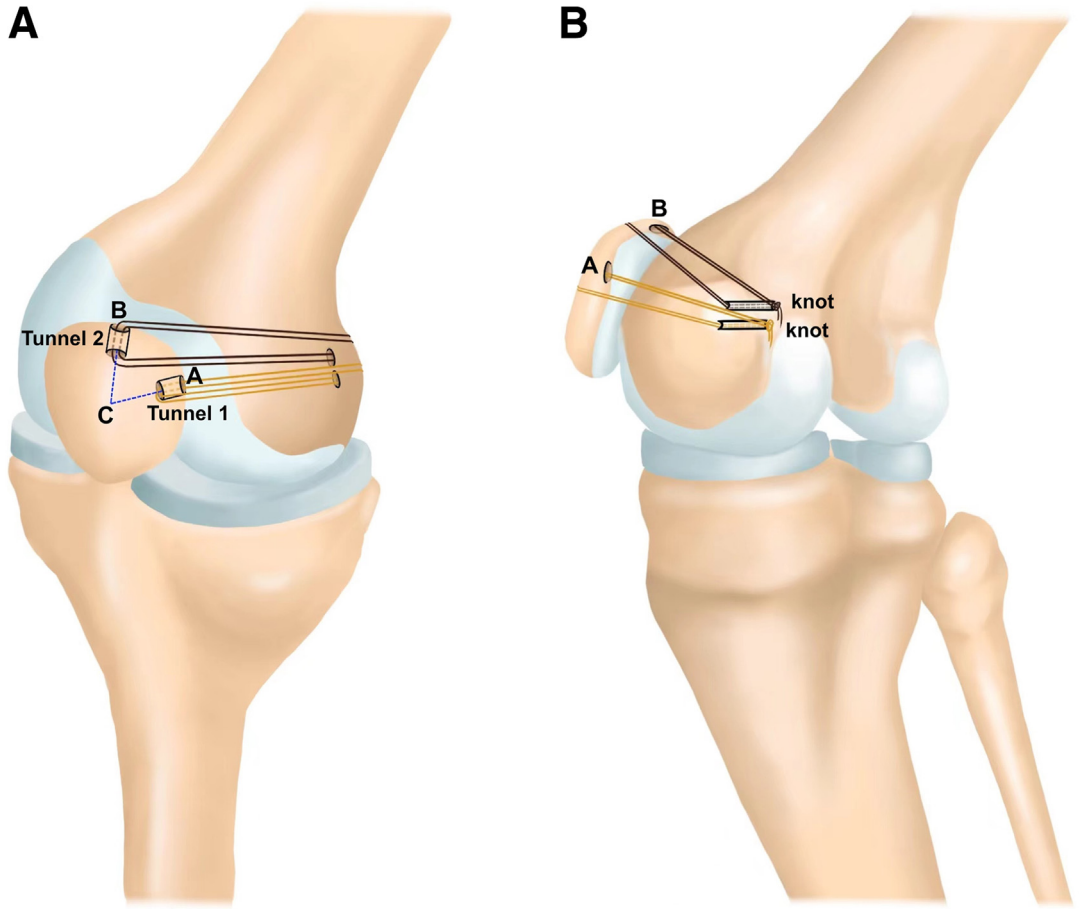

Fig 1. Schematic illustration of double-bundle medial patellofemoral ligament augmentation with Orthocord suture. (A) Anteromedial view. Patellar tunnels are created from the central area of the front surface (Point C) to the upper third point of the medial articular margin (Point A, tunnel 1) and to the middle of the superior articular margin (Point B, tunnel 2), respectively. Double-strand Orthocord suture is introduced into the patellar tunnel. (B) Posteromedial view. Physeal-sparing transosseous suture fixation is applied on the femoral side. Two femoral tunnels are made with half-circle cutting needle, which is pierced into the femoral origin of the MPFL and exits the posterior femoral cortex. The Orthocord suture is introduced into the femoral tunnel, with its free ends tied together and fixed at the external opening of the tunnel. MPFL, medial patellofemoral ligament.

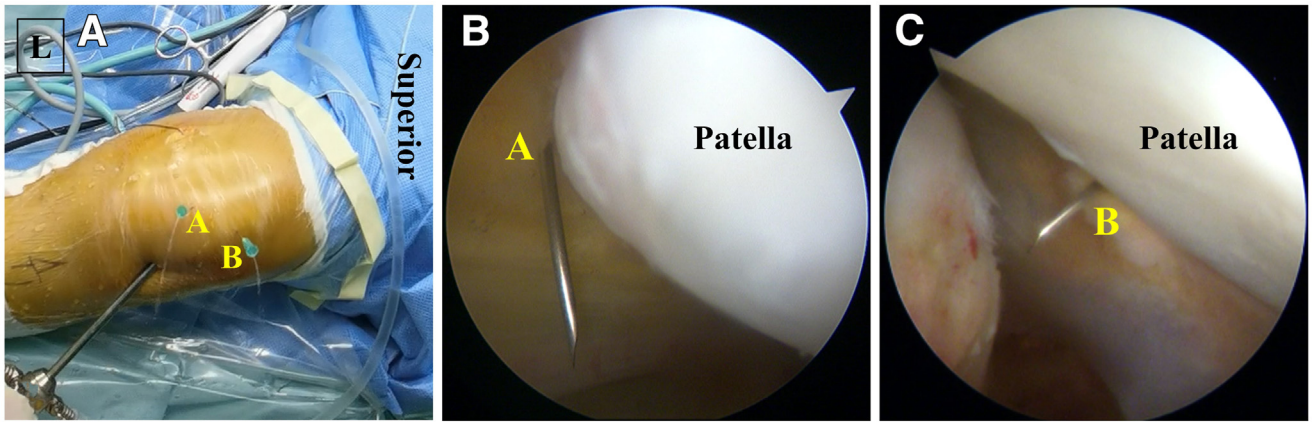

Fig 2. Location markers of the patellar tunnels. The patient is placed supine on the operating table (left knee). An anterolateral portal and an anteromedial portal are established. (A) Macroscopic view of guide needles. (B) Arthroscopic evaluation of the guide needle at point A through the anterolateral portal. (C) Arthroscopic evaluation of the guide needle at point B through the anterolateral portal. Point A, the upper third point of the medial patella. Point B, the midpoint of the superior patella.

Arthroscopic Portal Placement and Diagnostic Arthroscopy

An anterolateral portal and an anteromedial portal are routinely established. Diagnostic arthroscopy is performed to assess patellar tracking, loose bodies, and other intra-articular derangements of the knee (Video 1). Cartilage status is assessed intraoperatively according to the classification of International Cartilage Regeneration & Joint Preservation Society. With the patient under anesthesia, patellar tilt test and patellar mobility test are performed to evaluate the tightness of lateral restraints. The adductor tubercle (AT) and the femoral medial epicondyle (ME) are first identified through careful palpation.[19,20] A 2-cm medial incision is made between the 2 landmarks, and the femoral attachment of the MPFL is clearly exposed.

Creation of Patellar Tunnels

The superior and medial margins of the patella are carefully palpated. The upper third point of the medial margin (point A) and the midpoint of the superior margin (point B) are marked with two 10-mL needles (Fig 1). The guide needles are inserted into the articular cavity percutaneously under arthroscopic visualization (Fig 2). The 4 corners of the patella are palpated, and the central area of the patella (point C in Fig 1) is determined by the intersection point of 2 diagonals.

On the line connecting point A and point C, a patellar tunnel (tunnel 1 in Fig 1) is drilled percutaneously with a 1.5-mm Kirschner wire from the point 1 cm distant from point A (Fig 3A and B). The angle between the Kirschner wire and the front surface of the patella is maintained at 45° approximately, and the internal opening of the tunnel is located near the cartilage margin of the patella. Through the medial incision, a blunt cannula is passed between the deep fascia and the capsule to develop an extracapsular approach (Fig 3C). Guide suture (polydioxanone suture, PDS) is introduced into the patellar tunnel 1 by a spinal needle (Fig 3D and E). A penetrating grasper is introduced through the extracapsular approach and then pierced into the articular cavity to grasp the looped portion of the guide suture, pulling it out from the medial incision (Fig 3F and G). Along the guide suture, double-strand Orthocord suture (DePuy Synthes, Warsaw, IN) is passed through the patellar tunnel 1 (Fig 3H and I). Then, a subcutaneous approach is created with the blunt canula. The free end of the Orthocord suture is retrieved through the subcutaneous approach with a suture retriever until it exits the medial incision, and consequently a double-bundle structure is formed (Fig 4).

Similarly, another patellar tunnel (tunnel 2 in Fig. 1) is created percutaneously with a 1.5-mm Kirschner wire from the point 1 cm distant from point B (Fig 5A and B). Guide suture is introduced into the patellar tunnel 2 by a spinal needle (C and D). Through the previously established extracapsular approach, a penetrating grasper is introduced and pierced into the capsule to grasp the guide suture and pull it out via the medial incision (Fig 5C and E). Guided by PDS, the Orthocord suture is doubled and passed through the patellar tunnel 2 (Fig 5F and G). Another subcutaneous approach is created with the blunt canula. The suture retriever is used to retrieve a free end of the Orthocord suture bundle through the subcutaneous approach until its 2 limbs exit the medial incision (Fig 5H and I).

Creation of Femoral Tunnels

Through the medial incision, bony prominences of the AT and the ME are directly palpated with finger, and the position of the saddle sulcus between them is confirmed. The femoral fixation site is located within the sulcus.[21] A half-circle cutting needle with a

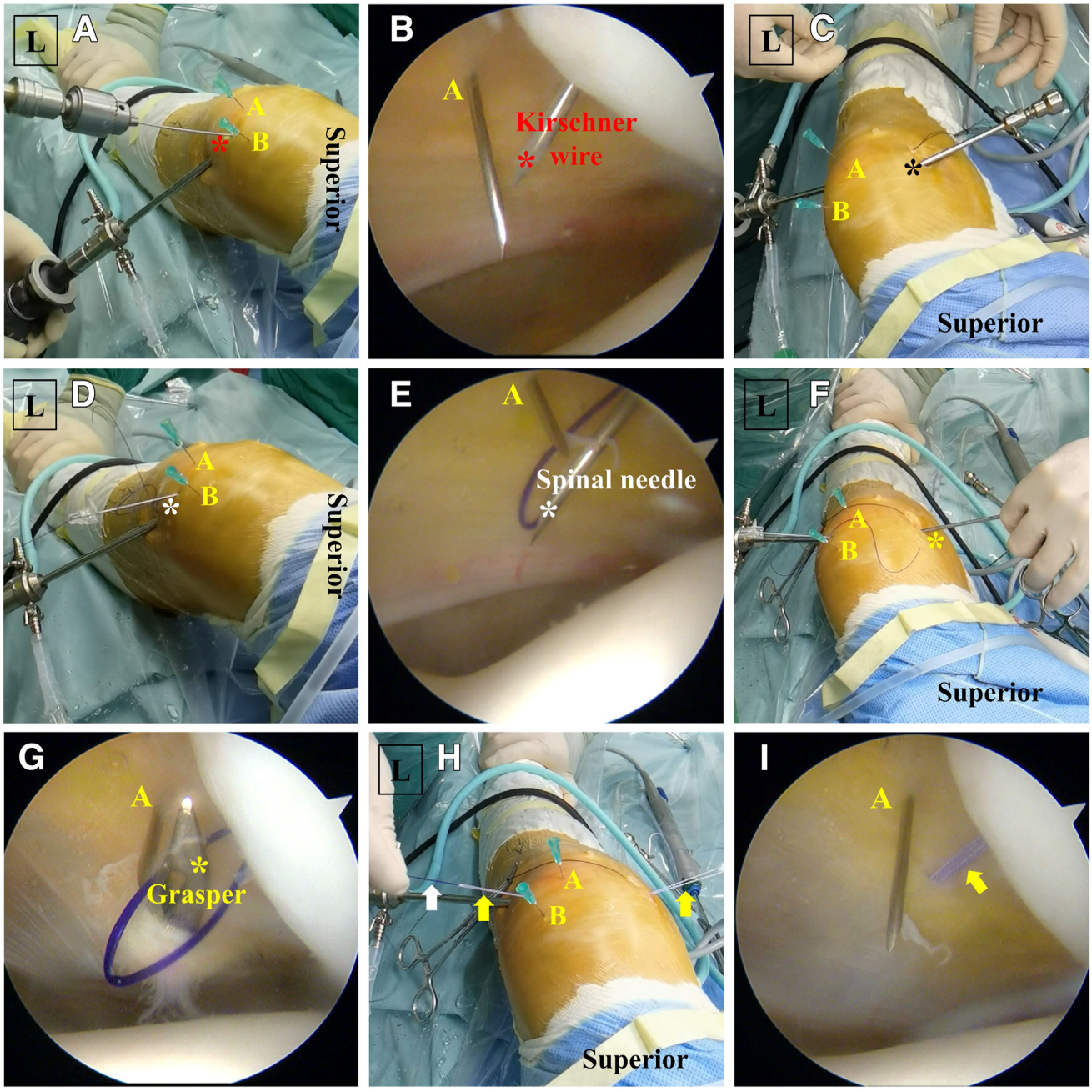

Fig 3. Arthroscopically assisted creation of patellar tunnel 1. The patient is placed supine on the operating table (left knee). An anterolateral portal and an anteromedial portal were established. (A) Macroscopic view of a Kirschner wire (red asterisk) drilling the tunnel. (B) Arthroscopic view of the Kirschner wire through the anterolateral portal. (C) Macroscopic view of a blunt cannula (black asterisk) developing the extracapsular approach. (D) Macroscopic view of a spinal needle (white asterisk) introducing the guide suture into the articular cavity. (E) Arthroscopic view (anterolateral portal) of the spinal needle. (F) Macroscopic view of a penetrating grasper (yellow asterisk) grasping the guide suture. (G) The penetrating grasper is pierced into the capsule to retrieve the looped portion of the guide suture. (H) Double-strand Orthocord suture (yellow arrows) is passed through the patellar tunnel 1 along the guide suture (white arrow). (I) Arthroscopic view (anterolateral portal) of double-strand Orthocord suture (yellow arrow) exiting the capsule. Point A, the upper third point of the medial patella. Point B, the midpoint of the superior patella.

diameter of 1.0 mm is pierced into the cortex of the sulcus (Fig 6A), and its position is reconfirmed with a finger. A guide suture (PDS) is passed through the looped portion of the Orthocord suture from patellar tunnel 1 and folded in half. Two ends of the guide suture are held together and sticked through the eye of the cutting needle. With the insertion site settled, the needle is passed in a proximal—posterior direction until

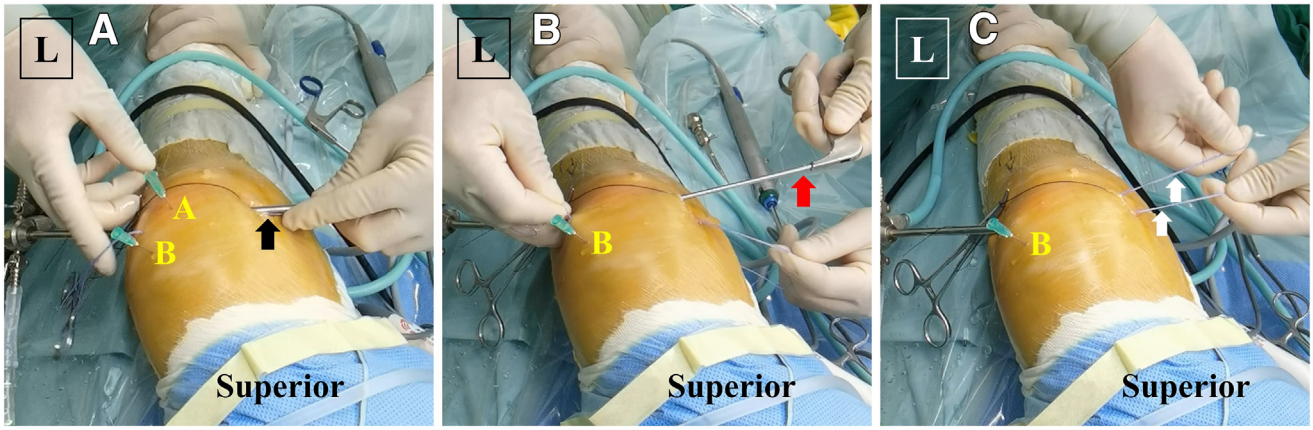

Fig 4. Techniques of retrieving the suture bundle through subcutaneous approach. The patient is placed supine on the operating table (left knee). (A) A subcutaneous approach is created with a blunt cannula (black arrow). (B) A suture retriever (red arrow) is used to retrieve the free end of the Orthocord suture and pull it back via the medial incision. (C) Two limbs (white arrows) of the suture bundle both exit the medial incision. Point A, the upper third point of the medial patella. Point B, the midpoint of the superior patella.

it pierces through the posterior femoral cortex. Along the guide suture, one end of the double-strand Orthocord suture from patellar tunnel 1 is introduced into the femoral tunnel. In similar fashion, a second femoral tunnel is made at a distance of approximately 5 mm from the first femoral tunnel. The Orthocord suture from patellar tunnel 2 is introduced into the second femoral tunnel. Two limbs of each Orthocord suture bundle are held together and tensioned (Fig 6B).

Lateral Release and Arthroscopic Re-Examination

The indication for lateral release is excessively tight lateral restraints, which is assessed by a positive passive patellar tilt test or less than one quadrant displacement.[19] The release is performed with coblation and shaver close to the lateral margin of the patella from inferior to superior (Fig 6C). The knee is cycled several times from full flexion to full extension to confirm that the suture bundle remains isometric and full flexion and extension can be achieved. In this way, the suture tension is settled. Arthroscopic examination is reperformed to evaluate patellofemoral congruence and patellar tracking during dynamic passive knee movements (Fig 6D).

Suture Fixation at Femoral Origin

With the knee flexed to 70°, knots are tied using the 2 ends of each Orthocord suture bundle at the external opening of each femoral tunnel (Fig. 1 and Fig 6E). Consequently, a double-bundle structure with 8 strands of Orthocord suture is created (Fig 6F). Incisions are closed anatomically. Dressings, bandages, and a hinged brace locked in full extension are applied.

Postoperative Evaluation and Rehabilitation

Postoperatively, a hinged brace is worn in the first 6 weeks. The next day after surgery, patients are allowed to bear weight as tolerated. Quadriceps isometric exercise begins the next day after surgery and lasts for at least 8 weeks. Range-of-motion exercise begins 4 days after surgery, with 90° flexion being achieved by postoperative 4 weeks. The degree of flexion gradually increases, and on average, a normal range of motion is expected to be achieved by 2 to 3 months after surgery. Controlled sports activities are allowed after 4 to 5 months, and full return to sports is recommended after 6 months. Computed tomography scans are obtained within 1 week after surgery to evaluate the patellofemoral congruence as compared with those taken before surgery (Fig 7).[19]

Discussion

The present Technical Note describes a novel technique of arthroscopically assisted double-bundle MPFL augmentation for recurrent patellar dislocation in skeletally immature patients. The transosseous suture fixation at femoral side balances the requirements of anatomic restoration, reliable fixation and physeal preservation.

MPFL augmentation has been investigated in many studies but mainly among skeletally mature patients.[17,18,22,23] The success rate of MPFL augmentation for preventing recurrent dislocations exceeded 90% at both short-term and long-term follow-up in adults.[22] Lee et al.[23] compared the clinical outcomes of MPFL augmentation and MPFL-R with tendon grafts. No

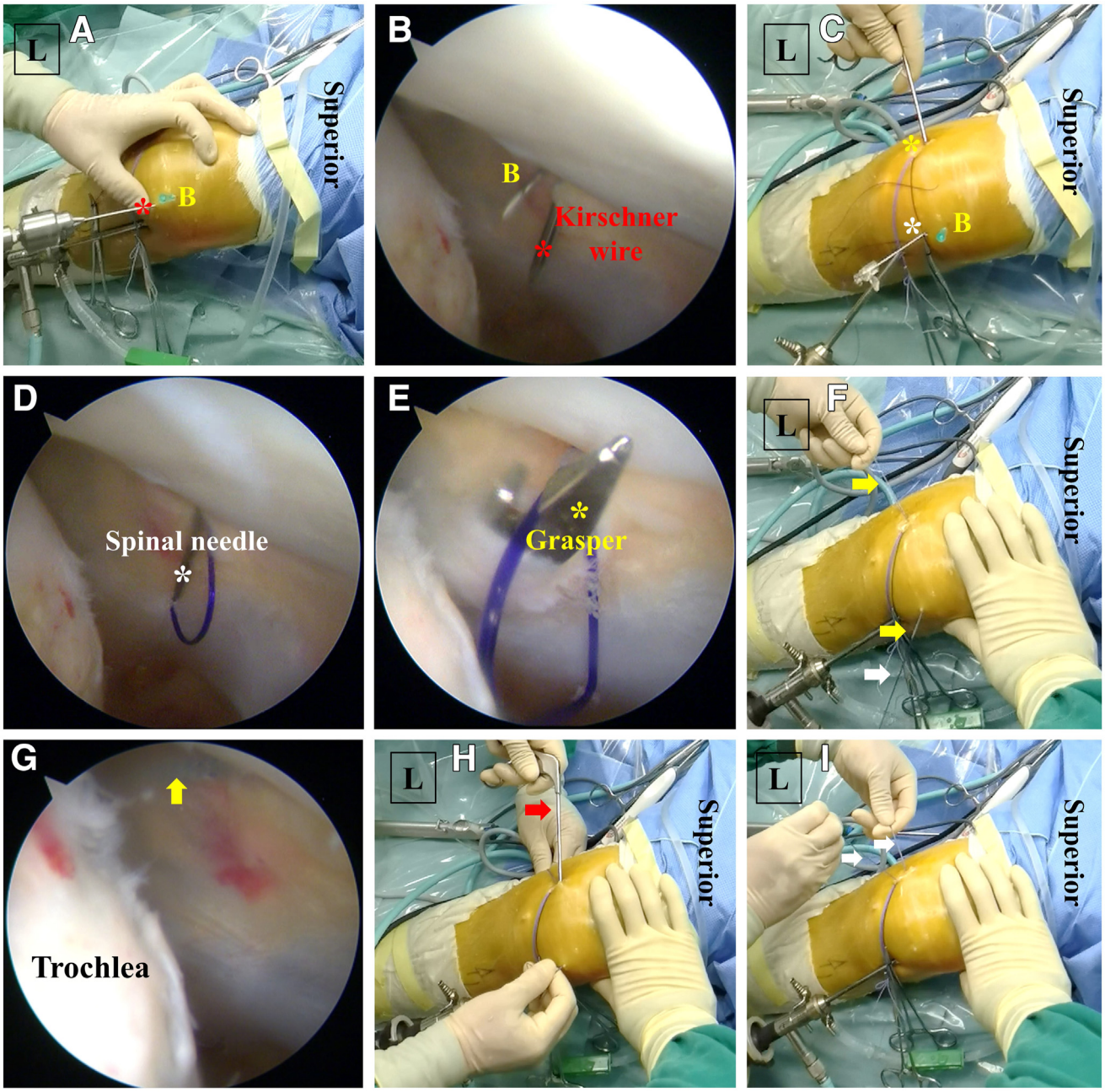

Fig 5. Arthroscopically assisted creation of patellar tunnel 2. The patient is placed supine on the operating table (left knee). An anterolateral portal and an anteromedial portal are established. (A) Macroscopic view of a Kirschner wire (red asterisk) drilling the tunnel. (B) Arthroscopic view (anterolateral portal) of the Kirschner wire. (C) After the guide suture is inserted into the capsule by a spinal needle (white asterisk), a penetrating grasper (yellow asterisk) is introduced through the previously established extracapsular approach. (D) Arthroscopic view of the spinal needle through the anterolateral portal. (E) Arthroscopic view (anterolateral portal) of the penetrating grasper pierced into the capsule to retrieve the looped portion of the guide suture. (F) Double-strand Orthocord suture (yellow arrows) is passed through the patellar tunnel 2 along the guide suture (white arrow). (G) Arthroscopic view (anterolateral portal) of the Orthocord suture (yellow arrow) exiting the capsule. (H) A suture retriever (red arrow) is used to retrieve a free end of the Orthocord suture and pull it back via the medial incision. (I) Two limbs (white arrows) of the suture bundle both exit the medial incision. Point B, the midpoint of the superior patella.

recurrent dislocations and no significant differences in PROMs were found between the 2 techniques. Recent biomechanical studies illustrated that suture tape augmentation of the MPFL resulted in similar contact pressures and joint kinematics compared with MPFL-R.[16,24] Therefore, MPFL augmentation may provide a

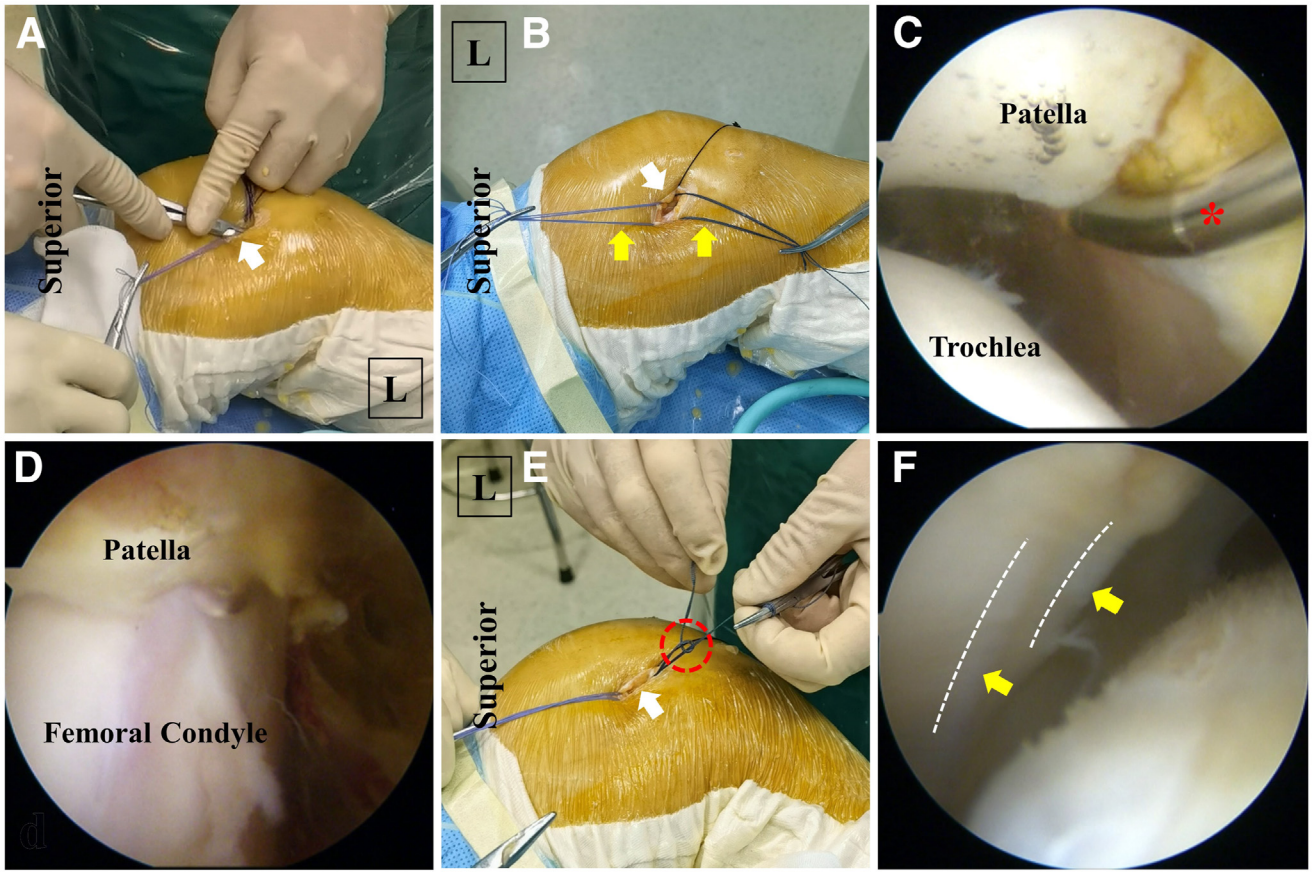

Fig 6. Physeal-sparing suture fixation at femoral origin and arthroscopic re-examination. The patient is placed supine on the operating table (left knee). An anterolateral portal and an anteromedial portal are established. (A) Through a medial incision (white arrow), femoral tunnels are made with a half-circle cutting needle, which are located within the sulcus between the adductor tubercle and medial epicondyle and exit the posterior femoral cortex. (B) Orthocord suture bundles (yellow arrows) are introduced into the femoral tunnels along guide suture and pulled out via the medial incision (white arrow). (C) If the lateral restraints are suggested to be excessively tight, a lateral release is performed with coblation and shaver (red asterisk) close to the lateral margin of the patella from inferior to superior. (D) Arthroscopic re-evaluation via the anterolateral portal demonstrates restored patellofemoral congruence during dynamic passive knee movements. (E) To fix the suture bundles, knots (red dotted circle) are tied using 2 ends of each suture bundle at the external opening of each femoral tunnel through the medial incision (white arrow). (F) Intra-articular view (anterolateral portal) of the double-bundle structure (dotted lines and yellow arrows) of the Orthocord suture.

promising alternative to current surgical algorithm of addressing recurrent patellar dislocation in skeletally immature patients.

Sherman et al.[18] first described open MPFL augmentation in children and adolescents in a technical report. Different from the suture anchor technique used by Sherman et al.,[18] the described procedure applies a double-tunnel transosseous suture fixation technique at the femoral origin of the MPFL. No interference screw is used, and the modified femoral tunnels created by cutting needle are small in size, which helps to preserve the integrity of the native femoral attachment to the greatest extent. More importantly, because the needle-created femoral tunnels lead to minimal invasion to the growth plate, the tunnels are not placed proximal or distal to the physis on purpose. Position of the femoral tunnels is only determined by the native insertion of the MPFL, which lies within the saddle sulcus between the AT and the ME.[25] Therefore, the described procedure helps to balance the potential conflicts between physeal preservation and anatomical restoration.

The Orthocord suture is composed of 62% polydioxanone and 38% ultrahigh molecular weight polyethylene, with an average tensile strength of 245 N (55 lbs). As reported by LaPrade et al.,[26] the mean MPFL ultimate failure load value is 178 N. Accordingly, the double-bundle structure with 8 strands of Orthocord suture provides adequate strength to imitate the biomechanical function of the intact MPFL. Moreover, 2 ends of the suture bundle are both fixed on bony structures. In contrast to soft-tissue fixation such as

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
Balance between physeal preservation and anatomic fixation at femoral origin.	The femoral fixation site is determined by palpation without assistance of intraoperative fluoroscopy.
Reliable fixation with 2 ends of the suture bundle lying on bony structures.	Sufficient visualization under arthroscope has a relatively longer learning curve.
Direct visualization of patellar tunnel creation under arthroscope.	
Minimally invasive procedures.	

medial retinacular plasty, the bone tunnel technique ensures the reliability and durability of graft fixation.

In addition, the described procedure is arthroscopically assisted and performed outside the synovium. The introduction of arthroscopy avoids longitudinal parapatellar incisions and directly visualizes the positioning and creation of patellar tunnels. No autologous tendons are required and minimal damage is caused to the surrounding soft tissue, namely, the articular capsule and the adductor magnus. This minimally invasive surgery tends to be more acceptable to pediatric patients and their parents. Fu et al.[27] suggested that the femoral trochlear morphology could be improved by early surgeries before epiphyseal closure in children with recurrent patellar dislocation. Therefore, this procedure may help to promote early surgical intervention in younger populations and prevent irreversible morphological changes of the patellofemoral joint.[28]

Despite the preliminary characteristics of this technique, there are some pitfalls that should be taken into consideration (Table 1). First, since Orthocord sutures are partially absorbable and may wear over time, long-term follow-up and further assessment of graft kinematics will be warranted. Second, the tension on and the isometry of the Orthocord suture bundle should be carefully evaluated before fixation to avoid potential suture cutting through the femoral tunnel and restricted range of motion. Third, the described technique especially suits patients with open femoral physes, which are assessed by plain radiographs before surgery. For skeletally mature patients, we still prefer to perform MPFL reconstruction with autograft.

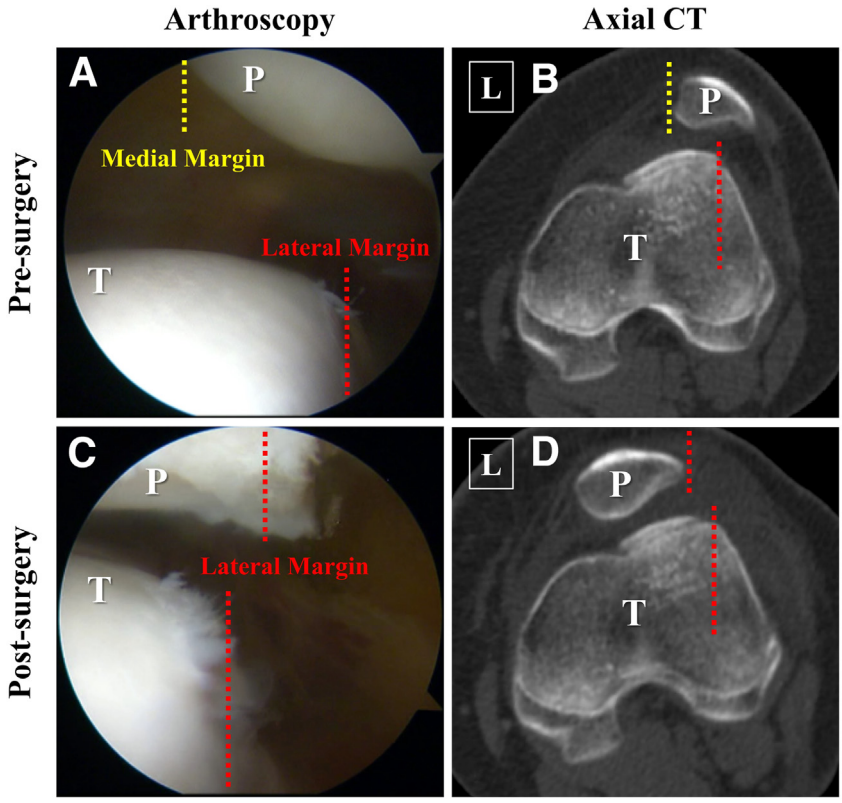

Fig 7. Comparison of patellofemoral congruence pre- and postsurgery (left knee). (A and C) Intraoperative assessments under arthroscopy. (B and D) Imaging evaluation with axial CT. Arthroscopic evaluation and CT images both demonstrate that the patellofemoral congruence is restored after MPFL augmentation. Yellow dotted line demonstrates the medial margin of the patella, whereas the red dotted line refers to the lateral margin of the patella or the trochlear facet. CT, computed tomography; MPFL, medial patellofemoral ligament; P, patella. T, trochlea.

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