Technical Note

Combined Procedure of Arthroscopic Pullout Medial Meniscal Root Repair From Lateral Tibia and Open-Wedge Distal Tibial Tubercle Osteotomy

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Abstract: Pullout repair of medial meniscal posterior root tears (MMPRTs) is generally recommended for patients with well-aligned knees, whereas open-wedge high tibial osteotomy (OWHTO) is often recommended for patients with MMPRTs and varus osteoarthritis. Although the management of MMPRTs with OWHTO has been controversial, retaining meniscal function can be expected through pullout repair. Conventionally, bone tunnels in pullout repair are created from the proximal anteromedial tibia. However, this technique could cause a killer angle of the repaired meniscus and could have a risk of turning the guidewire toward the neurovascular band. Therefore, we create a bone tunnel from the proximal anterolateral tibia combined with open-wedge distal tibial tubercle osteotomy, which can prevent an increase in postoperative patellofemoral contact stress; moreover, the bone tunnel can be created easily from the lateral tibia compared with OWHTO. This Technical Note describes the combined surgical procedure for patients with MMPRTs and varus osteoarthritis, which has advantages including physiological pullout direction of the repaired meniscus, lower risk of neurovascular damage, and placement of a longer plate screw that could interfere with the bone tunnel. We highlight the meticulous consideration given to the interference of the bone tunnel between the osteotomy line and plate screw.

Pullout meniscal root repair is usually recommended for patients with medial meniscal posterior root tears (MMPRTs) and well-aligned knees.[1,2] However, varus knee alignment could cause poor clinical outcomes after medial meniscal posterior root (MMPR) repair alone.[3] Recently, open-wedge high tibial osteotomy (OWHTO) has become a common recommendation for patients with MMPRTs and varus knee alignment or knee osteoarthritis (OA).[4] Some reports have shown that repair of MMPRTs with OWHTO induces a superior healing rate compared with unrepaired MMPRTs according to second-look arthroscopic findings.[4-6]

Conventionally, bone tunnels in pullout meniscal root repair concomitant with OWHTO have been created from the proximal anteromedial tibia; however, this technique can cause a "killer angle" of the repaired meniscus[7] and can turn the guidewire toward the neurovascular band (Fig 1A). Additionally, it might require shorter plate screws because of interference with the bone tunnel. To avoid this, we combine the bone creation technique from the lateral proximal tibia (lateral pullout technique) with open-wedge distal tibial tubercle osteotomy (OWDTO) for varus knees, which easily creates a bone tunnel from the lateral tibia because the lateral bone aperture area of the proximal bone fragment is wider than the OWHTO (Fig 1 C and D). In this article, we emphasize the interference of the bone tunnel between the osteotomy line and screw during combined surgery.

Surgical Technique

Indications

Our technique is indicated in patients with complete MMPRTs and varus knee OA of Kellgren-

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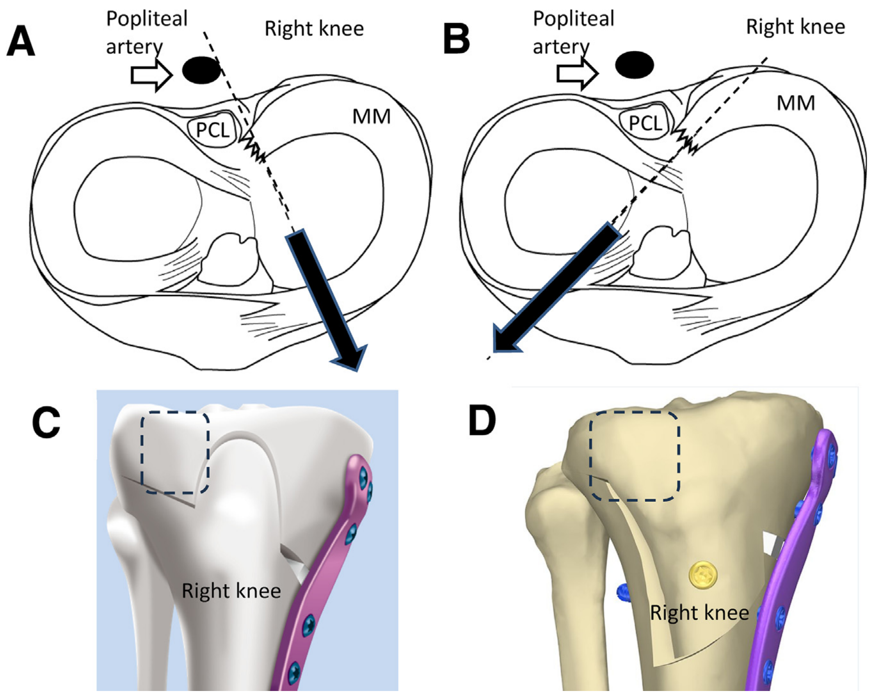

Fig 1. (A) Pullout direction to medial tibia. A risk of turning the guidewire toward the neurovascular band (black ellipse) is present. (B) Pullout direction to lateral tibia. The possibility of neurovascular damage is extremely low. (C, D) Bone space of proximal lateral tibia (dashed rectangles) of open-wedge high tibial osteotomy (OWHTO) (C) and open-wedge distal tibial tubercle osteotomy (OWDTO) (D). The lateral bone fragment of OWDTO could be wider than that of OWHTO. (MM, medial meniscus; PCL, posterior cruciate ligament.)

Lawrence grade 2 or lower, osteonecrosis of the medial femoral condyle, and no patellofemoral-compartment OA (Fig 2A). Magnetic resonance imaging often shows medial meniscal extrusion and chondral damage (Fig 2B). Varus malalignment with the mechanical axis (%MA: calculated as percentage of mechanical axis) is evaluated on whole-leg standing radiographs (Fig 2C).

Surgical Procedures

This surgical technique consists of superficial medial collateral ligament (sMCL) release to open the medial joint space, medial meniscal root repair with the lateral pullout technique and suture relay thread, OWDTO, and fixation of pullout threads at the proximal lateral tibia.

Release of sMCL

With the patient in the supine position, the knee is positioned using the proximal lateral thigh and foot supports, and the contralateral leg is placed lower during osteotomy (Fig 3, Video 1). After skin incision, the pes anserine is cut while leaving the stump, and the sMCL is completely released from the tibia to open the medial joint space.

Arthroscopic MMPR Repair With Bone Tunnel Creation From Lateral Tibia

Arthroscopic Diagnosis and Preparation. Arthroscopic evaluation requires the standard anterolateral and anteromedial portals. The MMPRT is diagnosed using a trans-notch view from the anterolateral portal. The torn meniscal root is easily lifted during probing (Fig 4A, Video 1).

Lateral Pullout Technique. A 2-cm oblique incision is made in the proximal lateral tibia around the Gerdy tubercle. A guide (type H; Smith & Nephew) for bone tunnel creation is introduced through the anteromedial portal, with valgus stress on the knee (Fig 4B, Video 1). The tunnel is aimed at a slightly posteromedial position behind the anatomic footprint. A single bone tunnel is created from the proximal anterolateral tibia using a 2.4-mm guidewire after 4.5 mm of over-drilling (EndoButton reamer; Smith & Nephew) (Fig 4 C and D, Video 1). The cartilage around the bone tunnel is removed by ring curettage (Arthrex) until the subchondral bone is exposed to heal the meniscal root (Video 1).

MMPR Repair With Modified Mason-Allen Suture

A No. 2 TigerWire suture (Arthrex) is sutured 5 mm medial from the torn edge of the MMPR with the Knee Scorpion (Arthrex) through the anteromedial portal (Fig 4E, Video 1). Next, a No. 2-0 Prolene suture (Ethicon) is passed for suture relay 10 mm medial to the torn edge and 5 to 7 mm ahead of the previous suture. A horizontal mattress suture is made by replacing the No. 2 Prolene suture with the TigerWire. A modified Mason-Allen suture[8] is made using SutureTape (Arthrex) posteromedially from the

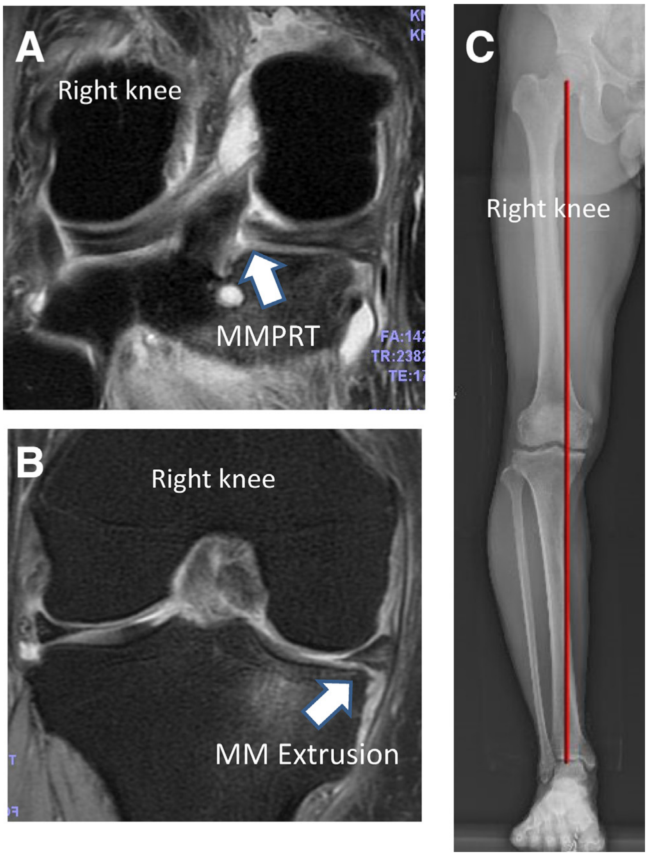

Fig 2. Surgical indication for procedure. Right knee with complete medial meniscal posterior root tear (MMPRT) (A) and meniscal extrusion (B) on coronal magnetic resonance imaging and varus knee osteoarthritis on whole-leg standing radiograph (C). The red line in (C) indicates the mechanical axis. (FA, fractional anisotropy; MM, medial meniscus; TE, echo time; TR, time to repeat.)

horizontal suture thread (Fig 4F, Video 1). Finally, a No. 2 FiberSnare suture (Arthrex) for suture relay is passed into the joint through the bone tunnel from the lateral tibia (Video 1).

Open-Wedge Distal Tibial Tubercle Osteotomy

During the OWDTO process, the EndoButton reamer is placed backward into the bone tunnel to protect the suture relay thread (Fig 5A, Video 1). OWDTO consists of triple-plane osteotomy: descending, arc, and coronal, which are modified according to the surgical technique of Akiyama et al.[9] Two parallel 2.0-mm Kirschner wires (K-wires) are inserted into the hinge point from the medial tibia along the coronal osteotomy plane line. Next, a 2.4-mm K-wire as a short-hinge pin is inserted into the hinge point in the anteroposterior direction. The compass is set around the short-hinge pin, and some drill holes for arc osteotomy are made using a 2.0-mm K-wire. First, descending osteotomy is performed, with the bone fragment measuring approximately 25 mm in length and 10 to 15 mm in thickness, using a reciprocating saw; second, arc osteotomy is performed along the arc drill holes; and finally, coronal osteotomy is performed using a bone saw (Fig 5 B and C, Video 1). Subsequently, 2 artificial bones with a correction angle are inserted into the osteotomy site according to the plan that the postoperative mechanical axis can pass through 62.5% in %MA (Video 1).

An additional bicortical anteroposterior screw with a washer is inserted under lateral fluoroscopy (Fig 5 D-G, Video 1). The cut pes anserine is repaired using No.0 PDS plus (Ethicon). Finally, a medial high tibial osteotomy (HTO) TriS plate (Olympus Terumo Biomaterials) is placed over the soft tissue, including the sMCL, on the medial tibia using locking screws. It is important to identify the screw that interferes with the bone tunnel and to insert a short plate screw into the screw hole under lateral fluoroscopy (Fig 6 A and B, Video 1).

Fixation of Meniscus-Repaired Threads at Proximal Lateral Tibia

Finally, the meniscus-repaired threads are passed into the bone tunnel using a suture relay thread. These

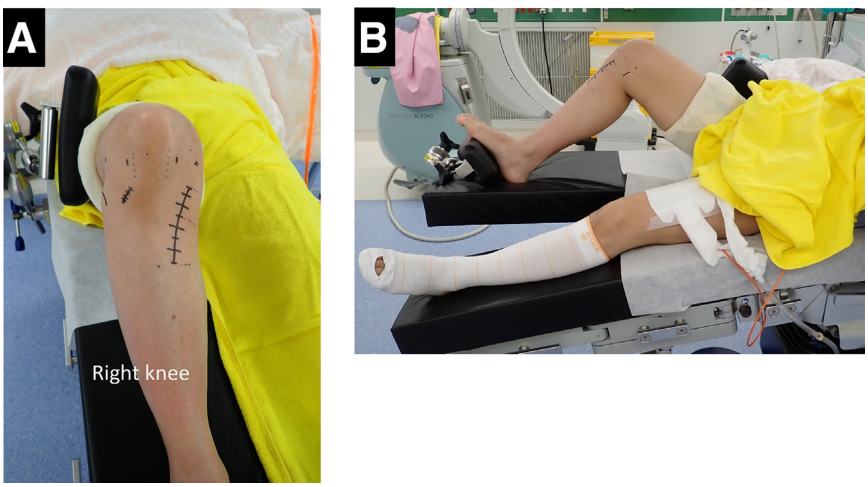

Fig 3. (A) Skin incision marking and right knee position using proximal lateral thigh and foot supports. A 7-cm skin incision is made at the proximal anteromedial tibia without using a tourniquet. (B) The contralateral leg is placed lower during osteotomy. The C-arm is positioned on the surgical leg side.

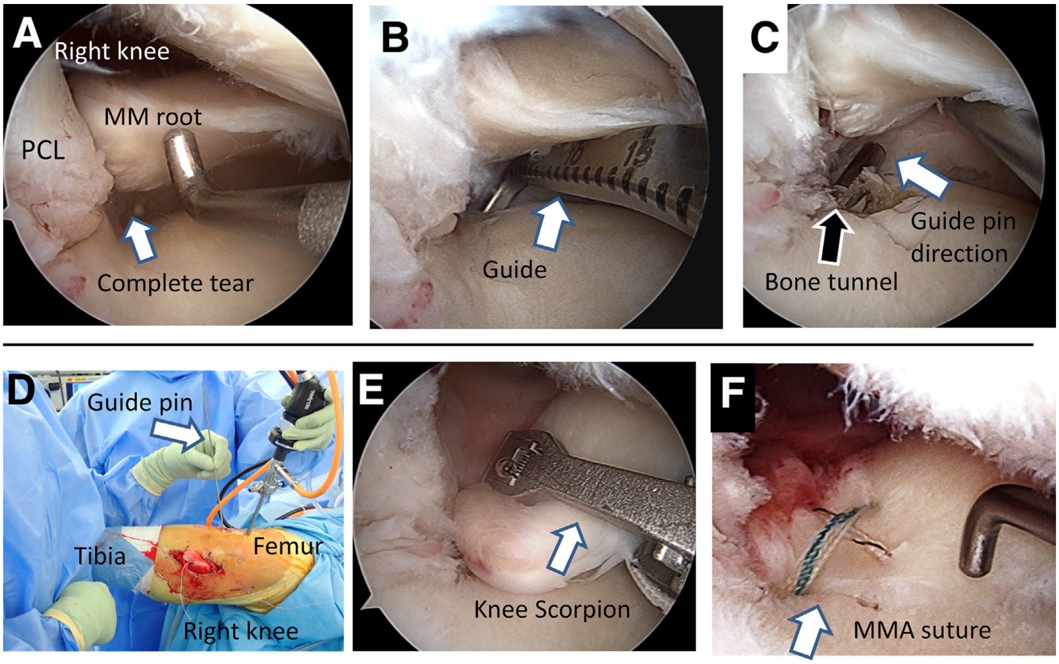

Fig 4. Bone tunnel creation from lateral tibia and medial meniscal posterior root (MMPR) repair with modified Mason-Allen (MMA) suture. (A) Arthroscopic image of complete MMPR tear in right knee using trans-notch view from anterolateral portal. The torn meniscal root is easily lifted during probing. (B) A guide is introduced at a slightly posteromedial position behind the anatomic footprint through the anteromedial portal. (C, D) The direction of the bone tunnel can be confirmed using a guide pin. (E) MMPR repair using Knee Scorpion. (F) MMA suture after open-wedge distal tibial tubercle osteotomy. After fixation of these threads, the repaired posterior meniscal root is confirmed to be stable and pulled out laterally. (MM, medial meniscus; PCL, posterior cruciate ligament.)

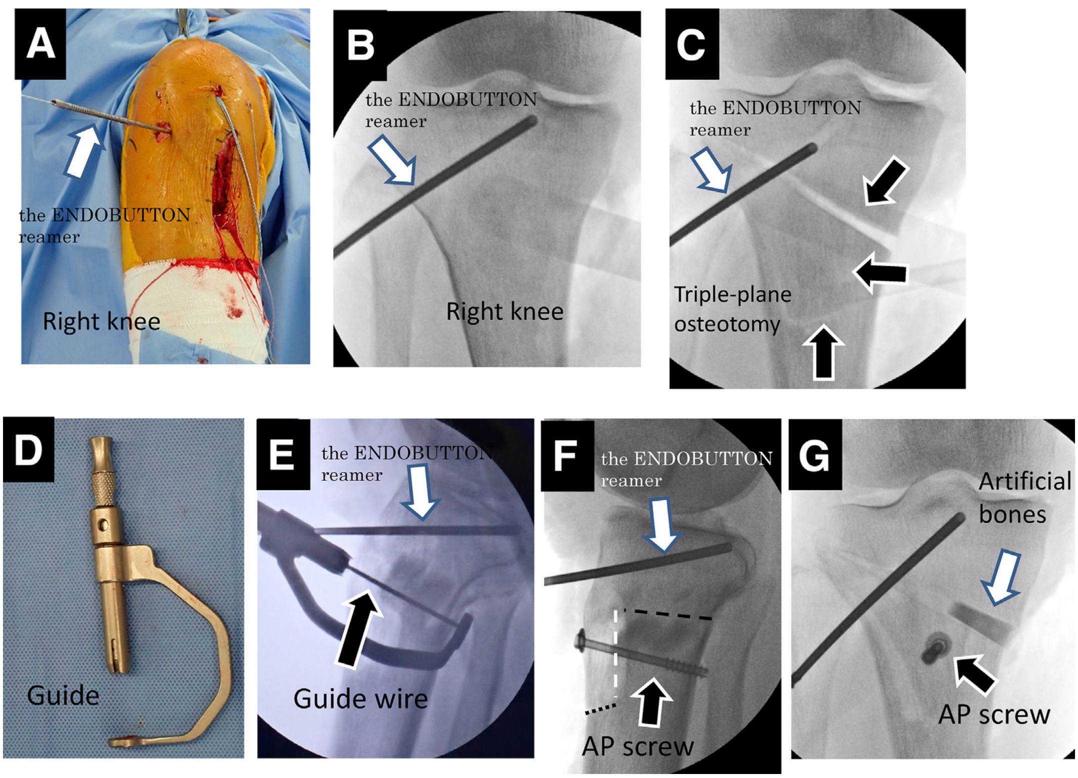

Fig 5. (A, B) During the process of open-wedge distal tibial tubercle osteotomy in the right knee, the EndoButton reamer is consistently inserted backward into the bone tunnel to protect the suture relay thread. (C) Once triple-plane osteotomy is completed, movement of the bone fragment can be confirmed. Black arrows indicate triple-plane osteotomy lines. (D-G) After insertion of artificial bones, an additional bicortical anteroposterior screw with a washer is inserted with a guide under lateral fluoroscopy. In (F) the white dashed line indicates the descending osteotomy line; the black dashed line indicates the coronal osteotomy line; the black dotted line indicates the arc osteotomy line. (AP, anteroposterior.)

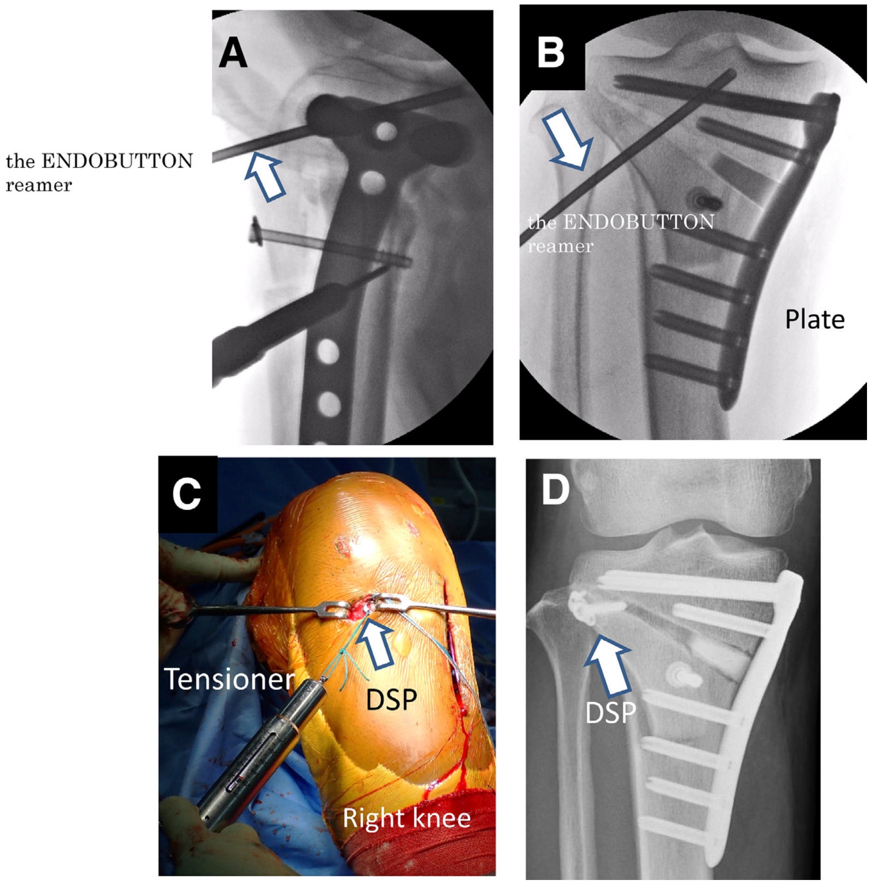

Fig 6. (A, B) Fixation of locking plate after identification of screw that is interfering with bone tunnel, allowing for insertion of short plate screw in screw hole under lateral fluoroscopy. (C, D) Fixation of meniscus-repaired threads at proximal lateral tibia in right knee with Double Spike Plate (DSP).

threads are fixed in the proximal tibia at 20 N with the knee at 90° with the Double Spike Plate (Meira) (Fig 4F and Fig 6 C and D, Video 1). Postoperative computed tomography shows that the bone tunnel in the joint is identified in a slightly posteromedial position behind the anatomic footprint (Fig 7A, Video 1). The bone tunnel aperture and Double Spike Plate are identified on the proximal lateral tibia, and the screw interfering with the bone tunnel is inserted at a shorter depth (Fig 7 B-E, Video 1).

Discussion

MMPR repair with HTO and HTO alone for MMPRTs with varus knee alignment remain controversial[4-6]; however, several studies have reported short-term clinical results within 2-year follow-up. MMPR repair with HTO was suggested to be advantageous for the environment around the knee joint at mid-term follow-up because the complete healing rates of second-look arthroscopy were good, with rates of 64.7% for pull-out repair with HTO, 23.3% to 40% for all-inside horizontal repair with HTO, and 15.6% for HTO alone in a previous study.[4-6]

Almost all previous studies reported on MMPR repair on the medial side. Little is known about factors that may be affected in treatment outcomes, including the quality of the repaired meniscus, pull-out direction, bone tunnel position, and repair techniques. We believe that our combined surgical technique has several advantages. Regarding the pullout direction of the repaired meniscus, traction of the repaired meniscus toward the lateral side is reported to be the ideal physiological direction for 2 reasons: First, the shape of the meniscus itself is C-shaped, which is directed toward the lateral tibia physiologically, and second, pullout in a medial direction could result in a killer angle of the repaired meniscus[7] (Fig 1 A and B). Therefore, the lateral pullout technique may be advantageous for MMPR healing.

Regarding neurovascular safety, Gupta et al.[10] reported that the use of a straight needle for MMPR with the anteromedial portal was found to be unsafe to the popliteal neurovascular bundle. Therefore, the guide pin in the medial pullout technique might approach the vicinity of the popliteal neurovascular bundle, whereas that in the lateral pullout technique is safe (Fig 1 A and B).

Regarding the plate screw, which could interfere with bone tunnel pullout, the lateral pullout

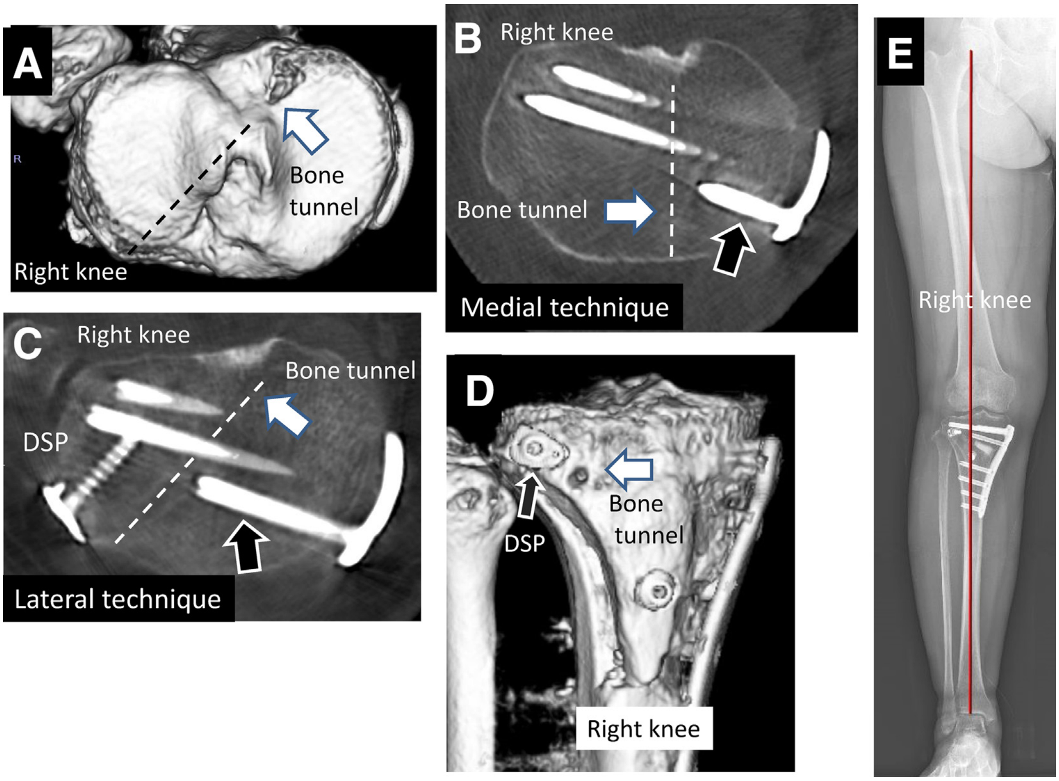

Fig 7. Postoperative computed tomography (CT) scans and full-length standing anteroposterior radiographs of right knee. (A) The bone tunnel (black dashed line) in the joint is identified in a slightly posteromedial position behind the anatomic footprint on 3-dimensional CT. (B-D) The screw (black arrows) causing interference with the bone tunnel is inserted to a shorter depth by the medial pullout technique (B) and by the lateral pullout technique (D) on axial CT, and the bone tunnel aperture and Double Spike Plate (DSP) are identified on the proximal lateral tibia on 3-dimensional CT. The white dashed lines in (B) indicate the bone tunnel of medial technique and the white dashed lines in (C) indicate the bone tunnel of lateral technique. (E) After surgery, successful alignment correction is achieved, as shown on the whole-leg standing radiograph. The red line in (E) indicates the mechanical axis.

Table 1. Pearls and Pitfalls

Pearls
Release of the sMCL is useful in approaching the medial joint space for meniscal repair.
Meniscal repair is recommended first, before osteotomy, and is performed with valgus stress of the knee.
The entry point of the tibial tunnel is aimed at the distal end of the Gerdy tubercle and the proximal end of the tibialis anterior muscle.
The tibial tunnel position is aimed at the slightly posteromedial position behind the anatomic footprint to relieve tension of the repaired meniscus.
The cartilage around the bone tunnel is removed with ring curettage until the subchondral bone is exposed for meniscal root healing.
A No. 2 TigerWire suture is sutured as the horizontal suture 5 mm medial as the posterior point and 7 to 8 mm medial as the anterior point from the torn edge of the MMPR using the Knee Scorpion through the anteromedial portal.
During the process of OWDTO, the EndoButton reamer should be consistently inserted backward into the bone tunnel to protect the suture relay thread.
During fixation of the plate, it is important to identify which screw is interfering with the bone tunnel under lateral fluoroscopy.
Pitfalls
A lateral small skin incision is needed.
If the entry point of the tibial tunnel is located too distally, the osteotomy line could interfere with the bone tunnel.
If meniscal suturing is performed near the torn edge, cutout of the repaired meniscal root could occur.
If the meniscus itself has significant degenerative changes, pullout meniscal repair may be impossible.
If there is some distance between the anatomic insertion and the torn meniscal edge, the anatomic tibial tunnel position could cause cutout of the repaired meniscus.
Fluoroscopy is needed to confirm interference between the bone tunnel and the plate screw.

MMPR, medial meniscal posterior root; OWDTO, open-wedge distal tibial tubercle osteotomy; sMCL, superficial medial collateral ligament.

Table 2. Advantages, Risks, and Limitations

Advantages	
	The pullout direction of the repaired meniscus from the lateral tibia could be physiological.
	The risk of neurovascular damage is reduced by the lateral pullout technique.
	A longer plate screw that could interfere with the bone tunnel could be placed during OWDTO.
	Creation of the bone tunnel from the lateral tibia is easy, and an increase in postoperative patellofemoral contact stress could be prevented by OWDTO.
Risks	
	Possibility of interference between bone tunnel and osteotomy line
	Possibility of skin irritation with anteroposterior screw
Limitations	
	Longer operation time
	Arthroscopic repair technique required
	Special instrumentation required
	Challenging technique
	More time required to use fluoroscopy
	Need for further studies regarding superiority of combined surgical procedure

OWDTO, open-wedge distal tibial tubercle osteotomy.

technique could use a longer plate screw than the medial technique. Nejima et al.[11] reported that insufficient screw insertion could lead to inferior stability of plate fixation. Therefore, it is better to make a plate screw that could interfere with the pullout bone tunnel as long as possible by the lateral pullout technique (Fig 7 B-D).

Regarding OWDTO, although the main advantage is the prevention of an increase in postoperative patellofemoral contact stress because of minimal change in patellar height, another advantage is compatibility with the lateral pullout technique. Because the proximal bone fragment is larger than that in OWHTO owing to the descending osteotomy, deciding the guidewire entry point at the lateral tibia could be easy (Fig 1 C and D).

This Technical Note describes a surgical technique combining the lateral pullout technique and OWDTO. The advantages of this combined technique are as follows: (1) The pullout direction of the repaired meniscus from the lateral tibia could be physiological; (2) there is a reduced risk of neurovascular damage; (3) there is placement of a longer plate screw that could interfere with the bone tunnel; and (4) there is ease of creation of the bone tunnel from the lateral tibia, and the postoperative patellofemoral contact stress could be increased by OWDTO. Pearls and pitfalls are presented in Table 1, and advantages and limitations are summarized in Table 2. It should be noted that this is a preliminary report, and further follow-up assessments of clinical and radiologic outcomes are necessary to investigate the long-term effects of this technique.

Disclosures

The authors report no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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