Technical Note

Simultaneous Correction of Varus Deformity and Posterior Tibial Slope by Modified Hybrid Closed-Wedge High Tibial Osteotomy

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Abstract: A large posterior tibial slope has been proven to be a risk factor for anterior cruciate ligament (ACL) injuries, ACL graft failure, and medial meniscus posterior root tear. In addition, such pathologies often are accompanied by varus alignment. Thus, simultaneous varus and slope-correction osteotomy is required in such cases. High tibial osteotomy (HTO) is a well-established treatment for medial compartment knee osteoarthritis. Several HTO surgical techniques have been proposed, and hybrid closed-wedge HTO has been found to correct both varus deformity and a large posterior tibial slope via modification of the transverse osteotomy procedure. This Technical Note describes a modified hybrid closed-wedge HTO for simultaneous varus and slope correction in patients with ACL deficiency and/or medial meniscus posterior root tear involving both varus deformity and a large posterior tibial slope. This technique may reduce the risk of failure of the ACL graft and/or repaired medial meniscus posterior root.

A large posterior tibial slope has been proven to be a risk factor for anterior cruciate ligament (ACL) injuries[1] as well as graft tear and insufficiency after ACL reconstruction.[2] Therefore, in cases of ACL deficiency involving a large posterior tibial slope, especially revision cases, anterior closing-wedge osteotomy as a slope-reducing osteotomy with concomitant ACL reconstruction is considered.[3-5] However, in such chronic ACL deficiency cases, medial meniscus (MM) injuries and medial compartment osteoarthritis (OA) often also are present, and simultaneous varus and slope correction would be required.[6]

Medial meniscus posterior root tear (MMPRT) has received increasing attention, and surgical intervention via MMPRT repair has been preferred to restore the load-distributing function of MM and eventually prevent OA progression.[7] However, MMPRT often complicates varus alignment; MMPRT repair alone would not work adequately in such cases.[8] In addition, a large posterior tibial slope has been shown to be a risk factor for MMPRT.[9] Therefore, in patients with MMPRT involving both varus deformity and large posterior tibial slope, simultaneous varus and slope-correction osteotomy is required.

High tibial osteotomy (HTO) is a well-established treatment for medial compartment knee OA. Several surgical techniques for HTO have been proposed, and hybrid closed-wedge HTO (CWHTO) has been found to correct both varus deformity and a large posterior tibial slope via modification of the transverse osteotomy procedure. Hybrid CWHTO was developed by Takeuchi et al.,[10] and it has several advantages over open-wedge HTO (OWHTO)[11] and conventional CWHTO.[12]

This Technical Note describes modified hybrid CWHTO for simultaneous varus and slope correction in

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patients with ACL deficiency and/or MMPRT involving both varus deformity and a large posterior tibial slope.

Indications

This technique is indicated for cases involving both varus alignment (weight-bearing line ratio <40%) and a large posterior tibial slope (posterior tibial slope angle >12°) with (1) chronic ACL deficiency with medial compartment OA and anterior tibial subluxation as well as (2) ACL revision surgeries, excluding high-level athletes. In such cases, concomitant ACL reconstruction with or without anterolateral structure augmentation is considered; however, if patients have fixed anterior tibial subluxation and lack subjective instability, hybrid CWHTO alone without ACL reconstruction is performed.

Another indication of this technique is for patients with MMPRT involving both varus alignment (weight-bearing line ratio <40%) and a large posterior tibial slope (posterior tibial slope angle >12°), where not only varus alignment but also a large posterior tibial slope are potential risk factors for MMPRT repair failure; in such cases, simultaneous MMPRT repair and hybrid CWHTO are performed.

Preoperative Planning

An anteroposterior long-leg weight-bearing radiograph is used for the preoperative planning of coronal-alignment correction (Fig 1). The proximal osteotomy line is drawn from the lateral tibial cortex, 40 mm distal to the lateral tibial joint surface, to the medial tibial cortex, and approximately 15 mm distal to the medial tibial joint surface. The hinge point is defined with respect to the length of the proximal osteotomy line and set at one-third of the medial cortex. The correction angle is set such that the weight-bearing-line ratio is aimed at 57%, and the distal osteotomy line is drawn accordingly. We intend for the alignment to be as neutral as possible (ideally, 50%) but not be undercorrected. Considering possible errors, we set the weight-bearing line ratio at 57%.

For sagittal alignment correction, a true lateral radiograph with full extension is viewed (Fig 2). Two circles, 5 cm apart, are placed in the proximal tibial

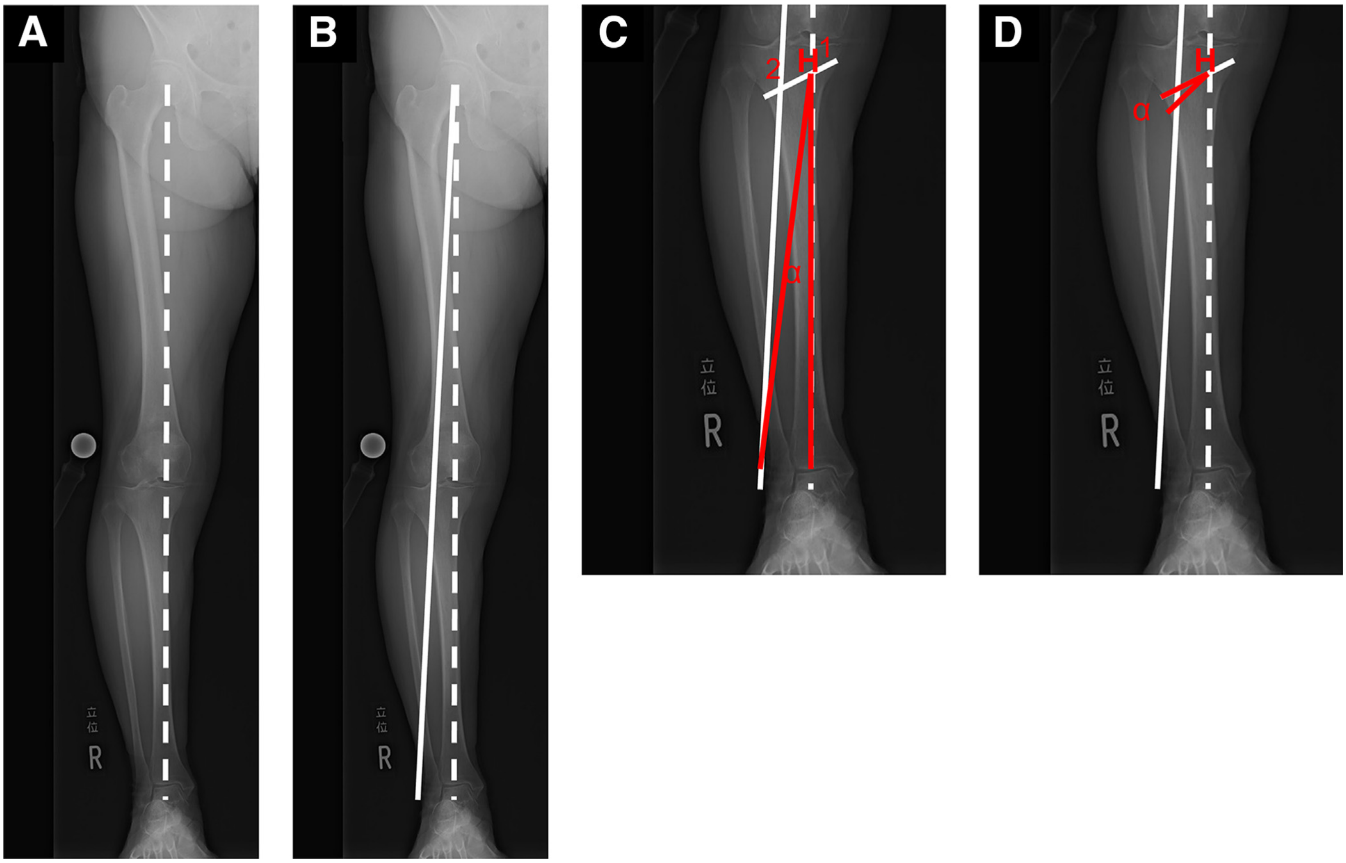


Fig 1. Preoperative planning in coronal plane. (A) A weight-bearing line is drawn from the femoral head center to the ankle center (dotted line). (B) A new weight-bearing line from the femoral head center through the point 57% of the weight-bearing-line ratio is drawn (solid line). (C) The proximal osteotomy line is drawn, and the hinge point (H) is defined with respect to the length of the proximal osteotomy line and set at one-third from the medial cortex. The correction angle (α) is subsequently measured. (D) The distal osteotomy line is drawn according to the correction angle.

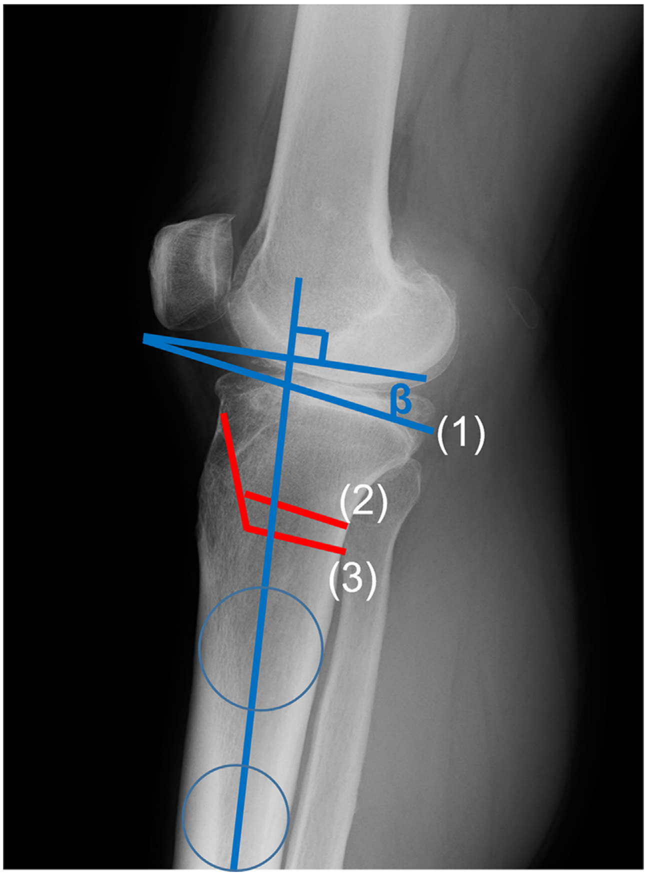


Fig 2. Preoperative planning in sagittal plane. Two circles 5 cm apart are placed in the proximal tibial shaft, and a line is drawn by connecting the centers of the 2 circles, defined as the tibial longitudinal axis. The posterior tibial slope angle is defined as the angle between the line perpendicular to the tibial longitudinal axis and the tangent to the tibial plateau (1). The proximal osteotomy line (2) is drawn parallel to the line tangent to the tibial plateau, and the distal osteotomy line (3) is subsequently drawn with the corrected posterior tibial slope angle.

shaft, and a line is drawn by connecting the centers of the 2 circles, defined as the tibial longitudinal axis. The posterior tibial slope angle is defined as the angle between the line perpendicular to the tibial longitudinal axis and tangent to the tibial plateau. The proximal osteotomy line is drawn parallel to the line tangent to the tibial plateau, and the distal osteotomy line is subsequently drawn with the corrected posterior tibial slope angle, which is normally set at 5°.

Surgical Technique (With Video Illustration)

The patient is positioned supine on a standard operating table (Video 1). A nonsterile tourniquet is applied to the upper thigh of the operated leg. The fluoroscopy unit is positioned on the medial side of the patient, and its inclination is set parallel to the lateral tibial plateau.

In cases of combined ACL reconstruction, ACL reconstruction is performed before osteotomy, without graft passage. After osteotomy is completed, graft passage and fixation are performed. In cases of combined MMPRT repair, transosseous MMPRT repair is performed without final fixation, and final fixation of the repair sutures is performed after the osteotomy is completed.

First, a fibular osteotomy is performed in the middle of the fibula. Segment resection is performed to remove approximately 20 mm of the fibula and enable tibial correction (Fig 3).

An 8-cm longitudinal incision is made on the anterolateral aspect of the proximal tibia. The fascia of the tibialis anterior muscle is cut, and the cutting line is extended to the retinaculum on the lateral side of the patellar tendon for subsequent ascending osteotomy. The retinaculum posterior to the Gerdy tubercle is also cut, and the tibial cortex posterior to the Gerdy tubercle is exposed. The tibialis anterior muscle is subsequently released from the lateral tibial cortex, and the posterior periosteum and soft tissue are released according to the osteotomy site (Fig 4).

After the lateral tibial cortex is exposed, a Kirschner wire is inserted from the lateral to the medial cortex along the proximal osteotomy line (Figs 5A and 6A). A short Kirschner wire is inserted percutaneously at the hinge point from the anterior to the posterior under fluoroscopy (Figs 5B and 6B). The distal osteotomy line is determined using a special goniometer (Mizuho, Tokyo, Japan) (Figs 5C and 6C), and another Kirschner wire is inserted along the distal osteotomy line from the lateral cortex to the hinge point (Figs 5D and 6D). In the sagittal plane, the proximal osteotomy line is drawn parallel to the tibial plateau, whereas the distal osteotomy line is drawn using the corrected posterior tibial slope angle (Fig 5E).

Ascending osteotomy is performed from a point proximal to the patellar tendon insertion to the transverse osteotomy lines, maintaining the thickness of the tibial tuberosity at 10 mm (Fig 7A). Transverse osteotomies are subsequently performed according to the lines drawn on the lateral tibial cortex and Kirschner wires (Fig 7 B and C). The lateral closed-wedge bone block is removed (Fig 7D). Finally, all Kirschner wires are removed except for the proximal osteotomy line, and the final osteotomy is performed according to the proximal osteotomy line such that the medial cortex is cut completely (Figs 6E and 7E).

After the osteotomy is completed, the proximal and distal segments are approximated, hyperextended, and rotated in the valgus direction with the lateral wedge closed and medial wedge opened (Fig 8A).

Osteotomy fixation is performed using a proximal-lateral tibial plate designed specifically for the hybrid CWHTO, that is, the Tris Hybrid Lateral 2 HTO plate

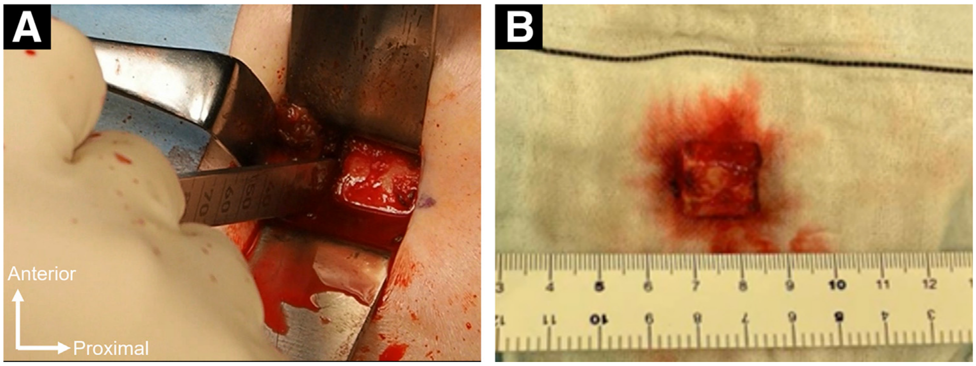


Fig 3. Fibular osteotomy. A case of medial meniscus posterior root tear with varus alignment and large posterior tibial slope; left knee with patient in supine position. (A) A fibular osteotomy is performed in the middle of the fibula. (B) Segment resection is performed to remove approximately 20 mm of the fibula.

system (Olympus Terumo Biomaterials, Tokyo, Japan) (Figs 6 F and G and 8B). A representative case is shown in Figures 9 and 10. Tips and pitfalls of this technique are listed in Table 1.

Postoperative Rehabilitation

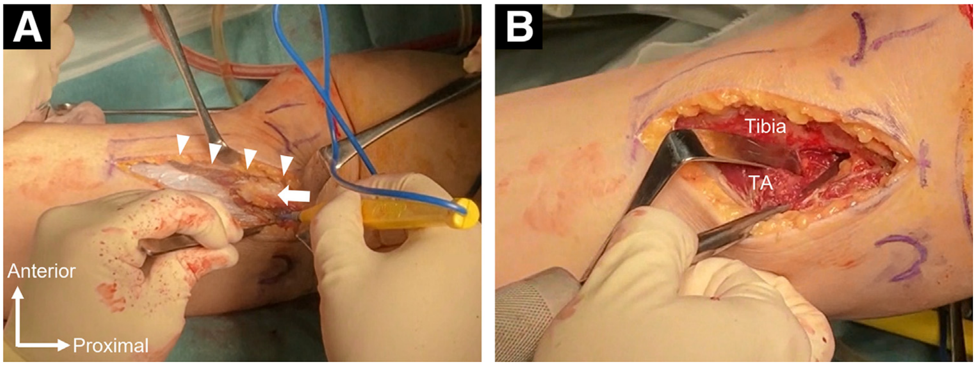
Range of motion exercises without restriction are encouraged immediately after surgery. Partial weight-bearing with a removable splint and crutches is allowed for the first 2 weeks. Thereafter, full weight-bearing is allowed as tolerated 2 weeks postoperatively.

Discussion

Several risk factors for ACL injuries exist, and bony morphologic factors have been proposed as a considerable risk factor.[13] Among several parameters, a large posterior tibial slope has been proven to be one of the strongest risk factors for ACL injuries, as well as graft tear and insufficiency after ACL reconstruction due to increased strain in the ACL and increased anterior tibial translation in ACL-deficient knees.[1,2] Therefore, in cases with ACL deficiency involving a large posterior tibial slope, especially in revision cases, anterior closing-wedge osteotomy has been performed as a slope-reducing osteotomy concomitant with ACL reconstruction, and satisfactory clinical outcomes with restored knee stability and graft-failure prevention have been reported.[3-5] However, in such chronic ACL deficiency cases, MM injuries as well as medial compartment OA often are also present, and simultaneous varus and slope correction would be required. In their biomechanical study, Imhoff et al.[6] reported that simultaneous varus and slope-correction osteotomy further decreased the anterior tibial translation and ACL-graft force in ACL-reconstructed knees. Arun et al.[14] also demonstrated in their case series of simultaneous ACL reconstruction and OWHTO that decreasing the tibial slope by >5° compared with the preoperative value had a functionally favorable effect on the reconstructed ACL graft and outcome.

MMPRT disrupts the meniscal hoop and causes MM extrusion, thus resulting in loss of load-distributing function and early degeneration of articular cartilage.[15] MMPRT repair has been preferred for the reconstruction of the meniscal hoop, correction of the

Fig 4. Tibia exposure. A case of medial meniscus posterior root tear with varus alignment and large posterior tibial slope; left knee with patient in supine position. (A) The fascia of the tibialis anterior muscle and the retinaculum on the lateral side of the patellar tendon (white arrowheads) are cut. The retinaculum posterior to the Gerdy tubercle (white arrow) is also cut, and the tibial cortex posterior to the Gerdy tubercle is exposed. (B) The tibialis anterior muscle (TA) is subsequently released from the lateral tibial cortex, and the posterior periosteum and soft tissue are released according to the osteotomy site.



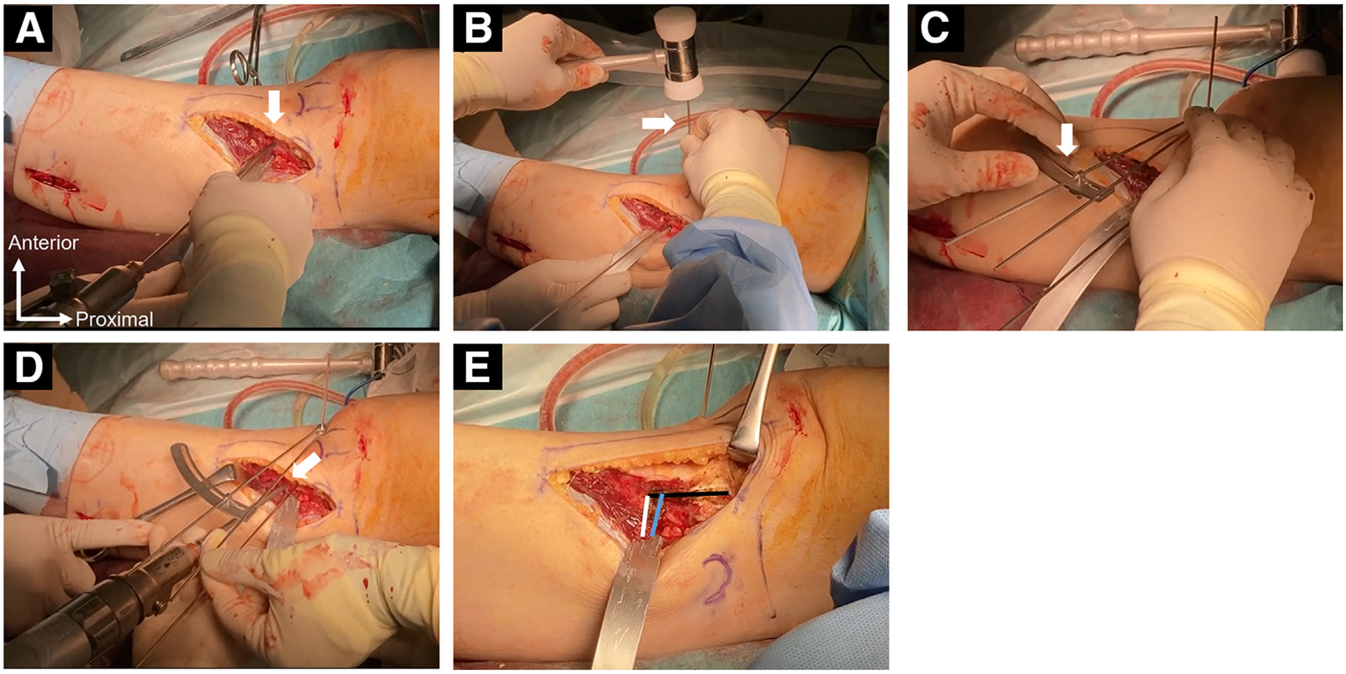


Fig 5. Tibia osteotomy preparation. A case of medial meniscus posterior root tear with varus alignment and large posterior tibial slope; left knee with patient in supine position. (A) A Kirschner wire (arrow) is inserted from the lateral to the medial cortex along the proximal osteotomy line. (B) A short Kirschner wire (arrow) is percutaneously inserted at the hinge point from the anterior to the posterior under fluoroscopy. (C) The distal osteotomy line is determined using a special goniometer (arrow). (D) Another Kirschner wire (arrow) is inserted along the distal osteotomy line from the lateral cortex to the hinge point. (E) Osteotomy lines are drawn so that the proximal osteotomy line (blue line) is drawn parallel to the tibial plateau, whereas the distal osteotomy line (white line) is drawn with the corrected posterior tibial slope angle.

meniscus extrusion to preserve meniscus function, and consequently, prevention of OA progression. However, most MMPRTs are associated with degenerative changes in middle-aged and older individuals. In addition, MMPRT is often complicated by varus alignment. Hence, repairing tears alone cannot always reduce extrusion and restore meniscus function with the reported secure fixation methods.[16,17] Ridley et al.[8] reported that increased preoperative varus alignment is associated with higher failure rates and lower patient-reported outcomes after isolated MMPRT repair. In addition, although no study has confirmed the correlation between posterior tibial slope and clinical results after MMPRT repair, a large posterior tibial slope has been shown to be associated with bilateral MMPRT[9] and the development of spontaneous osteonecrosis of the knee.[18] Therefore, in cases of MMPRT with both varus deformity and a large posterior tibial slope, simultaneous varus and slope-correction osteotomy are required.

Several surgical techniques for HTO have been proposed, including OWHTO and CWHTO. Among them, the hybrid CWHTO has several advantages over OWHTO and conventional CWHTO, and satisfactory short-term outcomes have been reported.[19] The term "hybrid" denotes a combination of the lateral closed wedge and medial open wedge created by a unique hinge point, which enables less wedged-bone loss at the lateral side and greater correction of the osteotomy with reduced leg shortening. In addition, step-off can be avoided, and a firm attachment of the lateral cortex is potentially achievable at the lateral osteotomy site by oblique osteotomy, enabling early full weight-bearing. Moreover, the following advantages over OWHTO have been reported: (1) more extensive correction is possible in patients with severe varus deformity, (2) it can be applied to patients with a flexion contracture up to 20°, and (3) it produces less lowering of the patellar and better joint congruity at the patellofemoral joint.[12] Therefore, the primary indications for hybrid CWHTO are as follows: (1) concomitant patellofemoral OA, (2) flexion contracture between 5° and 20°, and (3) large correction (>12° by OWHTO) with no desire for double-level osteotomy. In addition to the foregoing primary indications, we found that this technique potentially corrects both varus deformity and a large posterior tibial slope via modification of the transverse osteotomy procedure. Technically, this modified procedure is considerably easier than asymmetrical anterior closing-wedge osteotomy, with smaller exposure of the tibia's anterior aspect (Table 2). Another advantage is that interference between the osteotomy plate/screw and tibial tunnel for ACL reconstruction/transosseous

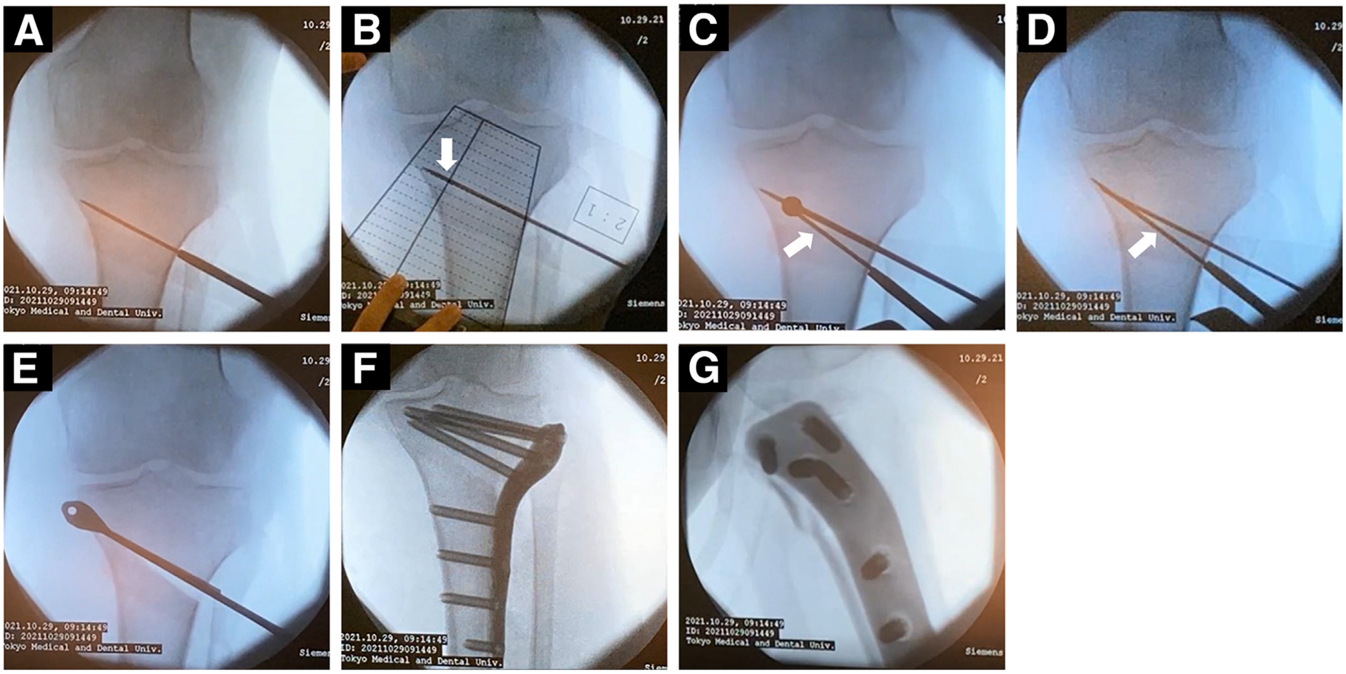


Fig 6. Surgical process examined under fluoroscopy. A case of medial meniscus posterior root tear with varus alignment and large posterior tibial slope; left knee with patient in supine position. (A) Fluoroscopy is set parallel to the lateral tibial plateau, and a Kirschner wire is inserted from the lateral to the medial cortex along the proximal osteotomy line. (B) A short Kirschner wire is inserted at the hinge point with respect to the length of the proximal osteotomy line and set at one-third distance from the medial cortex (arrow). (C) The distal osteotomy line is determined using a special goniometer (arrow). (D) Another Kirschner wire (arrow) is inserted along the distal osteotomy line from the lateral cortex to the hinge point. (E) After transverse wedge osteotomy, final osteotomy is performed according to the proximal osteotomy line, such that the medial cortex is cut completely. (F, G) After plate fixation, coronal (F) and sagittal (G) alignments are checked.

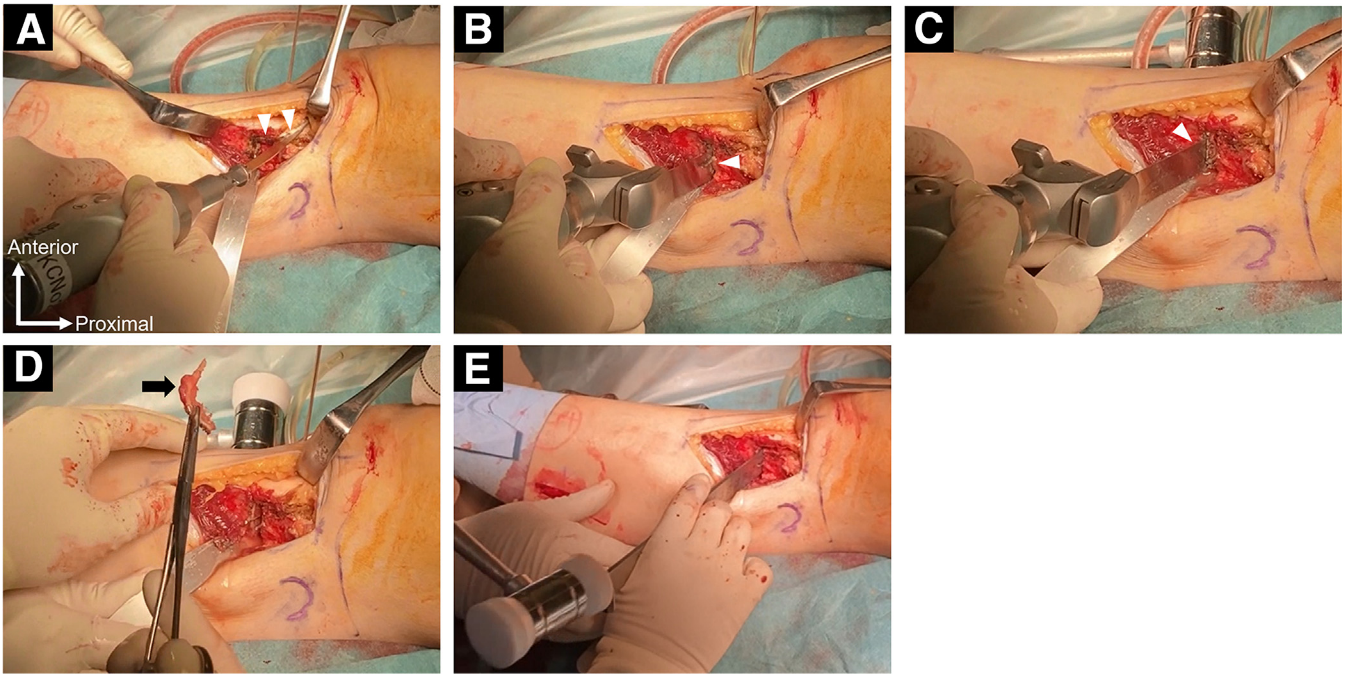


Fig 7. Tibia osteotomy. A case of medial meniscus posterior root tear with varus alignment and large posterior tibial slope; left knee with patient in supine position. (A) Ascending osteotomy (arrowheads) is performed. (B) Proximal transverse osteotomy (arrowhead) is performed. (C) Distal transverse osteotomy (arrowhead) is performed. (D) The lateral closed-wedge bone block (arrow) is removed. (E) The final osteotomy is performed according to the proximal osteotomy line, such that the medial cortex is cut completely.

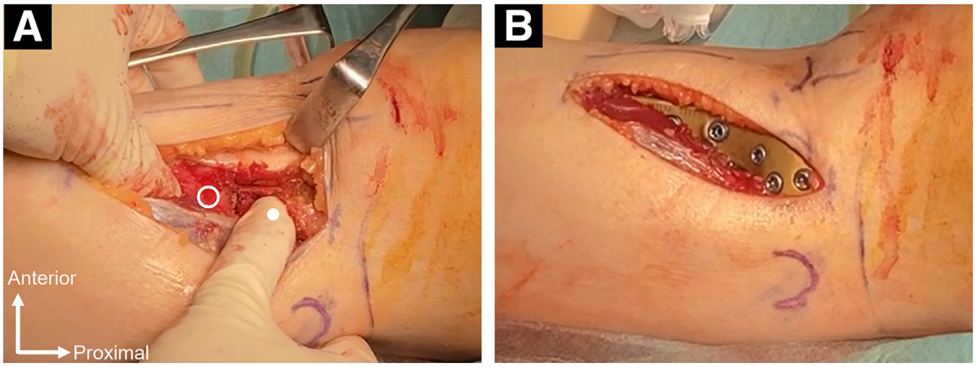


Fig 8. Correction and plate fixation. A case of medial meniscus posterior root tear with varus alignment and large posterior tibial slope; left knee with patient in supine position. (A) The proximal (filled circle) and distal (open circle) segments are approximated, hyperextended, and rotated in the valgus direction with the lateral wedge closed and medial wedge opened. (B) The osteotomy fixation is performed with a proximal-lateral tibial plate designed specifically for hybrid CWHTO.

MMPRT repair at the medial proximal tibia can be more easily avoided than in medial OWHTO. In contrast, this procedure requires fibular osteotomy. Another limitation is that hybrid CWHTO often requires a longer time until bone union than OWHTO, and in rare cases, lateral plate fixation alone is not sufficiently stable, and additional medial small-plate augmentation may be necessary. Moreover, this is a preliminary report, and further follow-up is necessary to investigate the long-term effects of the combined hybrid CWHTO technique for simultaneous varus and slope correction in terms of clinical outcomes and ACL graft/repaired meniscal root survival. Nevertheless, the modified hybrid CWHTO is a potentially favorable treatment option for patients with ACL deficiency and/or MMPRT involving both varus deformity and a large posterior tibial slope to reduce the risk of failure of the ACL graft and/or repaired MM posterior root.

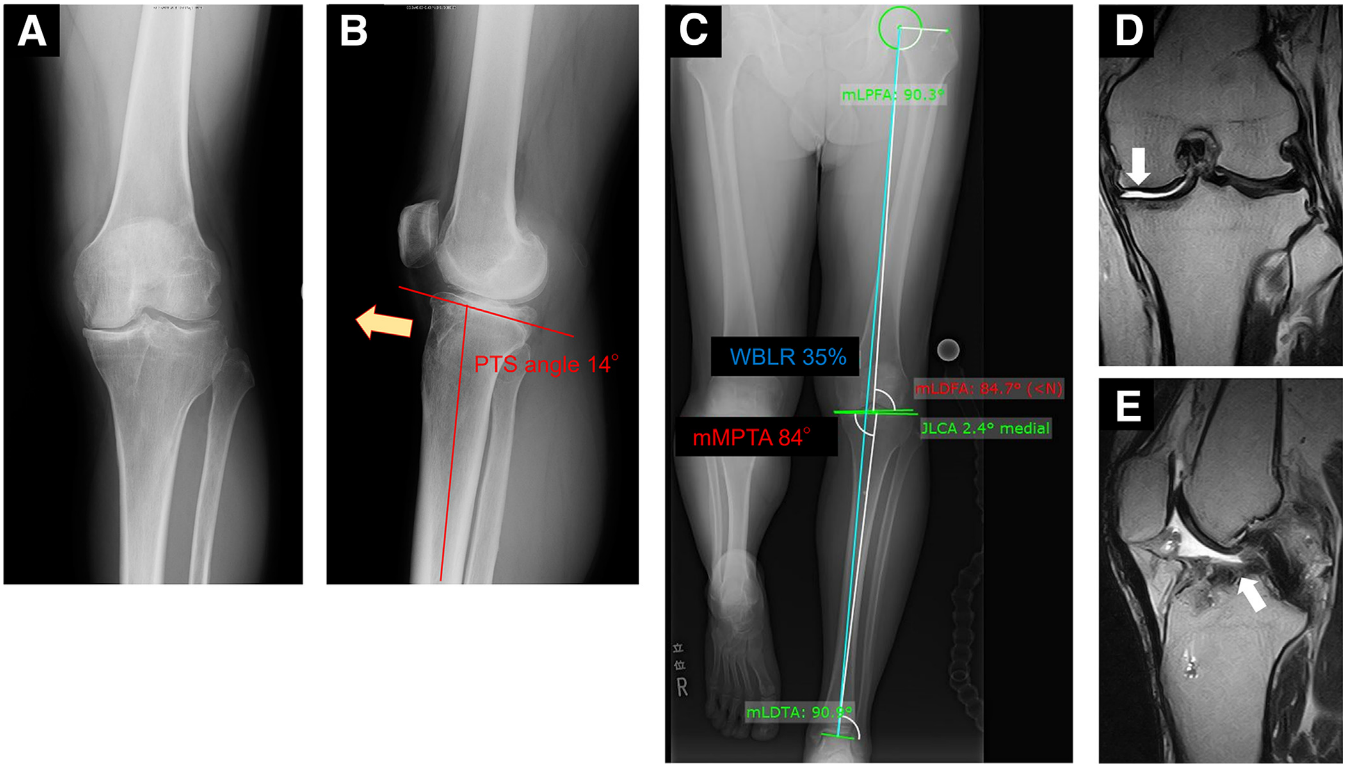


Fig 9. A case of ACL graft failure with medial-compartment osteoarthritis (OA); left knee. (A, B) Preoperative radiographs. A weight-bearing anteroposterior view (A) exhibited medial-compartment OA. A lateral view in full extension (B) exhibited a posterior tibial slope (PTS) angle of 14° and anterior tibial subluxation (arrow). (C) An anteroposterior long-leg weight-bearing radiograph revealed a weight-bearing-line ratio (WBLR) of 35% and mechanical medial proximal tibial angle (mMPTA) of 84°. (D, E) Preoperative magnetic resonance imaging findings revealed medial meniscus defect (arrow) in a coronal plane (D), and the reconstructed ACL disappeared (arrow) in a sagittal plane (E).

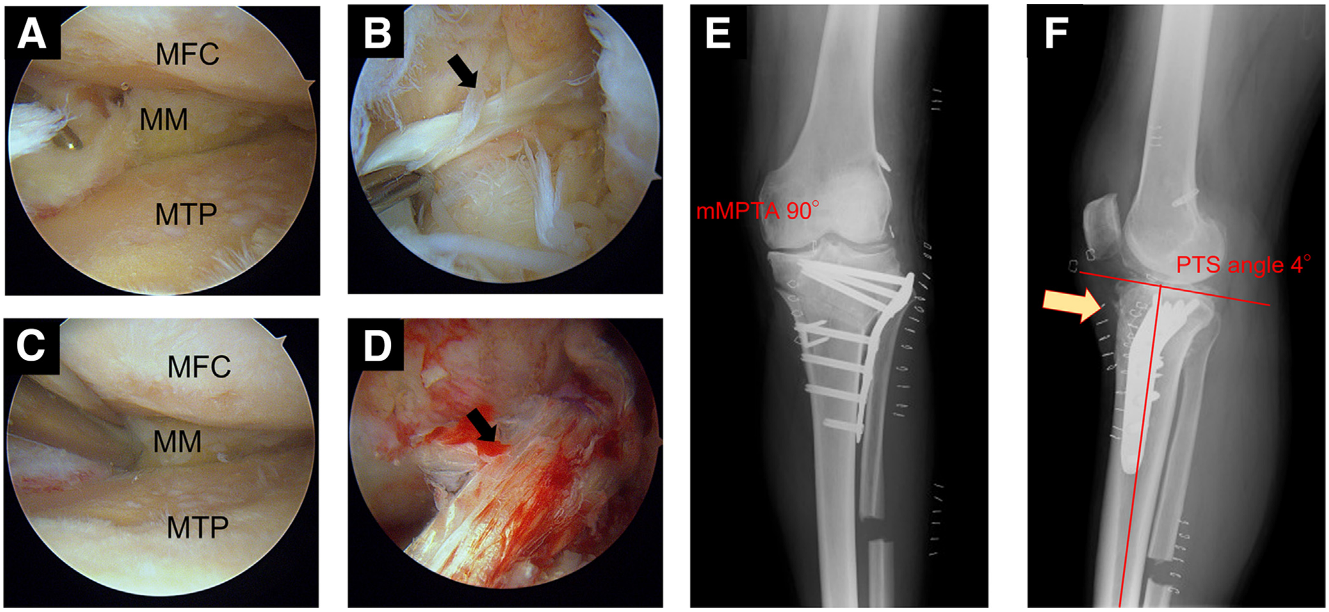


Fig 10. Postoperative findings. A case of ACL graft failure with medial compartment OA; left knee. (A, B) Preoperative arthroscopic findings exhibited medial meniscus defect (A), and the reconstructed ACL disappeared (arrow) (B). (C) Medial meniscus was debrided. (D) ACL was reconstructed (arrow) using a contralateral bone—patellar tendon—bone graft. (E) Postoperative anteroposterior view. Mechanical medial proximal tibial angle (mMPTA) was corrected to 90°. (F) Lateral view in full extension. The posterior tibial slope (PTS) angle was reduced to 4°, and anterior tibial subluxation was also reduced (arrow). (MFC, medial femoral condyle; MM, medial meniscus; MTP, medial tibial plateau).

Table 1. Tips and Pitfalls

Tips	Pitfalls
• Precise preoperative planning is critical to achieve desired simultaneous varus and slope correction. • In the coronal plane, a short Kirschner wire should be inserted at the hinge point under fluoroscopy, and the distal osteotomy line should be determined using a special goniometer. • In the sagittal plane, osteotomy lines are drawn so that the proximal osteotomy line is drawn parallel to the tibial plateau, whereas the distal osteotomy line is drawn with the corrected posterior tibial slope angle.	• Fibular osteotomy is necessary to enable tibial correction. • It is important to ensure that the posterior periosteum and soft tissue are released according to the osteotomy site, and a retractor should be inserted to avoid posterior neurovascular injury.

Table 2. Advantages and Limitations of This Technique

Advantages	Limitations
• Technically, this modified procedure is considerably easier than asymmetrical anterior closing-wedge osteotomy with smaller exposure of the tibia's anterior aspect. • Interference between osteotomy plate/screw and the tibial tunnel for ACL reconstruction/trans-osseous MMPRT repair at the medial proximal tibia can be more easily avoided than that in medial OWHTO.	• This procedure requires fibular osteotomy. • Hybrid CWHTO often requires longer time until bone union than OWHTO, and in rare cases, lateral plate fixation alone is insufficiently stable, and additional medial small plate augmentation may be necessary.

ACL, anterior cruciate ligament; CWHTO, closed-wedge high tibial osteotomy; MMPRT, medial meniscus posterior root tear; OWHTO, open-wedge high tibial osteotomy.

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References

1. Feucht MJ, Mauro CS, Brucker PU, Imhoff AB, Hinterwimmer S. The role of the tibial slope in sustaining and treating anterior cruciate ligament injuries. *Knee Surg Sports Traumatol Arthrosc* 2013;21:134-145.
2. Gwinner C, Janosec M, Wierer G, Wagner M, Weiler A. Graft survivorship after anterior cruciate ligament reconstruction based on tibial slope. *Am J Sports Med* 2021;49:3802-3808.
3. Sonnery-Cottet B, Mogos S, Thaunat M, et al. Proximal tibial anterior closing wedge osteotomy in repeat revision of anterior cruciate ligament reconstruction. *Am J Sports Med* 2014;42:1873-1880.
4. Song GY, Ni QK, Zheng T, Zhang ZJ, Feng H, Zhang H. Slope-reducing tibial osteotomy combined with primary anterior cruciate ligament reconstruction produces improved knee stability in patients with steep posterior tibial slope, excessive anterior tibial subluxation in extension, and chronic meniscal posterior horn tears. *Am J Sports Med* 2020;48:3486-3494.
5. Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2846-2852.
6. Imhoff FB, Comer B, Obopilwe E, Beitzel K, Arciero RA, Mehl JT. Effect of slope and varus correction high tibial osteotomy in the ACL-deficient and ACL-reconstructed knee on kinematics and ACL graft force: A biomechanical analysis. *Am J Sports Med* 2021;49:410-416.
7. LaPrade RF, Matheny LM, Moulton SG, James EW, Dean CS. Posterior meniscal root repairs: Outcomes of an anatomic transtibial pull-out technique. *Am J Sports Med* 2017;45:884-891.
8. Ridley TJ, Ruzbarsky JJ, Dornan GJ, et al. Minimum 2-year clinical outcomes of medial meniscus root tears in relation to coronal alignment. *Am J Sports Med* 2022;50:1254-1260.
9. Hiranaka T, Furumatsu T, Okazaki Y, et al. Steep medial tibial slope and prolonged delay to surgery are associated with bilateral medial meniscus posterior root tear. *Knee Surg Sports Traumatol Arthrosc* 2021;29:1052-1057.
10. Takeuchi R, Ishikawa H, Miyasaka Y, Sasaki Y, Kuniya T, Tsukahara S. A novel closed-wedge high tibial osteotomy procedure to treat osteoarthritis of the knee: Hybrid technique and rehabilitation measures. *Arthrosc Tech* 2014;3:e431-e437.
11. Eliasberg CD, Hancock KJ, Swartwout E, Robichaud H, Ranawat AS. The ideal hinge axis position to reduce tibial slope in opening-wedge high tibial osteotomy includes proximalization-extension and internal rotation. *Arthroscopy* 2021;37:1577-1584.
12. Ishimatsu T, Takeuchi R, Ishikawa H, et al. Hybrid closed wedge high tibial osteotomy improves patellofemoral joint congruity compared with open wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc* 2019;27:1299-1309.
13. Vasta S, Andrade R, Pereira R, et al. Bone morphology and morphometry of the lateral femoral condyle is a risk factor for ACL injury. *Knee Surg Sports Traumatol Arthrosc* 2018;26:2817-2825.
14. Arun GR, Kumaraswamy V, Rajan D, et al. Long-term follow up of single-stage anterior cruciate ligament reconstruction and high tibial osteotomy and its relation with posterior tibial slope. *Arch Orthop Trauma Surg* 2016;136:505-511.
15. Lerer DB, Umans HR, Hu MX, Jones MH. The role of meniscal root pathology and radial meniscal tear in medial meniscal extrusion. *Skeletal Radiol* 2004;33:569-574.
16. LaPrade RF, LaPrade CM, Ellman MB, Turnbull TL, Cerminara AJ, Wijdicks CA. Cyclic displacement after meniscal root repair fixation: A human biomechanical evaluation. *Am J Sports Med* 2015;43:892-898.
17. Nakata K, Shino K, Kanamoto T, et al. New technique of arthroscopic meniscus repair in radial tears. sports injuries: Prevention, diagnosis, treatment and rehabilitation. In: Doral MN, ed. *Sports injuries*. Springer: Berlin, Heidelberg, 2011;305-311.
18. Yamagami R, Taketomi S, Inui H, Tahara K, Tanaka S. The role of medial meniscus posterior root tear and proximal tibial morphology in the development of spontaneous osteonecrosis and osteoarthritis of the knee. *Knee* 2017;24:390-395.
19. Saito H, Saito K, Shimada Y, et al. Short-term results of hybrid closed-wedge high tibial osteotomy: A case series with a minimum 3-year follow-up. *Knee Surg Rel Res* 2018;30:293-302.