Technical Note

Precise Arthroscopic Mini-trochleoplasty and Medial Patellofemoral Ligament Reconstruction for Recurrent Patellar Instability With Severe Trochlear Dysplasia

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Abstract: More than 100 surgical procedures have been reported to address recurrent patellar instability. Trochlear dysplasia is the most common finding among the anatomic risk factors for recurrent patellar instability. Various studies have shown that trochleoplasty combined with medial patellofemoral ligament reconstruction is an effective technique to treat recurrent patellar instability. Nevertheless, trochleoplasty is still a daunting procedure for surgeons because of its multiple and gloomy complications. This article introduces a technique to treat recurrent patellar instability with severe trochlear dysplasia: precise arthroscopic mini-trochleoplasty (PAM trochleoplasty) combined with medial patellofemoral ligament reconstruction. This technique precisely removes the supratrochlear spur and trochlear bump, accurately reshapes the trochlear sulcus with minimal invasion and less osteotomy volume, and keeps the sulcus cartilage intact. The purpose of this technique is to develop trochleoplasty into a common and safe technique, which has good outcomes and low complications.

Patellar instability is a common problem that typically occurs in an adolescent population.[1] Approximately 50% of patients who experience subsequent patellar dislocation have recurrent patellar instability. Trochlear dysplasia is the most common finding among the anatomic risk factors for recurrent patellar instability in both adolescents and adults. Dejour et al.[2] found that trochlear dysplasia was present in 90% of cases with patellar instability. The procedure of open trochleoplasty combined with medial patellofemoral ligament (MPFL) reconstruction delivers good clinical results in the treatment of recurrent patellar instability.[3,4] However, trochleoplasty is still an uncommon and challenging surgical procedure, given that various complications compromise the outcomes of open trochleoplasty, with reports of knee arthrofibrosis in up to nearly 30% of cases, failure in up to 20% of cases,[5] and a reoperation rate of 25%[6] in some studies of this technique.

In this article, we describe our technique of precise arthroscopic mini-trochleoplasty (PAM trochleoplasty) and MPFL reconstruction to treat recurrent patellar instability with severe trochlear dysplasia. We suppose that PAM trochleoplasty may dramatically improve the complications of open trochleoplasty owing to the precise removal of the supratrochlear spur and trochlear bump, accurate reshaping of the trochlear sulcus, minimal invasion and osteotomy volume, and ability to maintain the cartilage and capsule integrity in this arthroscopic trochleoplasty.

Technique

A demonstration of the surgical technique is provided in Video 1. The indications and contraindications are presented in Table 1. Surgical steps are summarized in Table 2. Pearls and pitfalls are presented in Table 3. Advantages and limitations are summarized in Table 4.

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Preoperative Assessment

It is imperative that the preoperative case history is collected and a clinical examination and imaging are performed (Figs 1 and 2) to determine what surgical procedures should be performed (Table 1). All included patients have a history of recurrent patellar dislocation or subluxation. This is an indication for MPFL reconstruction because the MPFL is ruptured or deteriorated owing to recurrent patellar instability. The physical examination findings, including apprehension, medial and lateral patellar glide, and the J sign, are recorded.

Standard lateral radiographs and a computed tomography (CT) scan are useful to evaluate the trochlear morphology and to categorize trochlear dysplasia according to the Dejour classification.[2] In cases with severe trochlear dysplasia, including Dejour types B, C, and D, sulcus-deepening PAM trochleoplasty is considered (Figs 1A and 2A). Preoperative 3-dimensional CT is helpful to observe the fine shape of the supratrochlear spur, trochlear bump, and dysplastic trochlear groove in detail for the design of the new groove (Figs 1C and 2C). It is important to guide the procedures in PAM trochleoplasty to delicately and accurately burr the bone under the osteochondral flap. The CT scan provides information regarding the patellar tilt angle and sulcus angle. In cases with a patellar tilt angle greater than 20°, a lateral retinacular release can be considered. Standard lateral radiographs are useful to assess the Caton-Deschamps index ratio, which evaluates patella alta. In cases with a Caton-Deschamps index ratio greater than 1.3, a distalizing tibial tubercle transfer is suggested as a combined surgical procedure. The CT scan is useful in assessing the tibial tubercle—trochlear groove (TT-TG) distance. In cases with a TT-TG distance greater than 24 mm, a medializing tibial tubercle transfer is considered as a combined surgical procedure, whereas a minimally elevated TT-TG distance of less than 24 mm can be normalized by PAM trochleoplasty because the creation of a new trochlear sulcus can lateralize the groove by at least 5 mm.

Open physes, patellofemoral osteoarthritis (OA), and trochlear chondral defects are contraindications. Magnetic resonance imaging is helpful to find chondral defects or patellofemoral OA, in which brittle trochlear cartilage suggests that the osteochondral flap would crack and not be fixed during trochleoplasty.

Examination Under Anesthesia

After induction of general anesthesia, the patient is positioned supine on the operating table. Before the operation, examinations including patellar glide, lateral tilt, the J sign, and patellar tracking are performed to evaluate patellar instability. After a well-padded high-thigh tourniquet is applied, the operative leg is prepared and draped in sterile fashion without a leg holder.

Diagnostic Arthroscopy

Through standard anterolateral and anteromedial portals, diagnostic arthroscopy is performed with a 30° arthroscope (Smith & Nephew, Andover, MA). The shape of the femoral trochlea, patellar alignment and position, patellar tilt, maltracking, and the J sign, as well as the degree to which the patella is riding over the lateral femoral condyle, are evaluated and recorded. Any concomitant intra-articular pathology is addressed. Loose bodies and unstable cartilage flaps are removed. Chondroplasty is performed if needed.

Trochleoplasty

Theoretically, with the knee in extension, the patellar spine is on the medial side of a virtual line from the anterior superior iliac spine to the tibial tubercle. With a needle used as a guide and inserted into the joint at the cross of this virtual line and the superolateral border of the patella, the lateral edge of the entrance of the newly created trochlear groove is marked by a radiofrequency device on the soft tissue and cartilage proximal to the trochlea. Then, at 10 to 15 mm medial to the marker of the lateral edge of the new groove, another marker is established as the trough of the new groove (Fig 3).

Deepening of Sulcus and Osteochondral Flap Creation. Additional superolateral and superomedial portals are established to facilitate visualization and maneuvering (Fig 4A). Then, the surgeon changes his or her position to the proximal side of the patient's knee and beside the patient's thigh (Fig 4B, Video 1). The patient's hip is positioned in 30° of external rotation and the knee is positioned in 20° of flexion for maneuvering during PAM trochleoplasty. A 10-mm-wide zone is debrided proximal to the trochlea, and the anterior femoral cortex is exposed (Fig 5B). Using a 4-mm high-speed burr (Smith & Nephew) and small (6-mm) chisel, the surgeon creates a trough for the new subchondral groove shaped like a deep tunnel toward the intercondylar notch (Fig 5C). Then, using a 2-mm high-speed burr (Smith & Nephew) and 6-mm chisel, the surgeon widens the tunnel toward the lateral and medial sides and establishes the border of the new groove under the osteochondral flap. During the 2 aforementioned steps, the supratrochlear spur and trochlear bump are removed. By making numerous tiny bone fractures with the 6-mm chisel at the border of the new subchondral sulcus (Fig 6B) and trimming the border with the 2-mm high-speed burr and a small curette, a well-shaped new groove is created. According to preoperative 3-dimensional CT, the subchondral bone inside or outside the new trochlear sulcus can be discriminated. With monitoring under arthroscopy and the use of delicate instruments, these 2 different portions of subchondral bone are

Table 1. Indications and Contraindications

Indications
Recurrent patellar instability
Dysplastic trochlea (Dejour type B, C, or D)
TT-TG distance < 24 mm
Contraindications
Primary patellar dislocation
Normal or Dejour type A dysplastic trochlea
Open physes
Trochlear chondral defects or brittle cartilage

TT-TG, tibial tubercle—trochlear groove.

removed or held in reserve. Leaving 1 or 2 mm of subchondral bone attached to the osteochondral flap may help bone healing and avoid chondrolysis or necrosis. The cancellous bone outside the new groove beneath the osteochondral shell should be protected so that the height of the ridges of the original condyles can be maximally reserved.

Fixation of New Trochlea. Punching a coffee spoon or a thick stick, the surgeon makes the osteochondral flap malleable enough to be bent into the shape of the new groove and to be flush with the anterior femoral cortex, carefully avoiding breaking the cartilage (Fig 7C). A 4.5-mm Twinfix PK suture anchor (Smith & Nephew) is placed 10 mm proximal to the apex of the intercondylar notch. Fixation of the osteochondral flap is achieved with two 4.5-mm Footprint PK anchors (Smith & Nephew) proximal to the entrance of the new groove, with the flap being intensively pressed onto subchondral bone to achieve rapid bone healing (Figs 6 and 7). Three months after the operation, the nonabsorbable sutures should be removed under arthroscopy.

On reassessment of the new trochlear sulcus, a deep, well-shaped, lateralized groove can be observed (Fig 7E). The original flat trochlea, supratrochlear spur, and trochlear bump are replaced by a deep trochlear groove.

Lateral Retinacular Release. The procedure for lateral release depends on the findings of medial patellar glide on preoperative assessment. In the case of a medial patellar glide of less than 1 quadrant, full-thickness lateral retinacular release is performed from the superior pole of the patella to the inferior pole at 1 cm lateral to the patella. In the case of a medial patellar glide of more than 1 quadrant but less than 2 quadrants with a patellar tilt angle greater than 20°, partial release is performed. In the case of more than 2 quadrants, no release is performed. After debridement of the lateral synovium of the patella by a 4.5-mm soft-tissue shaver, through the anterolateral portal, a radiofrequency device is used to perform lateral retinacular release.

MPFL Reconstruction

Graft Harvest. Through a 2-cm incision at the level of the pes anserinus, the semitendinosus tendon is identified and harvested using a closed tendon stripper. The tendon is prepared, and the 2 ends of the tendon are stitched in standard baseball running fashion with No. 1 Vicryl suture (Ethicon, Somerville, NJ). Typically, the graft is between 22 and 28 cm in length and 6 mm in diameter.

Graft Fixation. Along the medial edge of the proximal half of the patella, a 2-cm longitudinal incision is made to the level superior to the capsule. The periosteum of the

Table 2. Surgical Steps

Patient Positioning, Graft Preparation, and Diagnostic Arthroscopy
Place the patient supine without placing a leg holder on the operative leg.
Harvest and prepare the semitendinosus tendon.
Perform diagnostic arthroscopy and assess the shape of the femoral trochlea, patellar position, patellar tilt, maltracking, and concomitant pathology.
Trochleoplasty
Mark the trough and lateral edge of the new trochlear groove.
Through superolateral and superomedial portals, debride a 10-mm-wide zone proximal to the trochlea.
Using a 4-mm burr, create the trough for the new subchondral groove shaped like a deep tunnel. Remove the supratrochlear spur and trochlear bump, and reserve the trochlear ridges.
Using a 2-mm burr and small chisel, trim the subchondral bone at the borders of the new trochlear ridges to make the flap malleable enough to be bent into the position of the new groove.
Punching a coffee spoon, mold the osteochondral flap onto the new groove.
Place a 4.5-mm Twinfix PK suture anchor 10 mm proximal to the apex of the notch. Fix the osteochondral flap with two 4.5-mm Footprint PK anchors proximal to the new groove.
MPFL reconstruction
Release the lateral retinaculum. Reassess the patellar position and tracking.
Fix the graft on the medial edge of the patella with two 3.5-mm Twinfix TI suture anchors.
Using intraoperative C-arm fluoroscopy, place a guide pin at the Schöttle point on the medial femoral condyle.
After assessing graft tension between full extension and flexion of the knee to avoid graft over-tightening medially, fix the graft at the Schöttle point with a 7-mm screw.
Reassess the shape of the new trochlea, patellar position and tracking, and reconstructed MPFL through the anterolateral portal.
Place the patient in a hinged-knee brace.

MPFL, medial patellofemoral ligament.

Table 3. Pearls and Pitfalls

Pearls
Thorough preoperative assessment is very helpful for guidance of precise mini-trochleoplasty. Preoperative 3D CT provides information on the position and fine shape of the supratrochlear spur and trochlear bump in detail.
The position of the additional superolateral and superomedial portals can be adjusted to facilitate performing trochleoplasty.
For most patients, positioning the knee in extension is not the best position for arthroscopic trochleoplasty. The patient's hip should be positioned in 30° of external rotation and the knee should be positioned in 20° of flexion to facilitate maneuvering during trochleoplasty.
Before trochleoplasty, marking the trough and lateral edge of the new trochlear groove is important.
With monitoring under arthroscopy and the use of a 2-mm burr, small chisel, and other delicate arthroscopic instruments, the new groove can be created precisely according to the design on preoperative 3D CT.
Leaving 1 or 2 mm of subchondral bone attached to the osteochondral flap may help bone healing and avoid chondrolysis or necrosis.
Maximally reserving the height of the ridges of the original condyles can provide stability to the patella.
The surgeon should use caution to prevent breaking the osteochondral flap, which is sometimes brittle.
The osteochondral flap is made malleable to be bent into the shape of the new groove and flush with the anterior femoral cortex so that the flap can be intensively fixed on bone to achieve rapid bone healing and avoid cartilage necrosis.
The surgeon should create a tunnel at the Schöttle point on the femoral condyle to accomplish an anatomic MPFL reconstruction.
The guide pin should be drilled in a proximal direction to avoid the two 4.5-mm Footprint PK anchors used to fix the osteochondral flap.
MPFL graft tension should be assessed before fixation in the femoral tunnel with the knee in 90° of flexion.
Pitfalls
Overlooking the information from preoperative MRI about chondral defects or patellofemoral osteoarthritis may result in a disaster during trochleoplasty.
Without referral to the marks under arthroscopy, the creation of the new groove beneath the osteochondral flap would lose orientation, which would compromise precise arthroscopic mini-trochleoplasty (PAM trochleoplasty); this is the most difficult procedure.
Breakage of the osteochondral flap can occur with rough maneuvering. Delicate surgical skill is needed to protect the flap and cartilage during arthroscopic trochleoplasty.
An osteochondral flap that is not malleable enough to be bent or unfastened fixation may result in chondrolysis, cartilage necrosis, or nonunion.
Full-thickness lateral retinacular release may result in overloosening and medial instability of the patella in some cases. The selection of lateral release depends on the findings of medial patellar glide on preoperative assessment.
Over-tensioning the MPFL graft may result in medial instability of the patella and an increase in patellofemoral joint pressure.

CT, computed tomography; MPFL, medial patellofemoral ligament; MRI, magnetic resonance imaging; 3D, 3-dimensional.

proximal third of the medial aspect of the patella is detached with a sharp elevator to create a base of a bleeding bony facet for graft fixation. Two 3.5-mm Twinfix TI anchors (Smith & Nephew) are inserted into the superior half of the medial patellar facet just off the patellar cartilage. Then, the prepared graft is fixed on bone with the sutures of these 2 anchors (Fig 8A).

A 2-cm longitudinal incision is made between the adductor tubercle and the medial femoral epicondyle (Fig 8B). With the capsule being kept intact, dissection is carried out to the level of the periosteum in the saddle area between the adductor tubercle and the medial femoral epicondyle. By use of intraoperative C-arm fluoroscopy to locate the Schöttle point[7] on a standard lateral view of the knee, a 2.4-mm guide pin is drilled through the Schöttle point in a proximal direction to avoid the 2 previously placed 4.5-mm Footprint PK anchors used to fix the osteochondral flap (Fig 8 C and D). Then, the guide pin exits through the lateral facet of the femur.

After the creation of a soft-tissue tunnel between layer 2 and layer 3 of the medial area of the patella, the graft is guided to pass through the tunnel with a suture loop or straight forceps. Two limbs of graft are looped around the root of the guide pin to assess the graft tension between full extension and flexion of the knee

Table 4. Advantages and Limitations

Advantages
Compared with open trochleoplasty, the described technique is minimally invasive.
This minimal osteotomy technique precisely removes the supratrochlear spur and trochlear bump and reserves the trochlear ridges so that it is unnecessary to place bone fragments under the osteochondral flap after burring to maintain the height of the trochlear ridges and a normalized sulcus angle.
During the entire trochleoplasty procedure, the cartilage of the groove remains intact, and it is unnecessary to make an extra cut on the cartilage to fit a new position. This provides rapid healing.
Mini-trochleoplasty creates a small osteochondral flap so that minimal implantation for trochlear fixation is required. Sometimes, the use of 2 anchors on the proximal and distal sides of the flap and 1 suture between them is enough.
Rapid and easy rehabilitation is possible. Because the joint capsule is intact during arthroscopic procedures, less arthrofibrosis occurs.
Limitations
The technique has a relatively longer learning curve.
A deformed view under arthroscopy may be misleading when performing trochleoplasty.
The technique cannot be combined with procedures for elevation of the lateral facet of the femoral condyle.

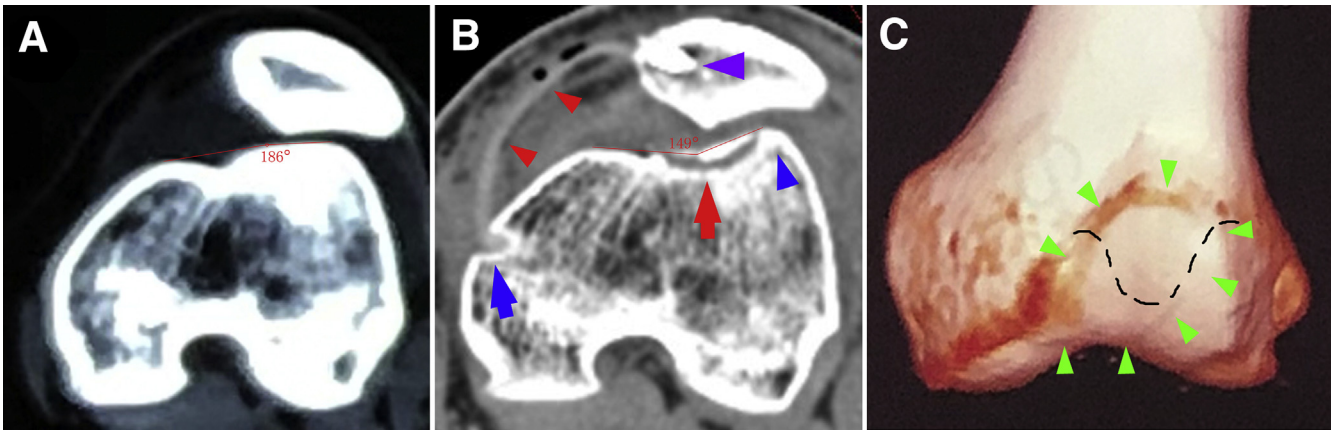

Fig 1. Left knee. (A) A preoperative axial computed tomography image shows patellar tilt and a Dejour type B dysplastic trochlea with an abnormal sulcus angle of 186°. (B) Postoperatively, patellar tilt, the sulcus angle, and trochlear dysplasia are obviously improved. The lateral ridge (blue arrowhead) is well preserved during precise arthroscopic mini-trochleoplasty (PAM trochleoplasty). The new groove (red arrow) with a sulcus angle of 149°, the femoral tunnel (blue arrow), and a 3.5-mm anchor (purple arrowhead) inserted into the patella for fixation of the reconstructed medial patellofemoral ligament (red arrowheads) can be seen. (C) The trochlear bump (green arrowheads) is identified and the ideal shape of the new groove (black dashed line) is designed on preoperative 3-dimensional computed tomography.

(Fig 8D). Because maximum tension is observed at 90° of flexion, the position on the 2 limbs looped around the pin is marked when the graft is tensioned at roughly 0.5 lb of force to avoid over-tightening. A 25-mm-deep bone tunnel is created by a 6-mm cannulated reamer over the 2.4-mm guide pin. With a guide pin, Vicryl suture stitched onto the 2 limbs of graft is introduced into the bone tunnel and exits through the lateral skin of the thigh. With the knee in 90° of flexion, the graft is tensioned at roughly 0.5 lb of force and fixed at the previous mark on the limbs by a 7-mm absorbable interference screw in the femoral bone tunnel. In the full cycle of knee motion, the new tracking and stability of the patella are assessed. At full extension, medial and lateral 1- to 2-quadrant glides are observed.

Arthroscopic Evaluation. Under arthroscopy, the shape of the new trochlear sulcus, patellar alignment and position, and patellar tracking are reassessed and recorded. The absence of patellar tilt, maltracking, and overhang is observed (Video 1). Furthermore, the tensioned reconstructed MPFL and new patellar tracking are found to be congruent with the new groove.

Postoperative Rehabilitation

Postoperatively, the patient is placed in a knee brace for 6 weeks. During the first 3 postoperative days, the knee is immobilized in 20° of flexion. The brace is set at 0° to 60° on day 4 and then at 0° to 90° from week 2 to week 4; unrestricted range of motion (ROM) is allowed after week 4. Quadriceps exercises and ankle pumps are started

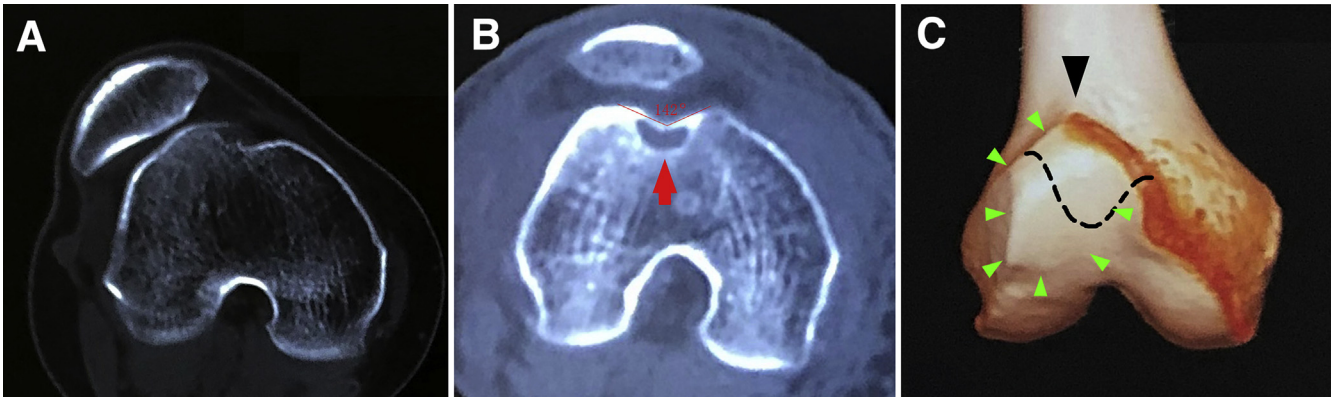

Fig 2. Right knee. (A) A preoperative axial computed tomography image shows patellar subluxation and a Dejour type D dysplastic trochlea with an abnormal sulcus angle. (B) Postoperatively, patellar subluxation, the sulcus angle, and trochlear dysplasia are obviously improved. The new groove (red arrow) has a normal sulcus angle of 142°. (C) The trochlear bump (green arrowheads) and supratrochlear spur (black arrowhead) are identified and the ideal shape of the new groove (black dashed line) is designed on preoperative 3-dimensional computed tomography.

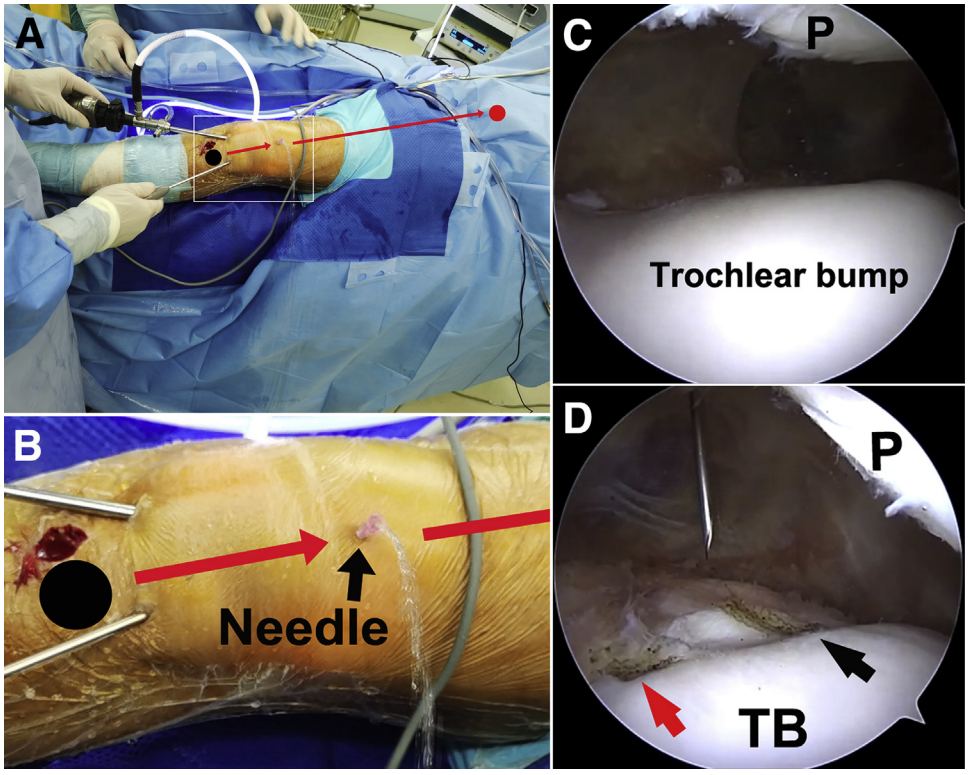

Fig 3. Left knee. (A) The lateral edge of the new trochlear groove is located by a guide needle inserted into the joint at the cross of the superolateral border of the patella and a virtual line (red arrows) from the tibial tubercle (black circle) to the anterior superior iliac spine (red circle). (B) Magnification of white rectangle in A. (C) Observation of patellar overhang and trochlear bump from anterolateral portal. (P, patella.) (D) With visualization from the anteromedial portal and guidance by the needle proximal to the patella (P), the lateral edge (black arrow) and trough (red arrow) of the new trochlear groove are marked.

immediately after the operation, whereas straight-leg raises start on day 4. The patient remains non–weight bearing for 2 weeks; partial weight bearing is then allowed from weeks 2 to 5, followed by full weight bearing after week 5. Return to a normal level of sports activity is allowed by 6 to 9 months postoperatively.

Discussion

Over 100 surgical procedures have been reported to treat recurrent patellar instability. In recent years, a variety of studies have shown that trochleoplasty combined with MPFL reconstruction is an effective technique for addressing recurrent patellar instability.[3,4] The MPFL is thought to be the most important structure preventing patellar dislocation.[8] In acute patellar dislocation, MPFL injury or contusion of the MPFL attachments can be observed, thus implying a ruptured or deteriorated MPFL owing to recurrent patellar instability. Many studies have reported that MPFL reconstruction yields good results in terms of preventing future dislocations.[9]

Today, open trochleoplasty techniques include (1) lateral-facet elevation trochleoplasty, which deepens the trochlear groove by elevating the lateral facet of the femoral condyle and was first reported by Albee; (2) sulcus-deepening trochleoplasty, which includes

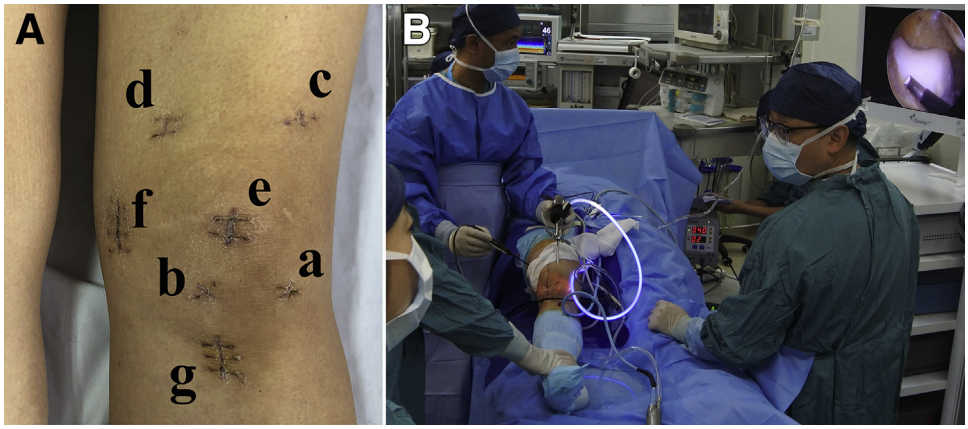

Fig 4. (A) Anterolateral (a), anteromedial (b), superolateral (c), and superomedial (d) portals and mini-open incisions for medial patellofemoral ligament reconstruction (e and f) and graft harvest (g) in left knee. (B) The surgeon stands on the proximal side of the patient's right knee to facilitate visualization and maneuvering for arthroscopic trochleoplasty through the superolateral and superomedial portals.

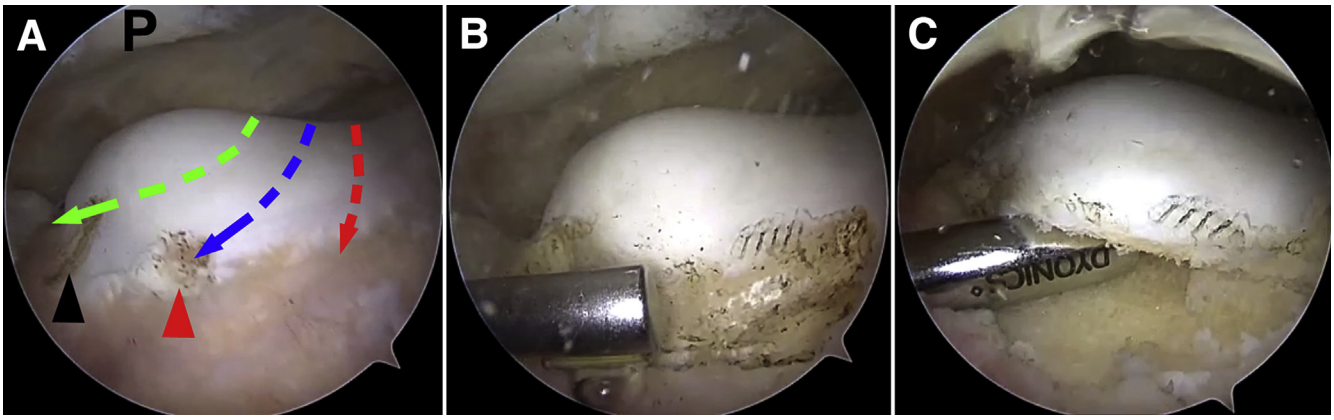

Fig 5. Left knee viewed from superomedial portal. (A) The original groove (red arrow) and the lateral edge (green arrow) and trough (blue arrow) of the new groove, directed by the previously made marks (black and red arrowheads), are identified. (P, patella.) (B) Debridement of a 10-mm-wide zone proximal to the trochlea. (C) Removal of cancellous bone by a high-speed burr.

2 types, Dejour sulcus deepening ("Lyon procedure") with a thick osteochondral flap and V-shaped osteotomy[10] and Bereiter-Gautier subchondral sulcus deepening with a thin osteochondral flap and U-shaped osteotomy[11]; and (3) recession wedge trochleoplasty.[12] The first 2 trochleoplasty procedures have been the most commonly used techniques in recent years. Trochleoplasty, as a solitary or concomitant treatment for recurrent patellar instability, is associated with significantly improved stability and function.[4,11,13] Nevertheless, trochleoplasty is still a daunting procedure for surgeons because of its multiple and gloomy complications. A 15-year follow-up study of trochleoplasty reported that 20% of patients had total failure and 23% of

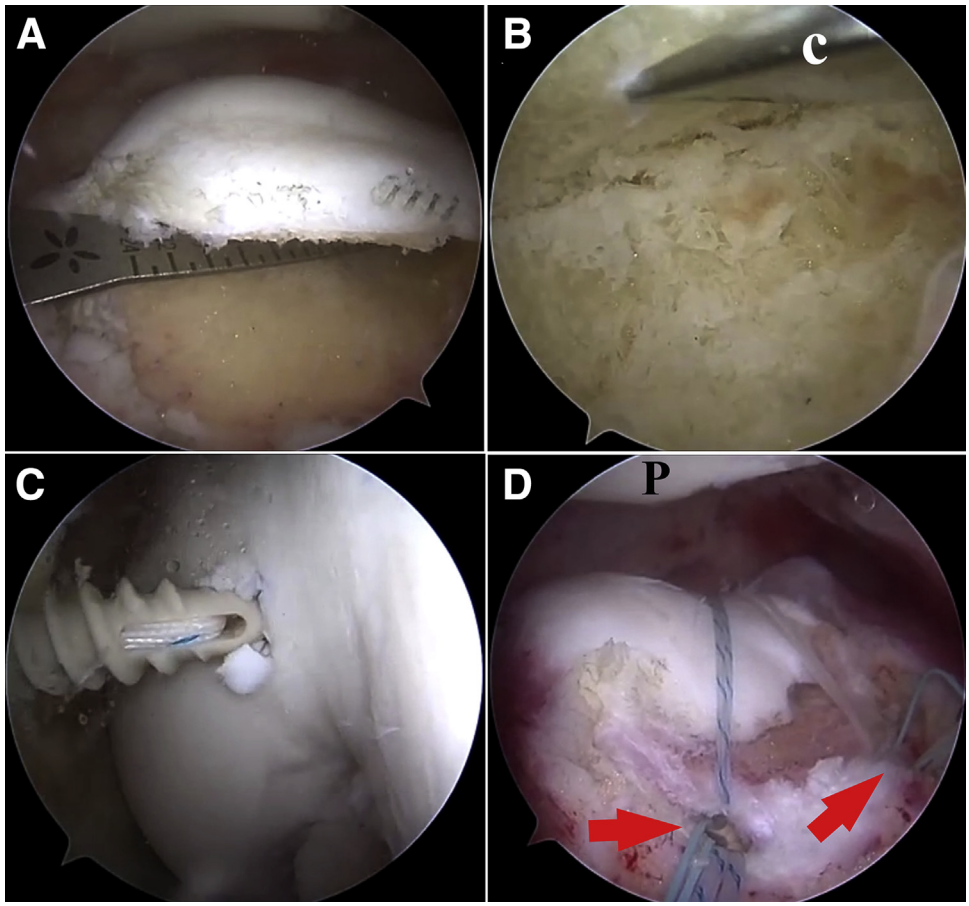

Fig 6. Left knee. (A) Viewing from the superomedial portal, a groove of the designed shape and size is roughly created. (B) Viewing from the superolateral portal, numerous tiny bone fractures are made by a 6-mm chisel (c) at the border of the new sulcus. (C) Viewing from the anterolateral portal, a 4.5-mm anchor is placed 10 mm proximal to the apex of the notch. (D) Viewing from the superolateral portal, with two 4.5-mm Footprint anchors (red arrows) proximal to the new groove, the flap is intensively pressed onto bone. (P, patella.)

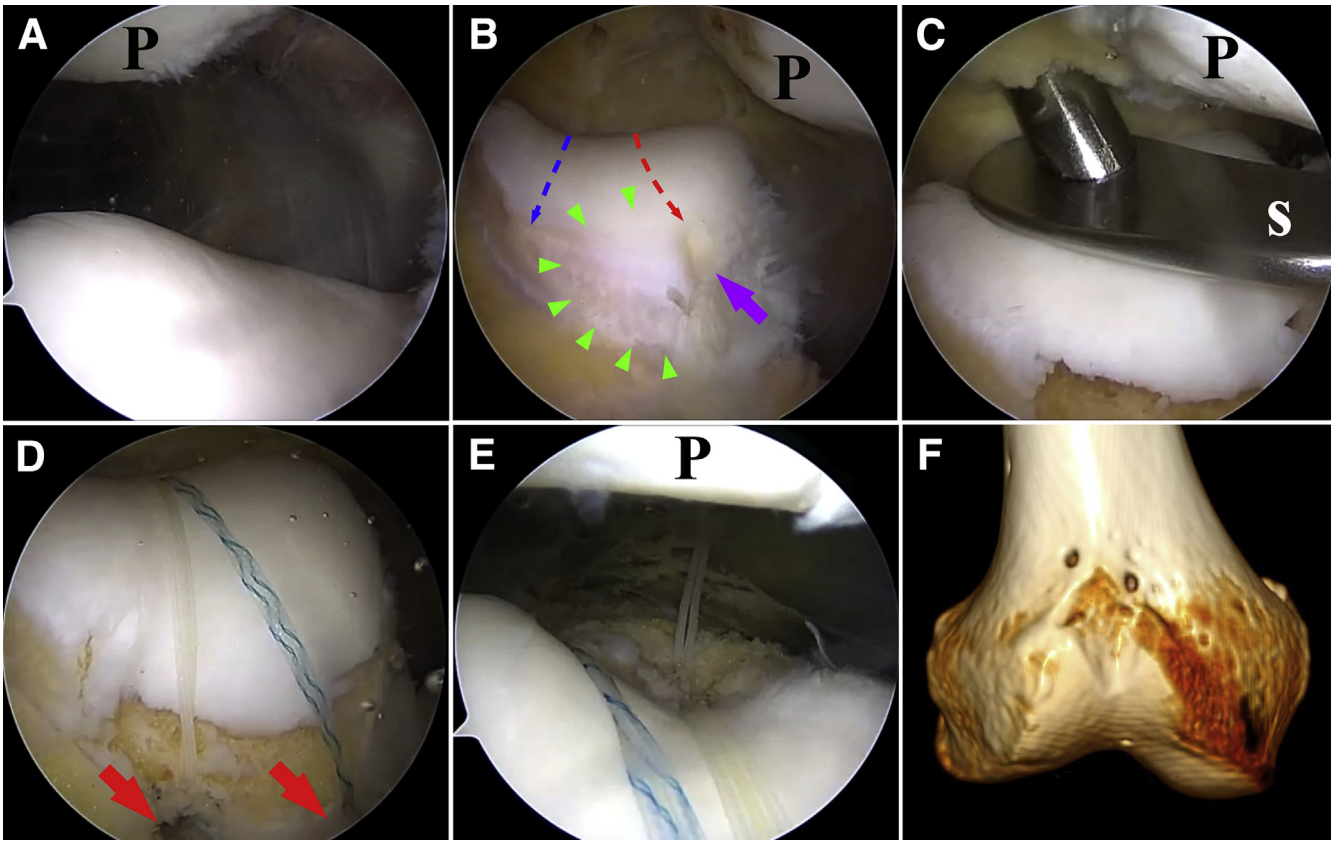

Fig 7. Right knee. (A) Patellar tilt and a flat trochlea are observed from the anterolateral portal. (B) Viewing from the superolateral portal, the supratrochlear spur (green arrowheads), original groove (blue arrow), and lateral edge (red arrow) of the new groove directed by the previously made mark (purple arrow) are identified. (C) Viewing from the superomedial portal, punching a coffee spoon (s), the osteochondral flap is made malleable to be bent. (D) Viewing from the superomedial portal, intensive fixation of the flap is achieved by two 4.5-mm Footprint anchors (red arrows) proximal to the new groove. (E) View from anterolateral portal showing well-shaped and normalized groove after trochleoplasty. (F) At 5 months postoperatively, 3-dimensional computed tomography shows the precisely created groove, coinciding with the preoperative plan (Fig 2C). (P, patella.)

patients identified postoperative stiffness at less than 90° of flexion.[5] Even in a systematic review evaluating 14 studies about the 3 most popular trochleoplasty techniques showing a relatively low rate of complications, the overall rate of complications was found to be 40%, including increased pain, loss of ROM, and OA, although the rate of patellar redislocation was only 2%.[13] Trochleoplasty procedures have continued to evolve over recent decades to decrease the associated complications, which is also the purpose of our PAM trochleoplasty technique.

Our PAM trochleoplasty technique is inspired by the Bereiter-Gautier subchondral sulcus-deepening technique,[11] as well as the first arthroscopic trochleoplasty technique reported by Blønd and Schöttle.[14] Compared with other types of trochleoplasty, the PAM trochleoplasty technique has some advantages: (1) Minimal invasion results postoperatively in less scar tissue, as well as less pain and possibility of loss of ROM. Both the capsule and cartilage of the groove remain intact, and it is unnecessary to make an extra cut on the cartilage to fit a new position (Video 1, Figs 6D and 7D), which is a regular procedure in the Dejour sulcus-deepening technique and recession wedge trochleoplasty.[10,12] Theoretically, if less invasion of the cartilage and osteotomy volume occurs, less arthrofibrosis will occur. (2) In the case of sulcus-deepening trochleoplasty and recession wedge trochleoplasty, osteotomy reduces the height of the trochlear ridges. Even in arthroscopic trochleoplasty performed as described by Blønd and Schöttle, the height of the lateral and medial ridges decreases with burring. It is unnecessary to remove the subchondral bone at the ridges in PAM trochleoplasty; hence, with monitoring under arthroscopy and the use of delicate instruments, the cancellous bone outside the new groove beneath the osteochondral shell is skillfully protected, and the height of the ridges of the original condyles is maximally reserved (Figs 1B, 2B, 6D, and 7 D-F). Preservation of the lateral-ridge height gives more osseous constraint to the patella in extension and early flexion. Furthermore, the normalized sulcus angle increases patellar stability. (3) The osteotomy volume (bone loss) is much less than that

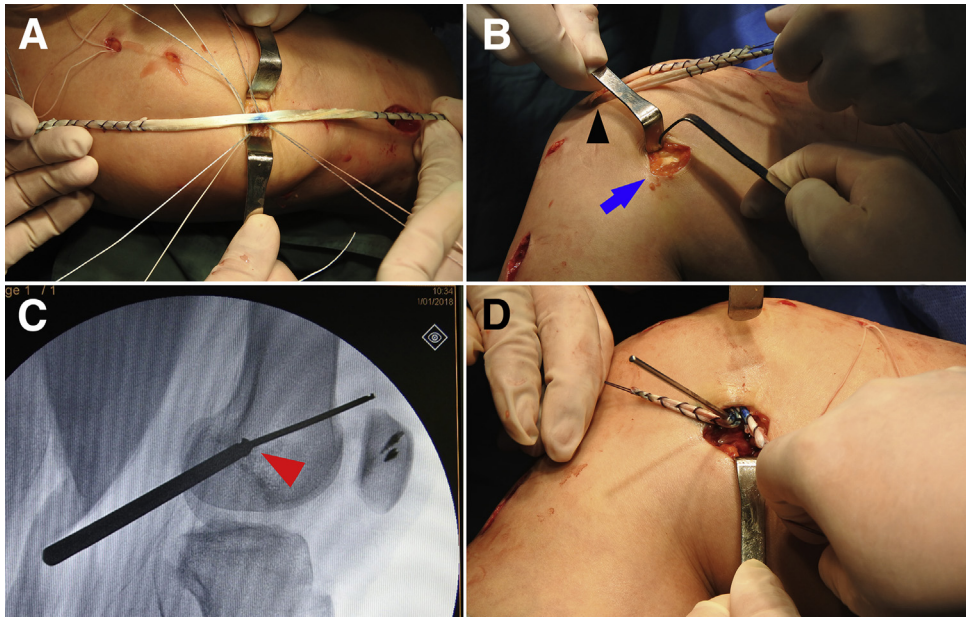

Fig 8. Right knee. (A) After two 3.5-mm anchors are inserted into the medial patellar facet, the graft should be fixed on bone with the sutures of these 2 anchors. (B) After graft fixation on the patellar side (black arrowhead), a 2-cm incision (blue arrow) is made between the adductor tubercle and medial femoral epicondyle for femoral tunnel preparation. (C) C-arm fluoroscopy is used to locate the Schöttle point (red arrowhead) for drilling of a 2.4-mm guide pin. (D) The 2 limbs of the graft are looped around the root of the guide pin to assess graft tension between full extension and flexion.

in open sulcus-deepening trochleoplasty. The osteotomy volume was 26% lower in a case that we treated by PAM trochleoplasty (Fig 9) than in a case that we treated using open Bereiter-Gautier sulcus-deepening trochleoplasty. (4) PAM trochleoplasty modifies the fixation procedures used for the osteochondral flap in the arthroscopic trochleoplasty technique described by Blønd and Schöttle. The osteochondral flap is intensively pressed onto subchondral bone and flush with the anterior femoral cortex, so the flap may achieve rapid bone healing and avoid chondrolysis or cartilage necrosis.

In the techniques of lateral-facet elevation trochleoplasty, Dejour sulcus-deepening trochleoplasty, and recession wedge trochleoplasty, except for the cut in the middle of 2 flaps, the fine shape of the original cartilage surface on the sulcus does not change. On the contrary, in the techniques of Bereiter-Gautier sulcus-deepening trochleoplasty and PAM trochleoplasty, the thin cartilage flaps are molded malleable enough to fit the new groove more smoothly in fine shape. Previous studies of trochleoplasty have shown that OA is a common complication,[5,13,15] which may be associated with patellofemoral incongruence caused by the trochleoplasty technique. Theoretically, in minute structure, when the new trochlear groove is more congruent with patellar tracking, less impingement will occur between the new sulcus and patella, which may result in the occurrence of less OA and less postoperative pain. After a change in fine shape, with

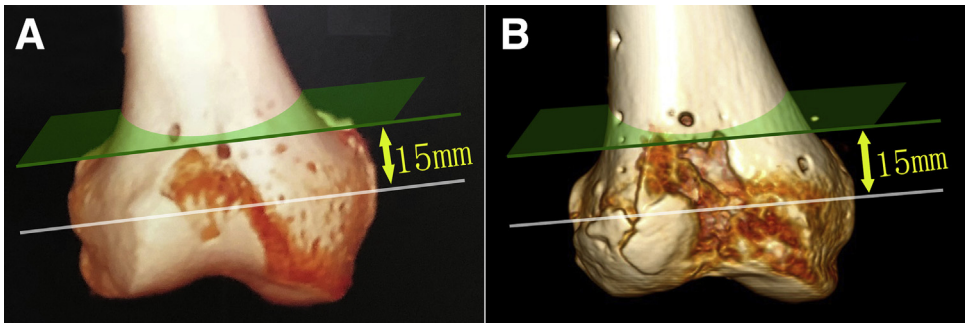

Fig 9. Postoperative 3-dimensional computed tomography images of right knees: comparison of osteotomy volume (bone loss) after precise arthroscopic mini-trochleoplasty (PAM trochleoplasty) (A) and open Bereiter-Gautier trochleoplasty (B) performed by same surgeon. The green plane perpendicular to the anterior femoral cortex and 15 mm proximal to the parallel white line between the lateral and medial femoral epicondyles cuts the femur. (A) In the PAM trochleoplasty case, the bone volume distal to the green plane (whole condyle) is 12,292.3 mm^3, and the osteotomy volume is 2,034 mm^3, which is 16.5% of the whole condyle. (B) In the open Bereiter-Gautier trochleoplasty case, the bone volume of the whole condyle is 10,382.8 mm^3, and the osteotomy volume is 2,329.7 mm^3, which is 22.4% of the whole condyle. Thus, the osteotomy volume is 26% lower with PAM trochleoplasty (i.e., [22.4% − 16.5%]/22.4%).

the relatively smooth shape of the new groove, PAM trochleoplasty may decrease the rate of complications.

Limitations exist regarding PAM trochleoplasty. It cannot be combined with procedures for elevation or lengthening of the lateral facet of the femoral condyle. The description of some advantages of PAM trochleoplasty is based on a theoretical analysis, which should be evaluated by long-term follow-up studies in the future. We suppose that, on the basis of further studies, PAM trochleoplasty combined with MPFL reconstruction will develop into a common technique for the treatment of recurrent patellar instability, which improves patellar-trochlear congruence in minute structure and decreases complications.

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