Technical Note

Interlocking Open-Wedge Distal Tibial Tuberosity Osteotomy: Stabilizing Technique in the Retro-Tubercle Without Complementary Screw Fixation

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Abstract: We present a knee osteotomy procedure that we have termed the interlocking open-wedge distal tibial tuberosity osteotomy. In this context, the term *interlocking* pertains to the manner in which the repositioned segments of the retro-tubercle seamlessly fit together as the transverse osteotomy opens to the intended corrective angle. This interlocking mechanism, serving as a distinctive feature, engenders a stable retro-tubercle configuration resembling a mortise-and-tenon joint. The distal end of the tibial tuberosity fits snugly behind the tibial diaphysis, augmenting stability and promoting the healing process. Consequently, poor union of the retro-tubercle caused by the widening of the retro-tubercle gap and an increase in posterior tibial slope are effectively prevented. In addition, the need for complementary hardware such as anteroposterior screw fixation, which is used to secure the retro-tubercle during the healing process, is notably eliminated. This elimination not only simplifies the surgical procedure but also eliminates potential complications that could arise from its use.

Distal tuberosity osteotomy (DTO) in open-wedge proximal tibial osteotomy was introduced by Gaasbeek et al.[1] as a technique to avoid distalization of the tibial tuberosity and thereby prevent postoperative patella infera. In fact, recent comparative studies reported that DTO significantly prevents cartilage degeneration of the patellofemoral (PF) joint associated with postoperative patella infera.[2-4] In contrast, DTO can have some perioperative problems, such as the risk of tibial tuberosity fracture, delayed or nonunion of the retro-tubercle gap, and an increase in posterior tibial slope (PTS) over time.[1,5,6] Therefore, in terms of surgical technique, DTO is considered to require complementary hardware such as anteroposterior (AP) screw fixation for stabilizing in the retro-tubercle, which might produce iatrogenic complication, such as screw prominence and tuberosity fracture.[7,8] Additionally, the AP bicortical screw can be headed to posterior neurovascular structures.[7-9] The surgeon should consider these negative aspects of the DTO technique and contemplate adjusting additional stabilization.

In this study, we introduce a technique called interlocking open-wedge distal tibial tuberosity osteotomy (interlocking DTO). The primary objective is to improve retro-tubercle stability and promote healing without a compulsory need for AP screw fixation (Fig 1). In interlocking DTO, as the transverse wedge opens to the intended corrective angle, the distal end of the tibial tuberosity fits snugly behind the tibial diaphysis, creating a stable retro-tubercle configuration that resembles a mortise-and-tenon joint.

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Surgical Technique

Indications

The indication for surgery was medial compartment osteoarthritis and osteonecrosis of the knee with persistent medial knee pain after at least 2 months of

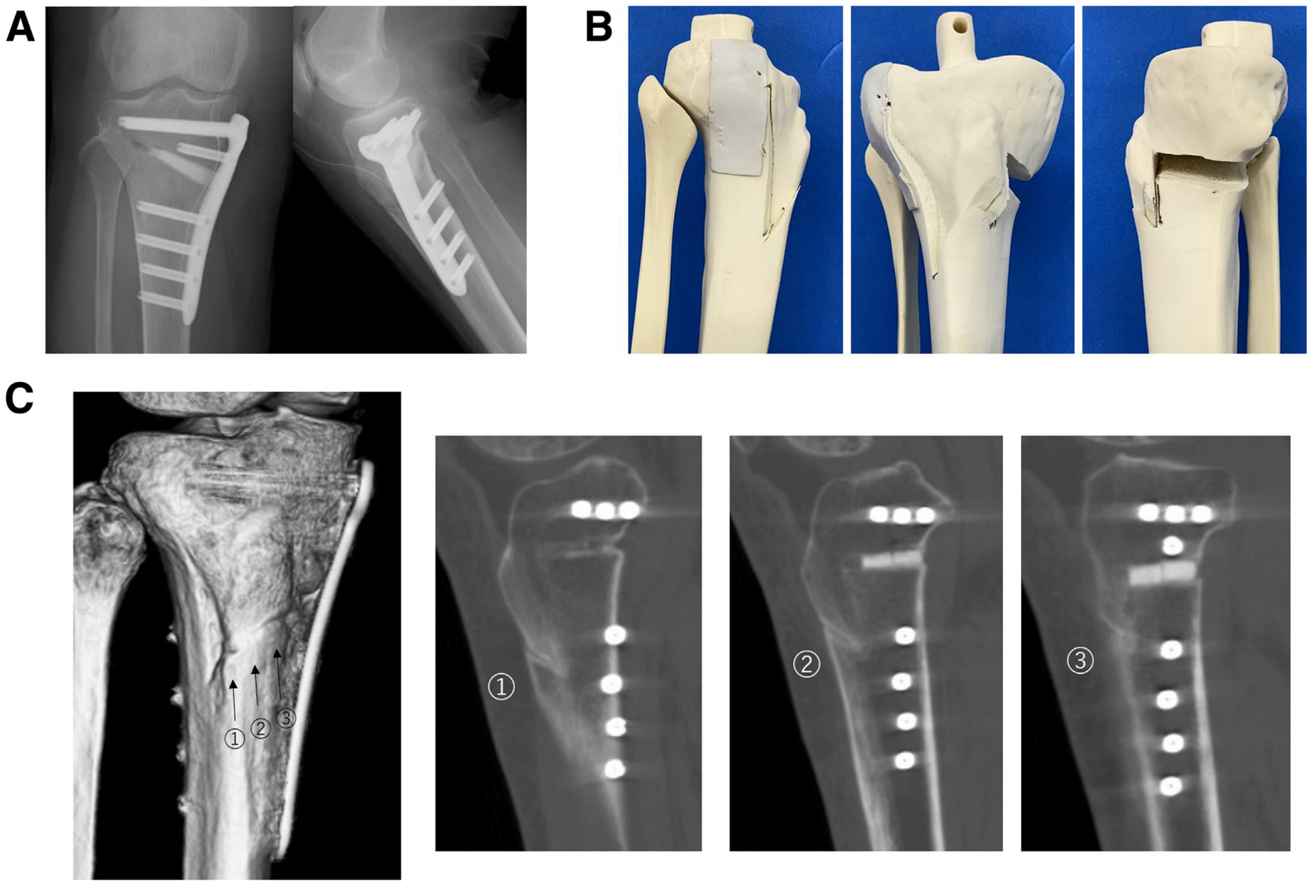

Fig 1. Representative images of interlocking open-wedge distal tibial tuberosity osteotomy (interlocking DTO). (A) Postoperative right knee radiographs of a 60-year-old woman who underwent interlocking DTO without complementary screw fixation. (B) A bone model of interlocking DTO that demonstrates a stable connection between the repositioned retro-tubercle segments. (C) A computed tomography scan of same patient as (A) that demonstrates excellent bone union (①, ②, ③) in the retro-tubercle 12 weeks after osteotomy.

conservative treatment. Patients with PF joint space narrowing on radiographs or arthroscopy were included if they were asymptomatic during a preoperative patellar grinding test.

Patient Positioning

In a supine position, lateral support is applied to the thigh from the outside to prevent external rotation of the hip joint in the extended position and to maintain a forward knee position throughout the operation.

Arthroscopy

Prior to the osteotomy, an arthroscopic examination is performed to assess the degree of cartilage degeneration in the medial, lateral, and PF compartments. This is followed by meniscal and/or cartilage repair procedures.

Exposure

An obliquely curved incision of approximately 8 cm is made from the proximal tibia to the medial side of the distal tibial tuberosity (Fig 2). The subcutaneous tissue is taken off from the fascia at the plate installation site. Using a caliper, a line located 15 mm thickness from the anterior edge of the tibial tuberosity is marked, and the pes anserinus tendons are severed at this line (Fig 3). The superficial medial collateral ligament is detached subperiosteally up to the level of the osteotomy. The posterior soft tissue is then peeled back, subperiosteally, with the knee in a flexed position, allowing for relaxation of the posterior soft tissue.

K-wire Guided Instructions Without Specific Devices (With Video Illustration)

Three 2.0-mm K-wires and two 1.5-mm K-wires are used as guidewires for 3 osteotomies: a transverse osteotomy in the proximal tibia and descending and oblique ascending osteotomies in the tibial tuberosity. The narrated video demonstrates the step-by-step procedure for all osteotomies (Video 1).

A Transverse Osteotomy in the Proximal Tibia

Under fluoroscopy, a first guidewire of the 2.0-mm K-wire, which serves as a reference for the transverse

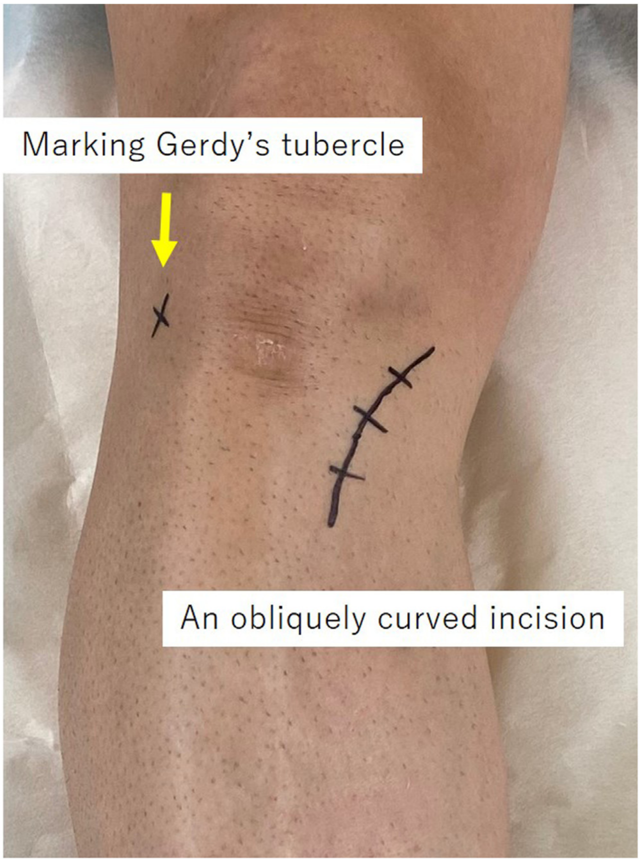

Fig 2. Skin incision. In a supine position, an obliquely curved incision is made from the proximal tibia to the medial side of the distal tibial tuberosity. Gerdy's tubercle is marked.

osteotomy (open-wedge plane), is inserted 40 mm below the medial articular surface of the proximal tibia toward the tip of the fibular head. Using calipers once again, a line located 13 to 15 mm thickness from the anterior edge of the tibial tuberosity is confirmed as a reference for the descending osteotomy and extended to reach the hypothetical intersection between the transverse osteotomy and the descending osteotomy (Fig 4A). With the assistance of fluoroscopy, a second guidewire of the 2.0-mm K-wire is inserted at the intersection between the transverse osteotomy and the descending osteotomy, confirming to penetrate the cortex bone just below Gerdy's tubercle (Fig 4B).

The medial cortex bone on the distal side of the 2 guidewires is cut using a bone saw. Along the guidewires, the cancellous bone is partially cut up to the hinge area using a thin-bladed chisel with a width of 15 mm (Fig 5A). After removing the first guidewire, posterior bone cortex is cut using a thin, single-edged reciprocating saw with posterior soft tissue fully retracted (Fig 5B). The blade of the reciprocating saw is then reversed and used to cut anteriorly to reach the second guidewire (Fig 5C).

Descending and Oblique Ascending Osteotomies in the Tibial Tuberosity

A third 2.0-mm K-wire guidewire, parallel to the second wire, is inserted at a distance of 15 mm distally from the second wire (Fig 6A). These 2 guidewires serve as a reference plane for the descending osteotomy (retro-tubercle plane). It is essential that a transverse osteotomy (open-wedge plane) and a descending osteotomy (retro-tubercle plane) are perpendicular to each other. Using a long micro bone saw, the descending osteotomy is initiated from the medial cortex while maintaining a 13- to 15-mm thickness of the tibial tuberosity (Fig 6B). A thin reciprocating saw is used to complete the osteotomy up to the second guidewire (Fig 6C). Then, a fourth 1.5-mm K-wire guidewire is introduced at the same point of the third guidewire and at a 45-degree angle across the proximal tibial bone axis as a reference for the distal end of descending osteotomy (Fig 7A). Then, with the blade of a reciprocating saw oriented distally, the descending osteotomy is completed to reach the fourth guidewire (Fig 7B). To ensure the interlocking mechanism, it is crucial that the distance from the hinge point to the lateral tip of the descending osteotomy is greater than the distance from the hinge point to the medial tip of the descending osteotomy (Fig 7C).

A fifth 1.5-mm K-wire, parallel to the fourth wire, is inserted to be tilted 40 to 45 degrees proximally from the descending plane as a reference for the oblique ascending osteotomy (Fig 8A). Then, using a long micro bone saw of approximately 40 mm length, the distal end of the tibial tuberosity bone is cut up in a proximal-medial to distal-lateral direction (Fig 8B). To enhance interlocking, fine-tuning can be performed to increase the size of the tenon part of tuberosity compared to the mortise part of the tibial diaphysis.

Interlocking Mechanism in the Retro-Tubercle as the Transverse Gap Opens

After completing all osteotomies, a gap opener is inserted in the transverse osteotomy. The transverse gap opens to intended corrective angle while crimping the retro-tubercle plane with a bone grasper anteroposteriorly and is filled with β-TCP blocks (Osferion; Olympus Terumo Biomaterials) (Fig 9A). In case there is any gap in the oblique ascending plane when crimping the retro-tubercle plane, the wedging technique can be employed using a thinly shaped β-TCP block for additional stabilization (Fig 9B). As a result, the distal end of the tibial tuberosity interlocks with and fits snugly behind the tibial diaphysis, creating a stable retro-tubercle configuration resembling a mortise-and-tenon joint. At this point, a stable retro-tubercle in knee flexion and extension can be confirmed even before plate fixation (Fig 9C). Then, the locking plate (TRIS system; Olympus Terumo Biomaterials) is used to

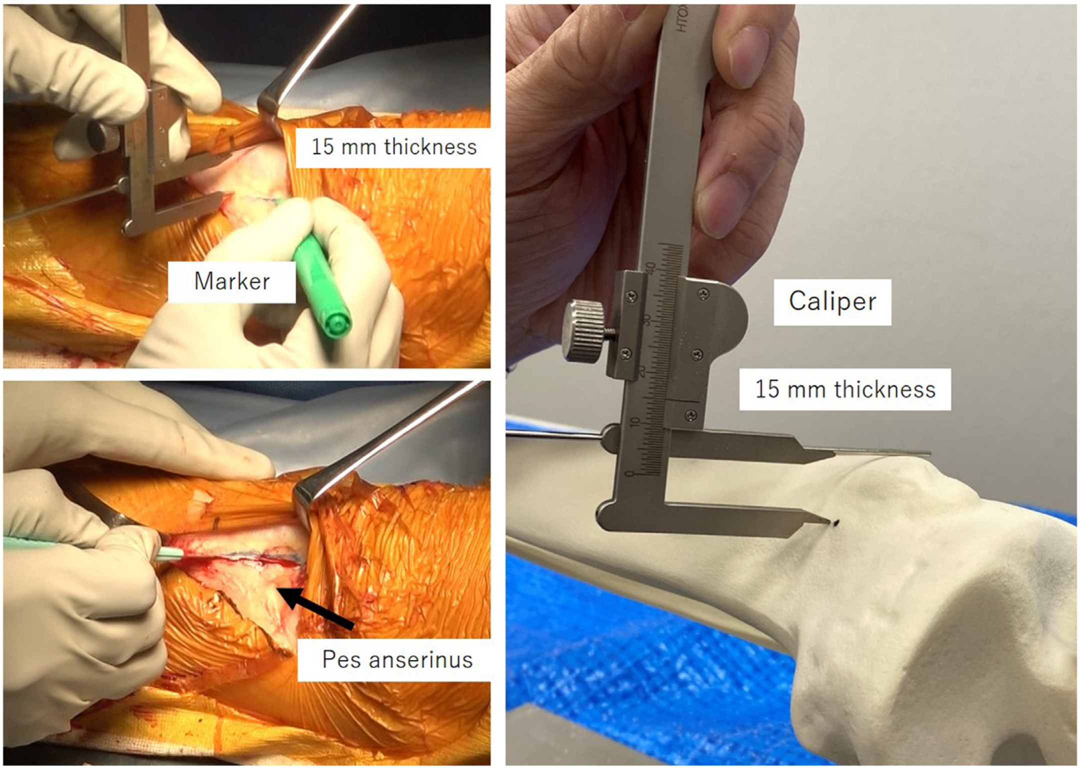

Fig 3. Determining the remaining thickness of the tibial tuberosity. Using a caliper, a line located 15 mm thickness from the anterior edge of the tibial tuberosity is marked, and the pes anserinus tendons are severed at this line.

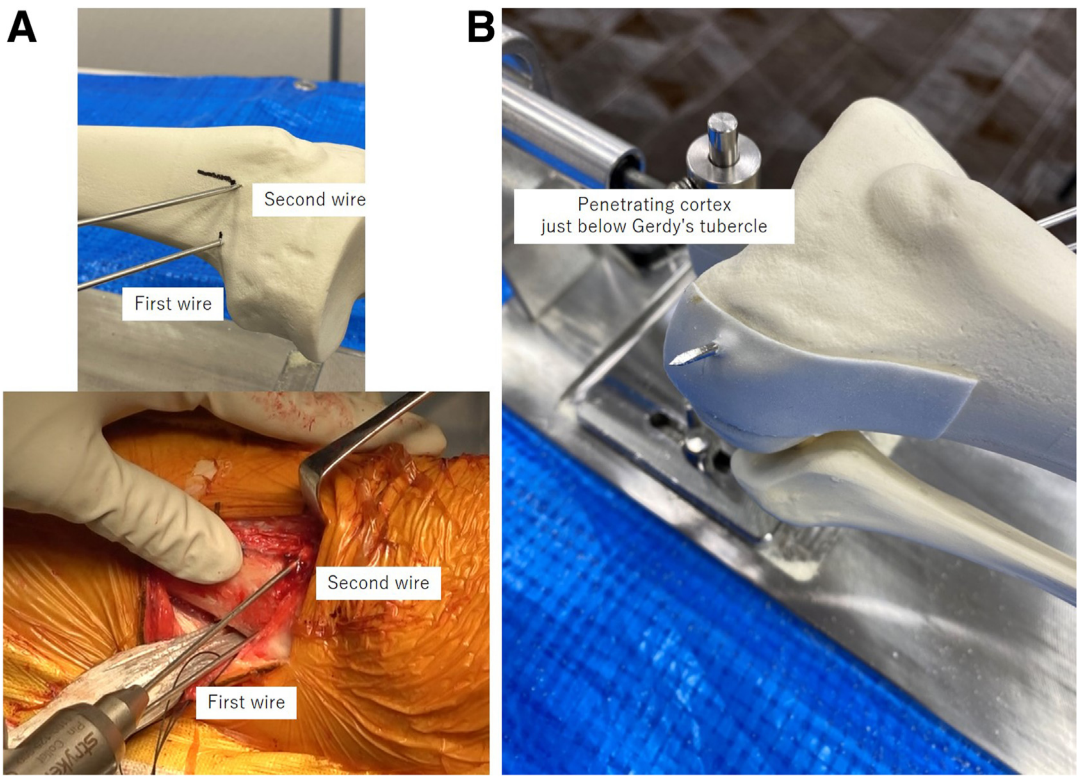

Fig 4. Guidewires for the transverse osteotomy. (A) Two guidewires of the 2.0-mm K-wire are inserted 40 mm below the medial articular surface of the proximal tibia toward the tip of the fibular head. (B) The second guidewire is inserted at the intersection between the transverse osteotomy and the descending osteotomy, penetrating cortex bone just below Gerdy's tubercle.

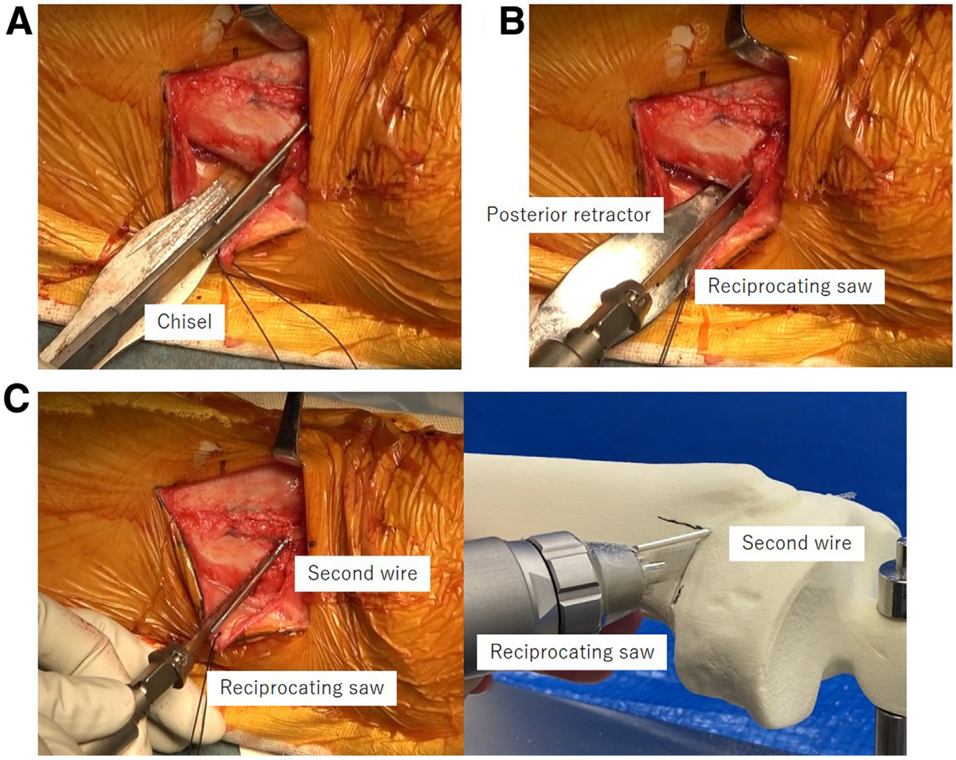

Fig 5. Transverse osteotomy in the proximal tibia. (A) Along the guidewires, the cancellous bone is cut up to the hinge area using a thin-bladed chisel. (B) The posterior bone cortex is cut using a thin, single-edged reciprocating saw with posterior soft tissue fully retracted. (C) The reversed blade of the reciprocating saw is used to cut anteriorly to reach the second guidewire.

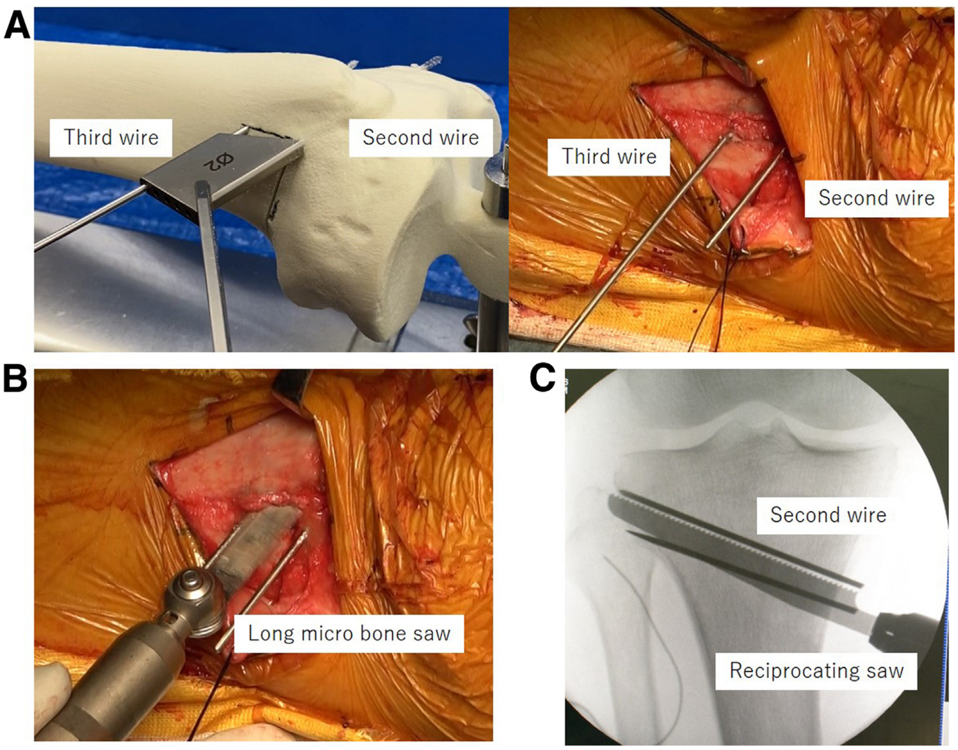

Fig 6. Descending osteotomy in the proximal direction. (A) A third 2.0-mm K-wire guidewire, parallel to the second wire, is inserted at a distance of 15 mm distally from the second wire. (B) Using a long micro bone saw, the descending osteotomy is initiated from the medial cortex while maintaining a 13- to 15-mm thickness of the tibial tuberosity. (C) Proximal descending osteotomy up to the second guidewire is completed using a thin reciprocating saw.

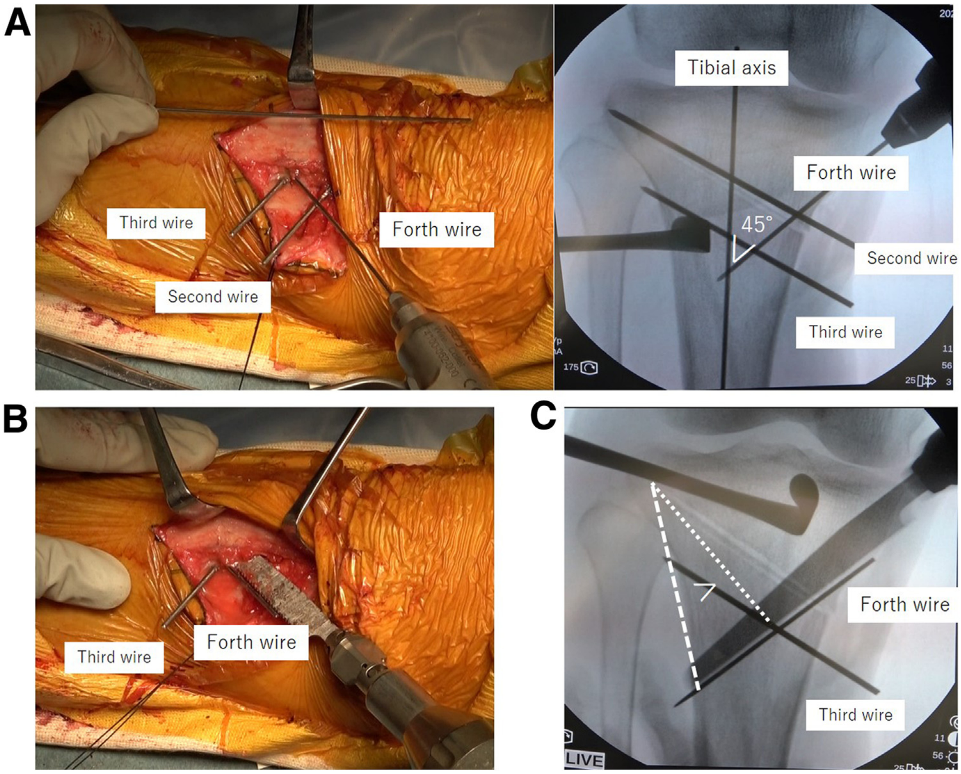

Fig 7. Descending osteotomy in the distal direction. (A) A fourth 1.5-mm K-wire guidewire is introduced at the same point of the third guidewire and at a 45-degree angle across the proximal tibial bone axis as a reference for the distal end of descending osteotomy. (B) With the blade of a reciprocating saw oriented distally, the descending osteotomy is completed to reach the fourth guidewire. (C) To ensure the interlocking mechanism, it is crucial that the distance from the hinge point to the lateral tip of the descending osteotomy is greater than the distance from the hinge point to the medial tip of the descending osteotomy.

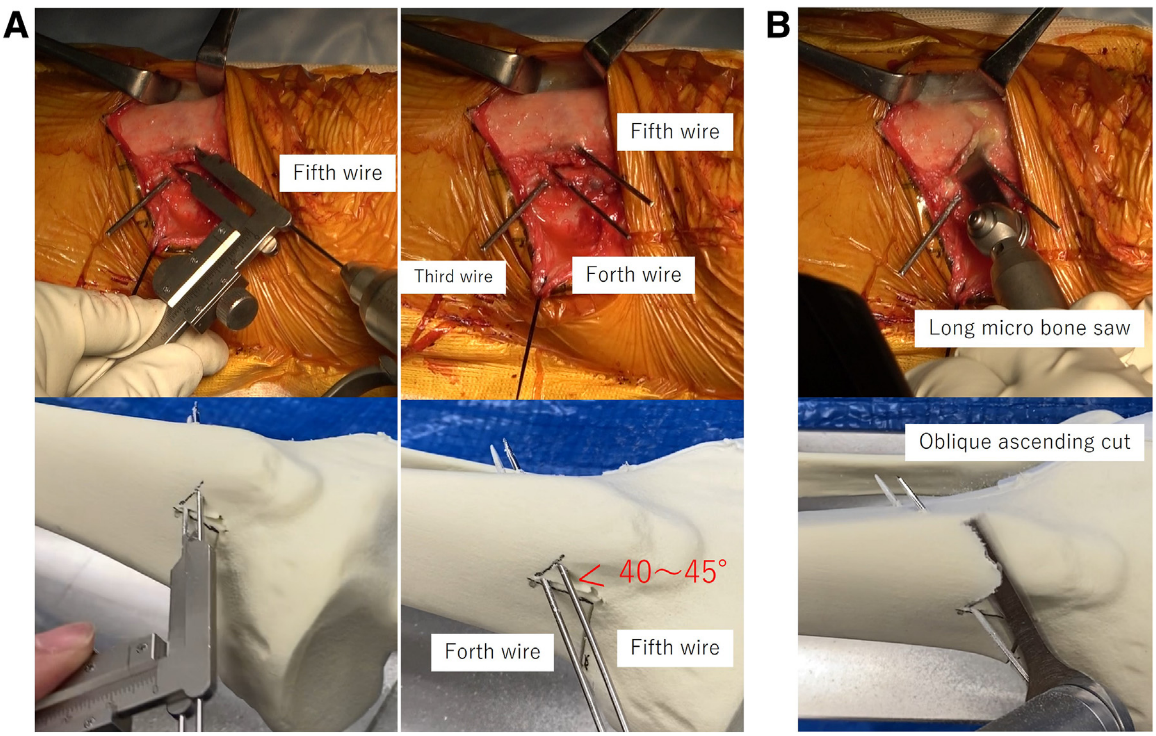

Fig 8. Oblique ascending osteotomies in the tibial tuberosity. (A) A fifth 1.5-mm K-wire, parallel to the fourth wire, is inserted to be tilted 40 to 45 degrees proximally from the descending plane as a reference for the oblique ascending osteotomy. (B) Along guidewires, the distal end of the tibial tuberosity bone is cut up in a proximal-medial to distal-lateral direction using a long micro bone saw of approximately 40 mm length.

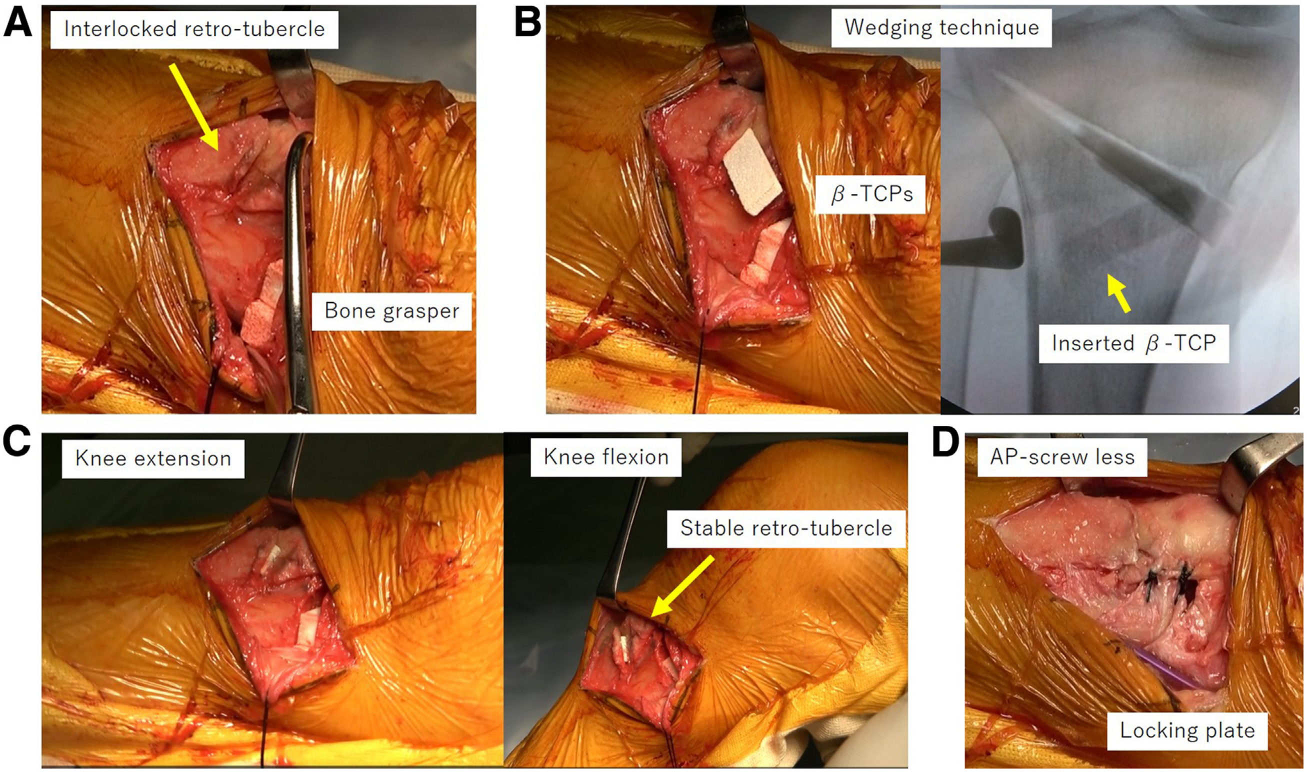

Fig 9. Completing interlocking mechanism in the retro-tubercle using the wedging technique. (A) The transverse gap opens to the intended corrective angle while crimping the retro-tubercle plane with a bone grasper anteroposteriorly and is filled with β-TCP blocks. (B) In case there is any gap in the oblique ascending plane when crimping the retro-tubercle plane, the wedging technique can be employed using a thinly shaped β-TCP block for additional stabilization. (C) Stable retro-tubercle in knee flexion and extension can be confirmed even before plate fixation. (D) The locking plate system is used to secure the osteotomy without a compulsory need for anteroposterior (AP) screw fixation.

Table 1. Pearls and Pitfalls

Pearls
- Forward knee position should be maintained throughout the operation.
- Transverse osteotomy is started at least 40 mm below the medial articular surface of the proximal tibia. This is important to ensure adequate space for the oblique ascending osteotomy.
- Transverse osteotomy and descending osteotomy must be perpendicular to each other.
- To ensure the interlocking mechanism, it is crucial that the distance from the hinge point to the lateral tip of the descending osteotomy is greater than the distance from the hinge point to the medial tip of the descending osteotomy.

Pitfalls
- A long micro bone saw of approximately 40 mm length is useful for the oblique ascending osteotomy.
- Especially in the oblique ascending osteotomy of tibial tuberosity, surgeons must be skilled in accurately placing the guidewires and cutting bone using an in vitro saw-bone model preoperatively.
- Osteotomy gap caused by bone saw influences the interlocking mechanism. In such cases, the wedging technique using a thinly shaped β-TCP block can be applied for additional stabilization.

Table 2. Advantages and Disadvantages of Interlocking Open-Wedge Distal Tibial Tuberosity Osteotomy

Advantages
- A stable connection between the repositioned retro-tubercle segments is established without complementary anteroposterior screw fixation.
- All osteotomies can be performed by K-wire guided instructions.
- The widening of the descending gap and an increase in posterior tibial slope are effectively mitigated by the wedging technique.
- The healing process in the retro-tubercle is promoted. Even in the event of hinge fracture, preferential healing of the retro-tubercle is observable.
- The postoperative patella infera is prevented without complications related to conventional distal tuberosity osteotomy.
- Same early weightbearing rehabilitation as conventional high tibial osteotomy can be performed.

Disadvantages
- Preoperatively, surgeons must be skilled using an in vitro saw-bone model. The precise execution of the interlocking mechanism requires careful attention to the angles and orientations of the osteotomy cuts.

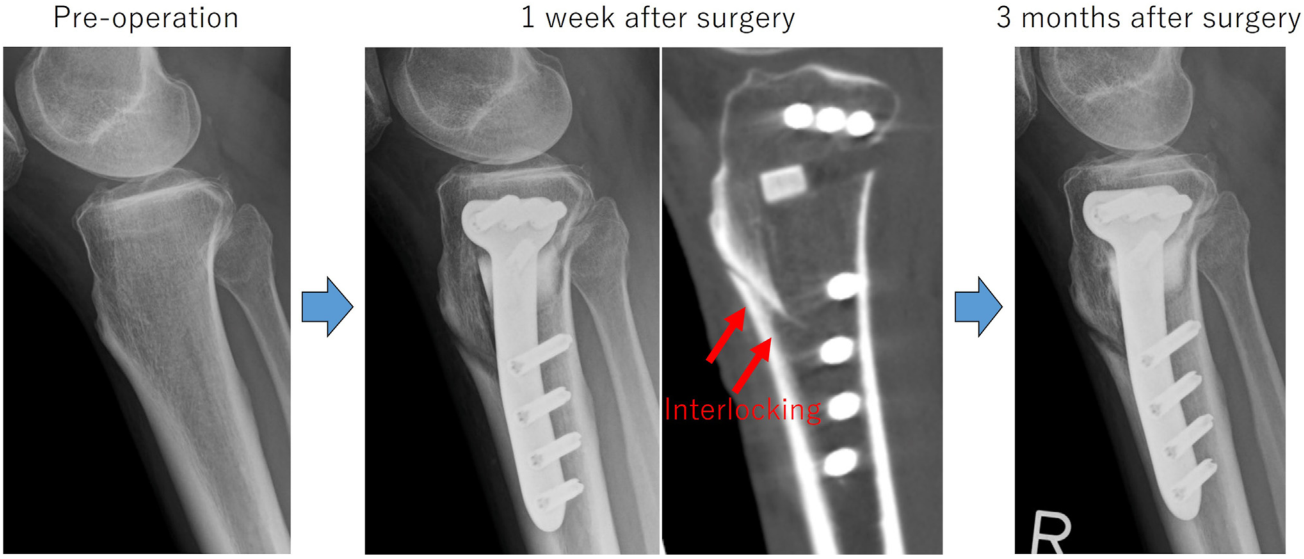

Fig 10. Representative sagittal views of radiographs and computed tomography scan after interlocking open-wedge distal tibial tuberosity osteotomy with 13 degrees of opening correction angle. Posterior tibial slope does not increase even after full weightbearing is permitted on postoperative day 7. The incorporation of a stable mortise-and-tenon joint structure ensures that the posterior tibial slope remains unaffected during the postoperative course when implementing an early full weightbearing rehabilitation protocol.

secure the osteotomy without a compulsory need for AP screw fixation (Fig 9D). The pearls and pitfalls of this technique are shown in Table 1.

Postoperative Rehabilitation

Full weightbearing is permitted on postoperative day 7. Quadriceps femoris training and range of motion training are performed without restriction.

Discussion

The core innovation of interlocking DTO lies in its unique mechanism, which establishes a stable connection between the repositioned retro-tubercle segments. This interlocking resembles the structural integrity of a mortise-and-tenon joint, wherein the distal end of the tibial tuberosity is securely positioned behind the tibial diaphysis. The mortise-and-tenon and wedging

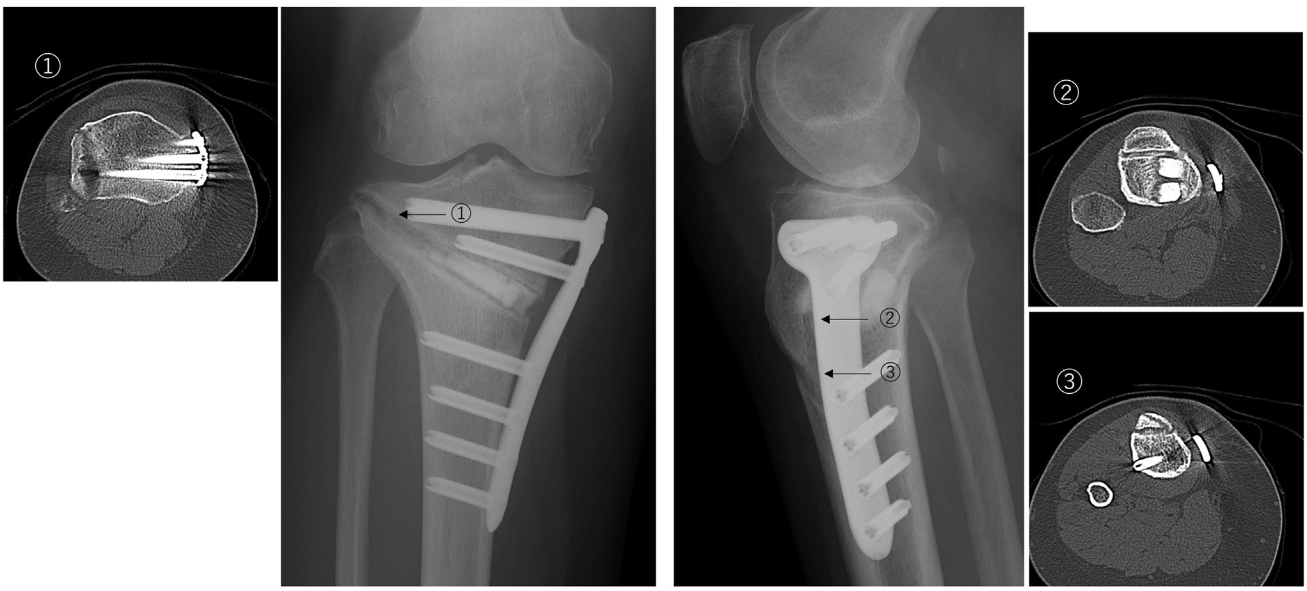

Fig 11. A case of hinge fracture. Even in the event of hinge fracture ①, preferential healing of the retro-tubercle is observable (②, ③). The promotion of characteristic bone continuity, coupled with the absence of metallic hardware penetrating the osteotomy, significantly facilitates the natural bone-healing process.

techniques share similarities with the practices of Japanese temple carpenters. As a result, the risk of delayed or nonunion in the retro-tubercle region, exacerbated by the widening of the descending gap and an increase in posterior tibial slope,[5,6] is effectively mitigated. The advantages and disadvantages of this technique are shown in Table 2.

One of the advantages of interlocking DTO is its potential to eliminate the reliance on additional AP screw fixation, a common practice in conventional DTO procedures.[7-9] By the AP screw-less methodology, interlocking DTO streamlines the surgical process and eliminates the inherent drawbacks associated with DTO such as subcutaneous irritation with screw prominence and inadvertent damage to posterior neurovascular structures. This streamlined approach not only simplifies the surgical technique but also holds the potential to enhance patient outcomes and postoperative recovery.

Interlocking DTO exhibits compelling evidence of bone healing in the retro-tubercle osteotomy 3 months postsurgery (Fig 1C). The promotion of characteristic bone continuity, coupled with the absence of metallic hardware penetrating the osteotomy, significantly facilitates the natural bone-healing process. The incorporation of a stable mortise-and-tenon joint structure ensures that the PTS remains unaffected during the postoperative course when implementing an early full weightbearing rehabilitation protocol (Fig 10). Notably, even in the event of hinge fracture, preferential healing of the retro-tubercle is observable (Fig 11).

It is crucial to acknowledge the learning curve associated with implementing interlocking DTO. The precise execution of the interlocking mechanism requires careful attention to the angles and orientations of the osteotomy cuts. Using an in vitro saw-bone model, preoperatively, surgeons must be skilled in accurately placing the guidewires, cutting bone, and ensuring the proper fit of the repositioned retro-tubercle.

In conclusion, the interlocking DTO technique showcases a promising solution for improving retro-tubercle stability and healing in open-wedge proximal tibial osteotomy. The interlocking mechanism effectively prevents complications associated with conventional DTO methods, resulting in reduced reliance on AP screw fixation. While further research and clinical validation are warranted, interlocking DTO holds the potential to reshape the landscape of knee osteotomy procedures and improve patient outcomes.

Disclosures

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