Technical Note

Anterior Open-Wedge Osteotomy to Correct Sagittal and Coronal Malalignment in a Case of Failed High Tibial Osteotomy and Failed Posterior Cruciate Ligament Reconstruction

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Abstract: Anterior open-wedge high tibial osteotomy of the proximal tibia is a reliable surgical procedure to treat genu recurvatum secondary to decreased posterior tibial slope. It is also useful in cases of posterior cruciate ligament (PCL) deficiency, especially after a failed PCL reconstruction procedure as reversal of posterior tibial slope is a common risk factor for failure of PCL reconstruction. In some knee joints, reversed tibial slope may be associated with varus or valgus deformity. We describe correction of reverse posterior slope along with varus deformity, which may result from a poorly performed high tibial osteotomy leading to failure of reconstructed PCL. In our technique, both of the above deformities are corrected simultaneously, thereby addressing the sagittal and coronal malalignments of the knee with one osteotomy.

Evaluation of the Knee Joint

A thorough physical examination of the knee should be done to identify ligamentous causes of knee hyperextension with Lachman, pivot, posterior drawer, varus stress, valgus stress, dial, and posterolateral drawer tests. The clinical examination must always include the contralateral limb, and previous surgical scars need to be assessed to plan any subsequent surgery.

Imaging

Patients should have lateral and long leg weight-bearing x-rays and Rosenberg views. To measure the tibial slope, the anatomic tibial axis is used with a full-length lateral tibia radiograph. To get a short lateral radiographic view of the knee, the knee is flexed to 20°, superimposing the posterior femoral condyles on one another using fluoroscopy. The anatomic axis is calculated by using points at approximately 5 and 15 cm distal to the joint line on both the anterior and posterior tibial cortices. The midpoints between the respective anterior and posterior points are established. These midpoints are connected with a vertical line to establish the longitudinal axis of the posterior tibial slope (PTS). The PTS is defined as the angle between the line perpendicular to the tibial diaphyseal axis and the line tangent to the most superior points at the anterior and posterior edges of the medial tibial plateau (90° − angle β).[1,2] The physiological PTS is about 7° (Figs 1-3).

Indications

Proximal tibial anterior opening-wedge osteotomy should be considered in patients with symptomatic genu recurvatum of more than 15° or recurrent instability or after a failed posterior cruciate ligament reconstruction. Contraindications are grade IV osteoarthritis (Kellgren & Lawrence) and severe leg malalignment (more than 10° of valgus or varus).

Surgical Technique

We describe a proximal tibial anterior open-wedge osteotomy to correct sagittal and coronal malalignment after a failed high tibial osteotomy and failed posterior cruciate ligament (PCL) reconstruction with

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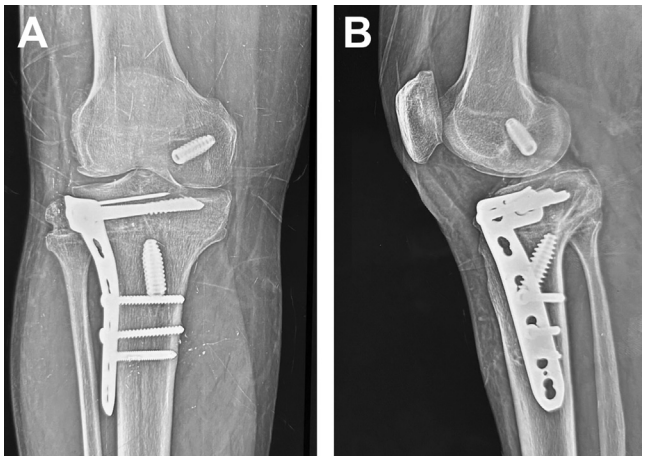

Fig 1. X-rays of the right knee. (A) Anteroposterior and (B) Lateral views. On presentation showed implants of a lateral closed-wedge high tibial osteotomy and posterior cruciate ligament reconstruction.

iliac crest autograft as a treatment for symptomatic genu recurvatum with 15° anterior tibial slope and 28% mechanical axis (MA) coronal limb alignment. The surgical technique is demonstrated in Video 1. A midline incision is made just medial to the tibial tuberosity starting from the level of the inferior pole of the patella to 8 cm distal to the tibial tuberosity. Full-thickness subcutaneous flaps are raised medially and laterally. Subperiosteal dissection is done under the medial collateral ligament up to the posteromedial tibial corner. On the lateral side, the tibialis anterior muscle is reflected off the tibia, and the dissection is carried up to the posterolateral corner staying above the proximal tibiofibular joint (Fig 4). The patellar tendon insertion is identified and isolated, and the tibial tuberosity is exposed. The osteotomy site is marked on both sides of the tibial tubercle measuring up to 7 cm down the anterior tibial crest. Cortical indentation is made using an osteotome at the proposed osteotomy before using a power saw. Then, a 7-cm bone block of the tibial tubercle of sufficient width and thickness is detached along with the attached patellar tendon as a single unit. This is covered with a vancomycin-soaked gauge piece and reflected proximally, and it is secured with a temporary stitch to the skin to prevent it from falling into the operative field. The PCL screw from the tibial tunnel is removed (Fig 5).

The knee is positioned at 80° of flexion with good posterior support. A C-arm is positioned to get a lateral view of the knee joint. Then, marking of the proposed osteotomy of the proximal tibia is made 5 cm distal to the joint line. Two monocortical parallel K-wires are passed under fluoroscopic guidance, orienting obliquely from distal to proximal on the sides of the tibial tuberosity bed (Fig 6). The K-wires are inserted until they touch the posterior cortex of the tibia, confirmed by fluoroscopy. They are aimed to reach the posterior cortex 6 to 7 mm distal to the joint line. A triangular proximal tibial segment is created with a higher posterior hinge. As the osteotomy is done proximal to the proximal tibiofibular joint, a fibular osteotomy is not required. A power saw (Precision System 8; Stryker) is used to make anterior, anteromedial, and anterolateral cortical cuts with the saw blade running flush on the K-wires inserted to guide the osteotomy. Once the cortical cuts are made, osteotomes are used to reach to within 1 cm of the posterior cortex through the full transverse width of the proximal tibia and taking care not to violate the posterior cortex (Fig 7). The posterior hinge is softened with a series of 3.2-mm drill holes except in the midline, where there is tunnel made for previous PCL reconstruction. The anterior gap is carefully opened with a laminar spreader (Fig 7). Based on the preoperative planning, estimating that 1-mm opening of the osteotomy is equivalent to 1° of tibial slope correction,[3] and the anterior gap is opened up to

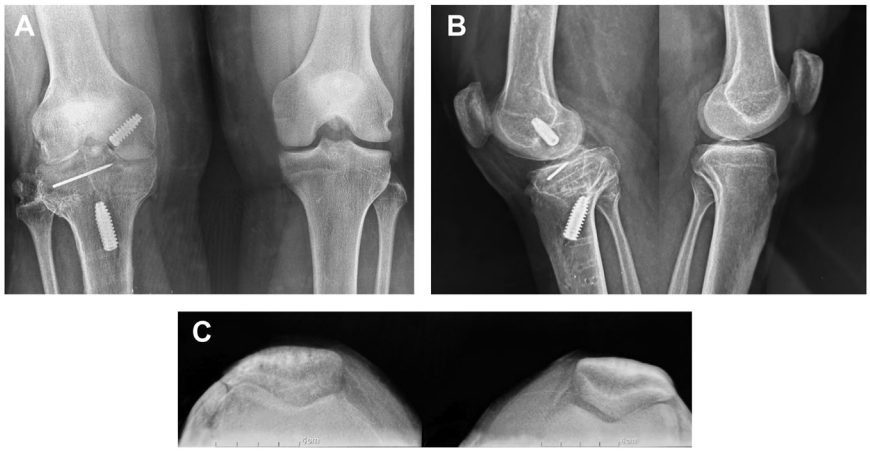

Fig 2. X-rays of both knee joints after implant removal in the right knee. (A) Standing anteroposterior view. (B) Lateral view. (C) Skyline view.

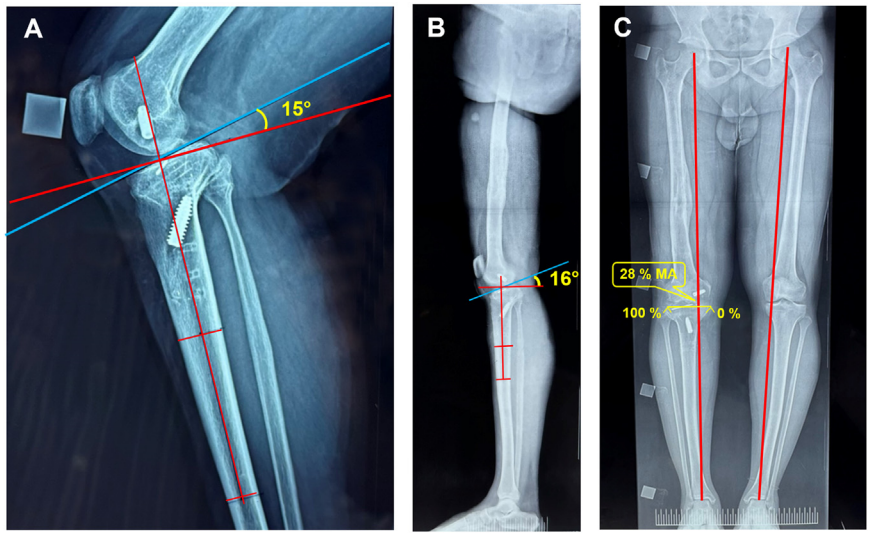

Fig 3. (A) Short lateral radiograph showing 15° of the anterior tibial slope. (B) Full-length lateral monopedal stance radiograph showing 16° of the anterior tibial slope. (C) Scanogram anteroposterior view shows 28% mechanical axis (MA) coronal limb alignment. %MA indicates the point of intersection between the mechanical axis and the tibial plateau, converted to a percentage from the medial edge (0%) to the lateral edge (100%).

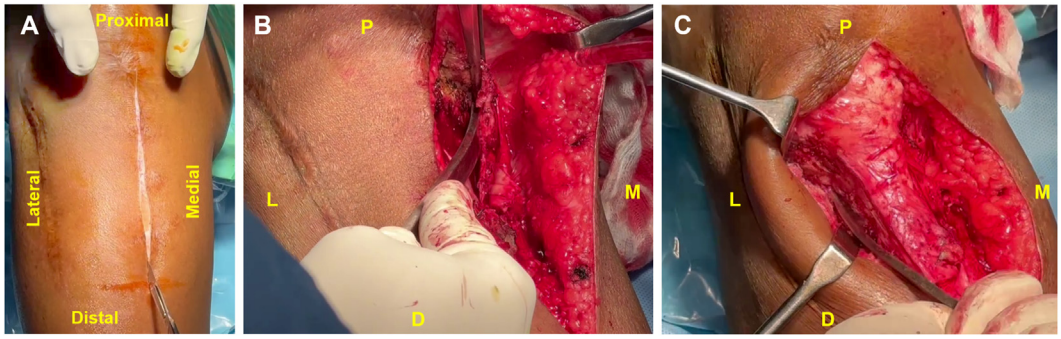

Fig 4. (A) Midline skin incision. (B) Medial dissection under the periosteum, deep to the medial collateral ligament up to the posteromedial corner of the tibia. (C) Lateral dissection elevating the tibialis anterior muscle and reaching the posterolateral corner of the tibia superior to proximal tibiofibular joint.

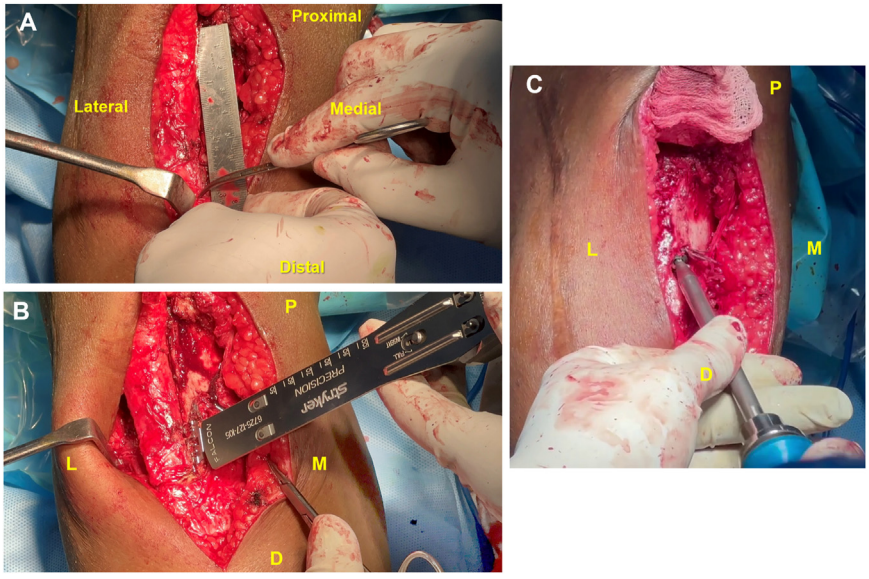

Fig 5. (A) Exposed patellar tendon and isolated tibial tuberosity with a 7-cm marking on the shin of the tibia. (B) Tibial tuberosity shingle osteotomy with a power saw through the indentations made by an osteotome from media to lateral. (C) Vancomycin-soaked gauze was used to cover the tibial shingle, which was sutured temporarily to the skin proximally. Removal of tibial interference screw.

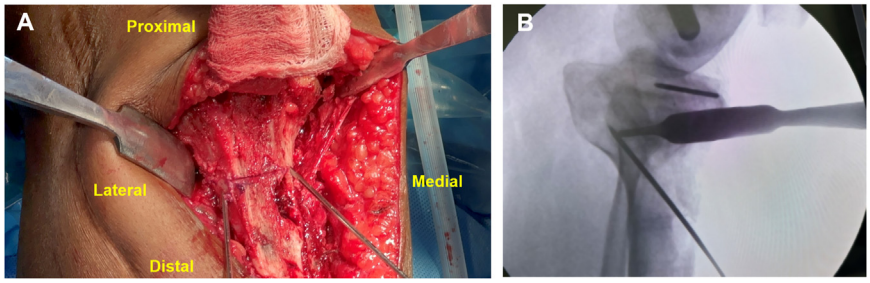

Fig 6. (A) Two monocortical parallel K-wires oriented obliquely from an inferior to a superior direction on the anterior tibial cortex. (B) Fluoroscopy image showing K-wires starting 5 cm below the joint line and reaching the posterior cortex.

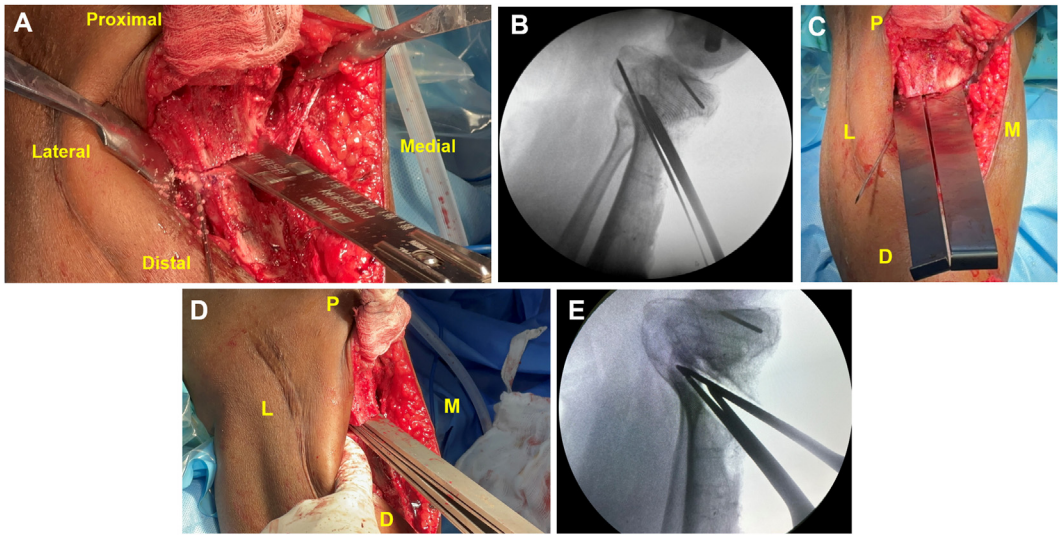

Fig 7. (A) Precision saw (Stryker) to make the anterior, anteromedial, and anterolateral cortical cuts. (B and C) Osteotome was used until it was within 1 cm of the posterior cortex both medially and laterally. Fluoroscopy image showing a K-wire 7 mm below the posterior joint line and passing the osteotome parallel with and above the guidewires. (D) To avoid risk of undesired posterior hinge fracture, the stacked osteotomes were left in place for few minutes to allow for the stress relaxation of the posterior cortex. (E) Fluoroscopy image showing gradual opening of the osteotomy with stacked osteotomes.

15 mm. This corrects the malalignment in the sagittal plane, which is confirmed by fluoroscopy. Later, the medial side laminar spreader is opened more under fluoroscopic guidance to correct the coronal malalignment, to see that MA is 50%, which widens the medial opening to 17 mm, correcting the varus deformity (Fig 8). Then, the osteotomy site is filled with 2 wedge-shaped tricortical grafts harvested from the iliac crest. One 17-mm-thick graft is inserted on the medial side of the osteotomy between the cortices of the medial tibia as the medial column support, and one 15-mm-thick graft is inserted on the lateral side of the osteotomy between the cortices of the lateral cortex as the lateral column support. The rest of the void is filled with cancellous bone graft from the iliac crest (Table 1).

Two staples (Stayfix T, 35 × 25 mm; BIOTEK) are inserted anteriorly across the grafts (Fig 8). Drill holes are made for the entry points of staples on the anterior tibial cortex on either side of the osteotomy to avoid fractures while inserting the staples. Then the tibial tubercle is fixed with 3 screws: 1 above and the other 2 below the osteotomy gap so that the tibial tuberosity shingle will act like a biological plate across the osteotomy (Fig 9). Finally, the tibial tubercle is put back in its bed in the proximal segment of the tibia but is proximalized in the distal tibial shin to the extent of the osteotomy gap (15 mm of proximalization in this case) (Fig 10). It is ensured that the relationship between the proximal fragment of the tibia and the corresponding portion of the tibial tubercle is not lost to avoid the iatrogenic patella infera. The tourniquet is released, and adequate irrigation is done after addressing all the bleeders. The wound is closed in layers and dressed with adequate padding.

Postoperative Rehabilitation

The knee joint is immobilized in an extension brace, and weight-bearing is not allowed for the first 8 weeks.

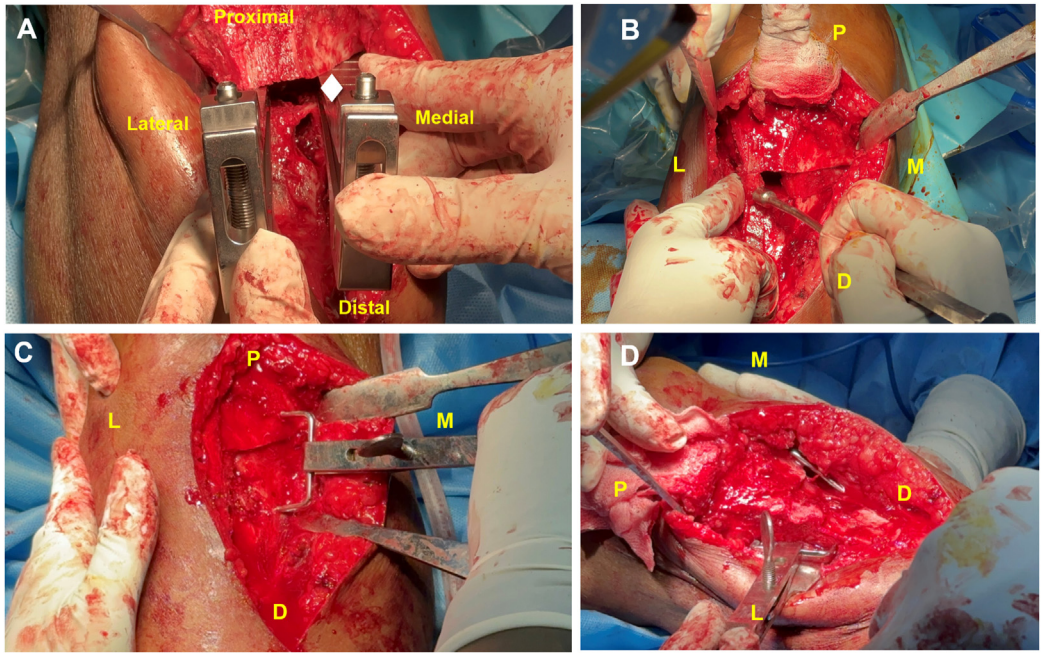

Fig 8. (A) Medial spreader was opened 3 mm (diamond) more than the lateral spreader to correct the coronal varus malalignment. This case had mild varus, which we could correct with differential opening of the medial and lateral parts of the osteotomy, but correction of any associated severe coronal malalignment would not have been possible with this technique. (B) A 17-mm tricortical graft was placed under the anteromedial cortex. A 15-mm tricortical graft was placed under the anterolateral cortex. (C) A medial staple was placed across the osteotomy. (D) Lateral staple was being placed across the osteotomy on the lateral side of the tibial tuberosity.

Gentle range of movement exercises are started after 48 hours with passive mobilization. Hyperextension is avoided. Our goal of 0° to 90° of flexion by the end of 3 weeks is achieved. Deep vein thrombosis prophylaxis is given for 2 weeks postoperatively with oral rivaroxaban 10 mg once a day. X-rays are done following surgery and again at 4 weekly intervals (Fig 11). At 8 weeks, there is evidence of healing of the osteotomy and then partially protected weight-bearing is started. Twenty-five percent body weight per week is allowed until full weight-bearing can be achieved without any pain.

Discussion

A decreased posterior tibial slope is associated with an increased risk of posterior cruciate ligament failure, anterior knee pain, and premature osteoarthritis.[4] Also, it leads to a greater hyperextension of the knee and genu recurvatum deformity. Dejour et al.[1] opined that sagittal osteotomies should be considered either

Table 1. Pearls and Pitfalls of the Discussed Technique

Pearls	• For good soft tissue closure around the osteotomy, subperiosteally elevate the anterior compartment up to the proximal tibiofibular joint laterally and medially to the posteromedial tibial cortex.
	• Knee should be flexed during high tibial osteotomy to minimize risk to posterior neurovascular structures.
	• Insert guiding K-wires under fluoroscopy to prevent inadvertent damage to the neurovascular structures.
	• Opening-wedge osteotomy cut needs to include complete medial and lateral cortices to ensure adequate posterior hinge.
	• An osteotomy opening of 1 mm is equivalent to 1° of tibial slope correction.
	• Opening of the osteotomy is progressed slowly using a specific spreader device and leaving it in place for at least for 5 minutes to allow for stress relaxation of the posterior cortex to minimize the risk of an undesired fracture.
	• To prevent patella infera, the tibial tuberosity bone block is advanced proximally in relation to the distal tibial fragment by the same amount as the opening-wedge osteotomy.
	• Filling the remaining gaps with the bone graft minimizes the risk of complications like delayed union or nonunion.
Pitfalls	• There is a potential risk of popliteal neurovascular bundle injury. Exercise caution to maintain the posterior tibial cortex and use fluoroscopic guidance for pin placement.
	• Opening osteotomy through centrally placed laminar spreader alone can cause disruption of cancellous bone. Place laminar spreaders medially and laterally under stronger cortical bone to complete correction.
	• There is a risk of fracture of the posterior tibial cortex during opening osteotomy.
	• With opening-wedge osteotomies, there is a risk of nonunion or delayed union. This can be minimized by filling the gaps with bone graft.

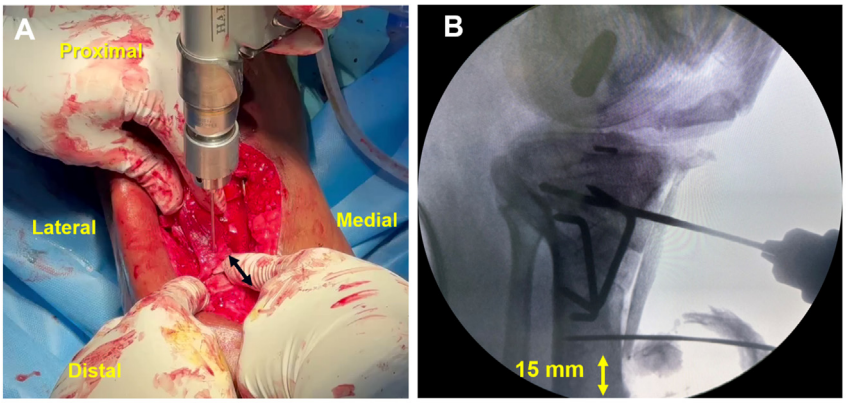

Fig 9. (A) Bicortical fixation of the tibial tuberosity shingle. (B) Fluoroscopy image showing tuberosity shingle fixation with 15-mm proximalization on the distal tibia.

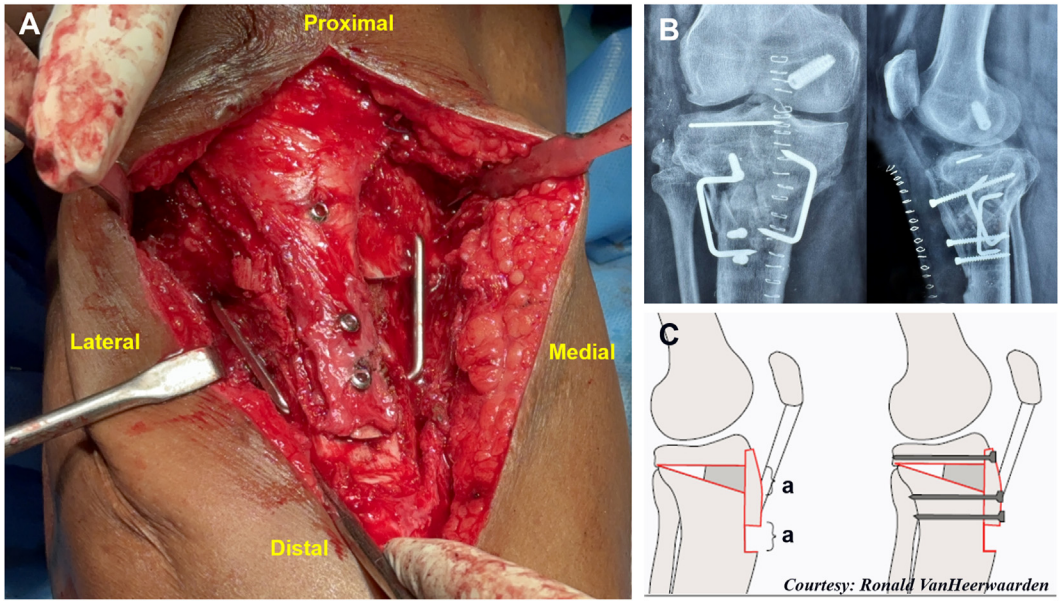

Fig 10. (A) Final fixation of the osteotomy and tibial tuberosity shingle. (B) Postoperative anteroposterior and lateral views showing tuberosity shingle fixation with 3 screws and opening-wedge osteotomy with 2 staples. (C) Diagrammatic representation of the fixation technique of a tuberosity shingle with 1 screw above the graft and 2 screws below the graft. Proximalization of the tibial tubercle was also seen ("a") (15 mm), which was equal to the width of the opening-wedge osteotomy.

adjuvant treatments for failed cruciate ligament reconstructions or primary procedures to correct significant knee instability and abnormal changes of the PTS. As posterior slope decreases, forces through the PCL increase and can lead to rupture of the PCL and subsequent instability or graft failure in cases of PCL reconstruction.[5] Anterior open-wedge high tibial osteotomy (AOWHTO) aims to increase the posterior slope so that the forces through the PCL decrease due to downward forces being anteriorly directed in the tibia.

Anterior open-wedge osteotomy has been mainly described for genu recurvatum, secondary to increased anterior tibial slope.[6] Anterior opening-wedge osteotomy may be done proximal to the tibial tuberosity (TT), as described by Lexer,[7] Bohn,[8] and Brett[9]; at the level of the TT with the tibial tubercle osteotomy, as described by Lecuire et al.[10]; or distal to the TT, as described by Campbell.[11] Osteotomies below the TT are associated with low healing potential, and because the osteotomy level is far from the site of bony deformity, it necessitates a greater angular correction and addition of a fibular osteotomy.[12] Osteotomies above the TT are close to the site of deformity, but the proximal fragment is small, with a less stable posterior hinge, and affects the patellofemoral functions.[13]

We did AOWHTO at the level of the TT with a tibial tuberosity osteotomy to avoid patella infera.[14] We achieved good fixation with staples, which was described by Dejour.[13] Some authors described fixing the osteotomy with screws[15] and some with plates.[16-18] Revision PCL reconstruction can be performed in a second stage, but it is not required in all cases. Weiler

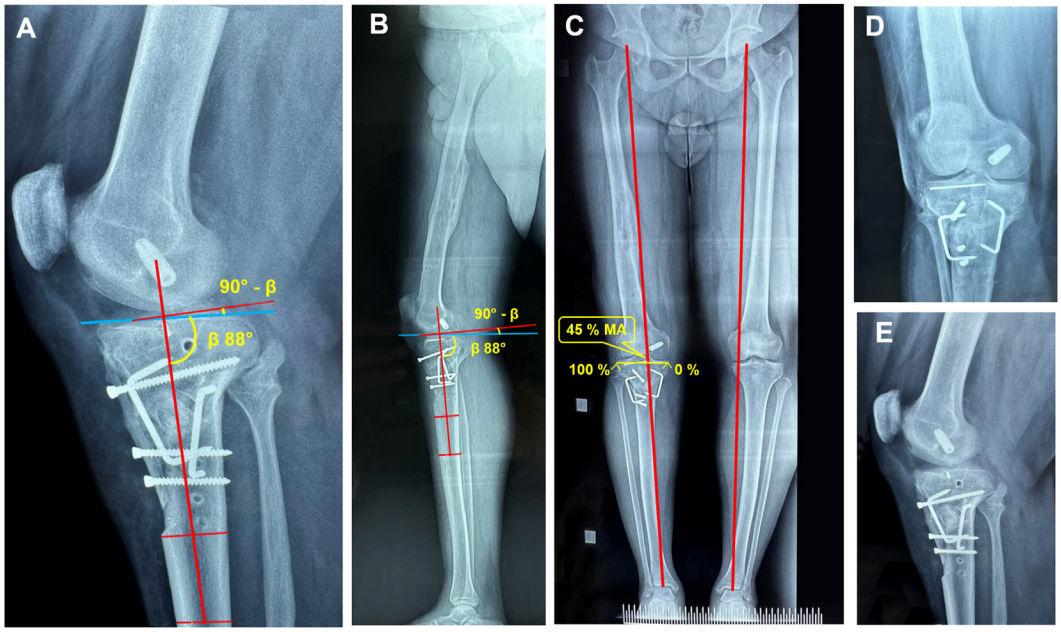

Fig 11. (A) Postsurgery short lateral radiograph showing 2° of posterior tibial slope (tibial diaphyseal axis 90° − β). (B) Postsurgery full-length lateral monopedal stance radiograph showing 2° of the posterior tibial slope (tibial diaphyseal axis 90° − β). (C) Postsurgery scanogram anteroposterior (AP) view showing 45% mechanical axis coronal limb alignment. (D, E) One-year postsurgery x-rays of the right knee AP and lateral views showing good union of the osteotomy and tuberosity shingle. Osteotomy healed well without any complications by the end of 6 months. The patient walked with a normal gait with no pain and subjective instability, was able to go down the stairs and ramp without any difficulty, and went back to farming. Posterior drawer's laxity became grade II from grade III. Hyperextension got reduced to 5° from preoperative 25°. The medial proximal tibial angle became 89° from preoperative 84°, and lateral distal femoral angle became 87° from preoperative 86°.

et al.[19] reported on a series of 6 patients undergoing AOWHTO for chronic PCL deficiency with a decreased posterior tibial slope, and only 2 patients required PCL reconstruction subsequently. PCL reconstructions will fail without the correction of a reverse tibial slope. Anterior open-wedge osteotomy of the proximal tibia is a reliable surgical procedure to treat reverse tibial slope and, in some cases, may avoid the need for reconstruction of the PCL. Table 1 describes the pearls and pitfalls of the surgical technique of anterior opening-wedge high tibial osteotomy. Table 2 describes the advantages and disadvantages of AOWHTO. This is an efficient and reproducible technique to perform AOWHTO in patients with genu recurvatum due to reversal of the tibial slope.

Disclosures

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 2. Advantages and Disadvantages of the Discussed Technique

Advantages	• Osteotomy is performed through cancellous bone, which has greater healing potential than an infratubercle osteotomy through cortical bone.
	• Tibial tuberosity osteotomy avoids patella infera and acts as a biological plate.
	• Allows for correction of sagittal plane tibial slope and genu recurvatum.
	• Can correct mild coronal malalignment with differential opening of the medial and lateral parts of the osteotomy.
	• Can provide stability to a PCL-deficient knee, potentially limiting the need for second-stage PCL reconstruction.
	• Can perform simultaneous bone grafting of PCL tunnels if tunnel osteolysis is present.
Disadvantages	• Technically demanding procedure.
	• Risk of injury to the popliteal neurovascular bundle if care is not taken.
	• Rehabilitation requires 8 weeks of non−weight bearing.
	• Donor site morbidity at the iliac crest.
	• Limitation: to correct severe coronal malalignment.

PCL, posterior cruciate ligament.

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