Technical Note

Slope Increasing Medial Opening Wedge Proximal Tibial Osteotomy for Preventive Offloading of the Posterior Cruciate Ligament and to Correct Varus Malalignment in the Setting of a Failed Posterior Cruciate Ligament Reconstruction

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Abstract: The primary role of the posterior cruciate ligament (PCL) is to prevent posterior tibial translation (PTT). PCL graft forces increase as the posterior tibial slope decreases. Therefore, in the setting of a failed PCL reconstruction, the posterior tibial slope should be evaluated as a potential factor to offload the PCL graft. Patients with a failed PCL reconstruction or chronic PCL instability have an additional risk of meniscal tear and osteoarthritis (OA) development. PCL reconstruction failures may be associated with a decreased tibial slope and varus malalignment, which further increases the risk of subsequent meniscal and cartilage injuries. A slope increasing medial opening-wedge proximal tibial osteotomy (MOWPTO) has been shown to slow progression of medial knee OA, decrease the amount of PTT in the PCL-deficient knee, protect PCL reconstructions, and postpone the need for a total knee arthroplasty. A revision second-stage PCL reconstruction may be indicated to address ligament instability after the slope increasing MOWPTO heals, if the patient has symptomatic residual PTT. This Technical Note outlines the technique for a slope increasing MOWPTO to offload the PCL and to correct varus malalignment that may accelerate degenerative effects on the medial compartment in the setting of a failed PCL reconstruction and medial compartment OA.

Recent literature has reported that decreased posterior tibial slope (PTS) increases the force experienced by the posterior cruciate ligament (PCL) and is a possible risk for the cause of a failed PCL reconstruction.[1,2] The PCL is responsible for stabilization of the tibia on the femur; therefore, it functions to resist posterior tibial translation (PTT), varus and valgus strain, and external rotation. Restoring the function of the PCL in the case of chronic injury can restore stability, increase mobility, decrease pain, and reduce the risk of further knee injury.[3,4] Slope increasing medial opening-wedge proximal tibial osteotomies (MOWPTOs) have been proven as an effective strategy to correct varus malalignment and tibial slope, effectively reducing PCL graft stress and medial compartment overload, as well as reducing residual PTT from a PCL tear or PCL graft tear. Increasing PTS has a protective effect on PCL reconstruction (PCLR) grafts, making assessment of the tibial slope important when evaluating a chronic PCL injury or PCLR failure.[1] A grade 2 PCL injury also leads to increased PTT, with 8 to 11 mm of PTT seen on PCL stress x-rays for a complete PCL tear.[5] An increase in PTT is considered another risk factor in developing knee arthritis and contributes to knee instability.[6,7] In such cases, a slope increasing MOWPTO is indicated to address the PCL tear or PCL graft tear.

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Table 1. Step-by-Step Guide and Surgical Pearls and Pitfalls for a Slope Increasing Medial Opening-Wedge Proximal Tibial Osteotomy for Preventive Offloading of the Posterior Cruciate Ligament and to Correct Varus Malalignment in the Setting of a Failed Posterior Cruciate Ligament Reconstruction

Steps	Surgical Pearls and Pitfalls
Create an opening incision along anterior knee, 6 cm distally to the joint line.	Utilize prior PCL tibial tunnel incision if able.
Perform a subperiosteal dissection anteriorly under the patellar tendon and deep infrapatellar bursa.	Dissect posteriorly until able to palpate the posteromedial aspect of the fibular head and styloid.
Create medial and lateral arthroscopic portals.	
Identify prior PCL graft and assess functionality.	An ACL slack sign may indicate a nonfunctional PCL. Then a probe may be used to pull the ACL anteriorly, and the tibia should be reduced anteriorly.
A shaver, curette, and rasp may be used to debride the previous femoral PCL tunnel.	Cleaning the PCL tunnel prepares the area for possible second-stage PCL reconstruction and for easy placement of bone allograft.
Use reamers to debride the previous tibial PCL tunnel.	Create a posteromedial portal for ease of access.
Place a guide pin through the PCL tibial tunnel and hand ream until the tunnel is completely debrided and bleeding edges are visualized.	Use a large curette to protect the pin from overpenetration and gradually increase the reamer size to prevent further bone removal.
Use guide pins parallel to the joint and aim toward the fibular head to determine osteotomy location.	Fluoroscopy is helpful to determine guide pin placement.
Use an oscillating saw to a depth of 5 mm along the medial aspect to create an osteotomy.	Use a small osteotome anteriorly and posteriorly, with a middle osteotome in the midportion.
Advance the osteotome, leaving 1 cm of lateral cortical hinge.	Use a finger to palpate the osteotome along the posterior tibial cortex to protect the neurovasculature.
Place an opening spreader to correct the measurement.	Leave in place for 5 minutes to allow for stress relaxation of the lateral cortical hinge.
Place an osteotomy plate in the proximal tibial osteotomy location and fix using cancellous screws proximally and cortical screws distally.	To prevent propagation, create an incision over Gerdy's tubercle and place a large staple.
Pack bone allograft into the PCL tunnels and osteotomy site.	Bone allograft stimulates bone growth of the tunnels and osteotomy sites.

ACL, anterior cruciate ligament; PCL, posterior cruciate ligament.

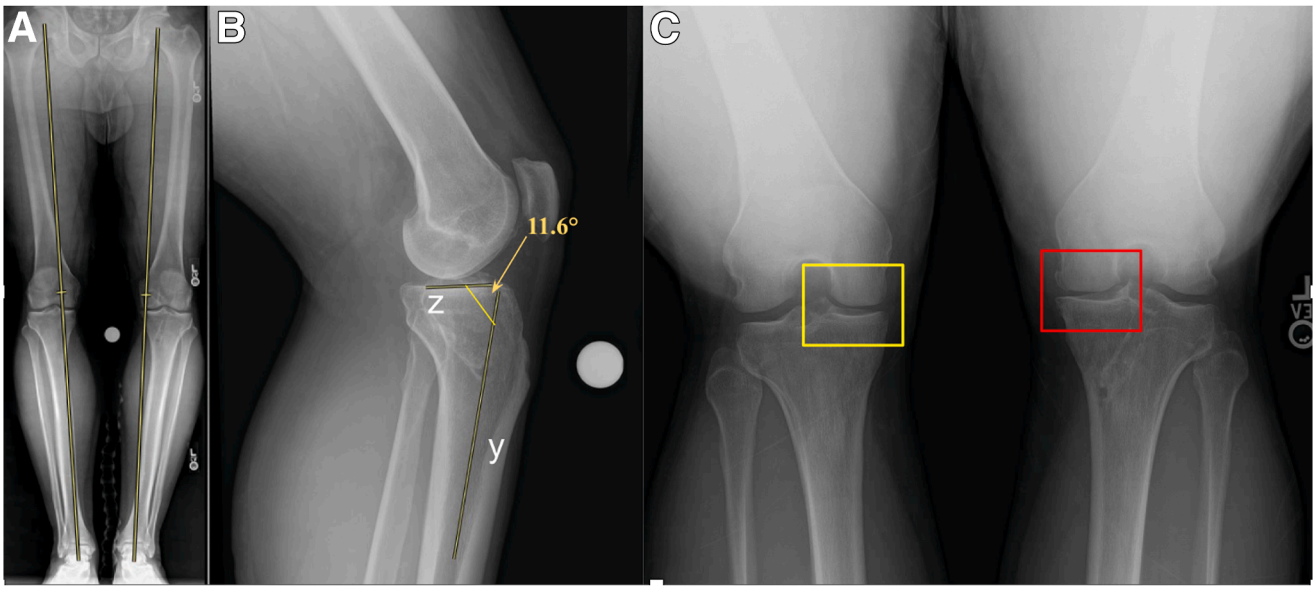

Fig 1. Preoperative long-leg, lateral, and Rosenberg radiographs showing varus malalignment, posterior tibial slope, and a decreased medial compartment joint space of the left knee. (A) Long-leg radiograph showing varus malalignment passing into the left medial compartment. Mechanical alignment is found through lines connecting the center of the femoral head to the center of the talar dome. Varus alignment is present if mechanical alignment is shifted medially in relation to the apex of the medial tibial eminence. (B) Lateral view radiograph of left posterior tibial slope. Posterior tibial slope angle is found by forming 1 line through the anatomic center of the tibia (y) and a second line following the tibial plateau (z). (C) Rosenberg view of bilateral knees showing medial compartment joint space narrowing of the affected knee (red box) compared to the unaffected knee (yellow box).

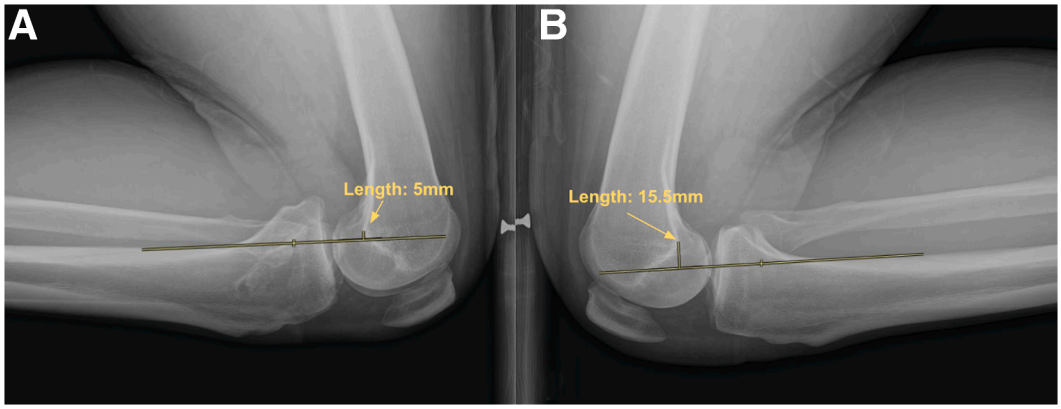

Fig 2. Lateral kneeling posterior cruciate ligament (PCL) stress x-rays showing posterior tibial translation differences between the PCL-deficient knee (A) and contralateral knee (B). This measurement is found by drawing a line along the posterior cortex of the tibia, and a second line is drawn up or down to Blumensaat's point, found to be 5 mm in the affected knee (A). This measurement is compared to the contralateral knee, found to be 15.5 mm (B). The difference is 10.5 mm, reinforcing that a difference greater than 8 mm is consistent with a complete PCL tear.

Surgical Technique

A detailed video regarding a slope increasing MOWPTO for preventive offloading of the PCL and to correct varus malalignment in the setting of a failed PCLR is provided in Video 1. The step-by-step guide and surgical pearls are in Table 1.

Patient Evaluation

A thorough clinical examination should be performed, including knee range of motion, posterior drawer, Lachman's, pivot shift, and varus and valgus testing. Long-leg radiographs should be obtained to evaluate coronal alignment, and a lateral x-ray to measure posterior tibial slope and PCL stress x-rays should be viewed to evaluate for increased PTT in the affected knee (Figs 1, 2). Knee magnetic resonance imaging should also be obtained to visualize prior graft viability and other potential pathology before proceeding.

Anesthesia and Positioning

The patient is placed in the supine position on the operating table and induced under general anesthesia. A knee examination is performed to validate clinical examination findings. A well-padded high thigh tourniquet is placed on the surgical leg. The surgical leg is placed in a leg holder (Mizho OSI) and the nonsurgical leg into an abduction stirrup (Birkova Product LLC). For infection prophylaxis, 2 g of perioperative cefazolin is administered if no allergy is documented.

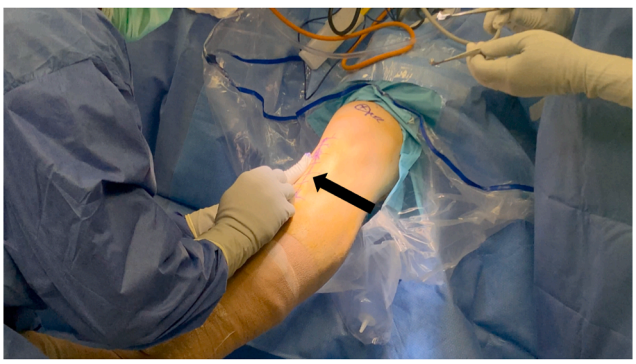

Fig 3. A vertical surgical incision is created along the anteromedial left knee while the patient is in a supine position to prepare for medial opening-wedge proximal tibial osteotomy. The incision utilizes the primary tibial tunnel incision (black arrow) from the previous posterior cruciate ligament reconstruction. The incision begins along the anterior left knee joint line and is extended 6 cm distally.

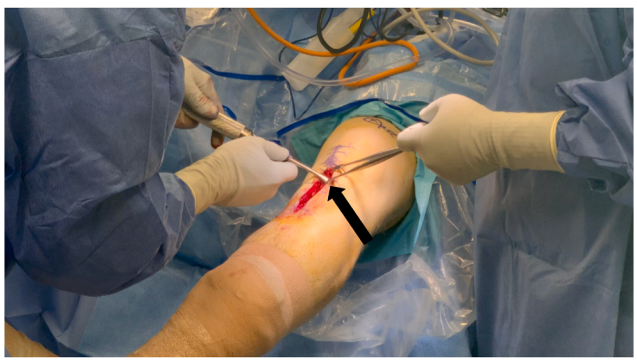

Fig 4. In a supine position, a subperiosteal dissection is conducted to prepare the left anterior knee for a medial opening-wedge proximal tibial osteotomy. Dissection begins beneath the patellar tendon and deep infrapatellar bursa. A Cobb elevator is then used to dissect posteriorly (black arrow) beneath the medial collateral ligament and popliteus musculature until the fibular head and styloid are palpable.

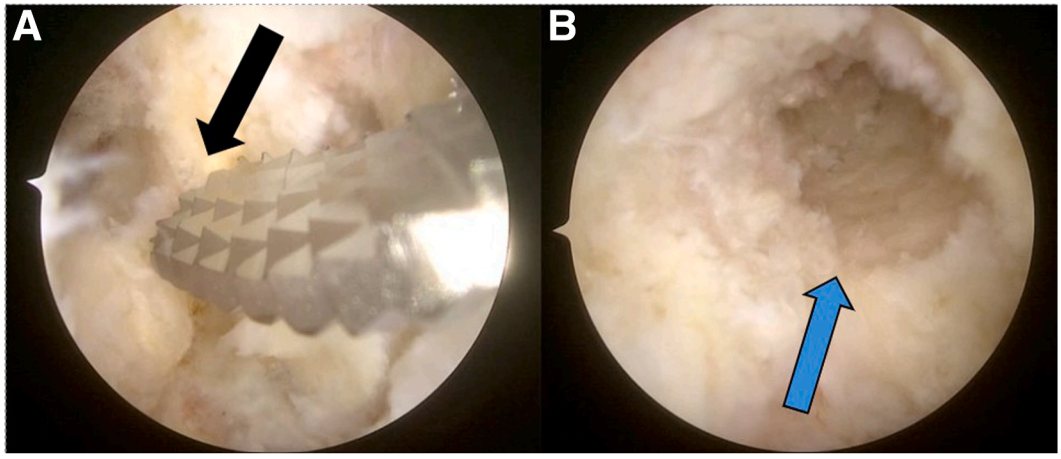

Fig 5. Anteromedial and anterolateral views of the left posterior cruciate ligament (PCL) femoral tunnels during and after debridement. (A) A shaver, curette, and rasp (black arrow) are used to debride the failed PCL femoral tunnel of all scar tissue and previous suture material viewed through an anteromedial portal. (B) The failed PCL tunnel (blue arrow) is completely debrided through an anterolateral portal until bleeding bone edges are seen.

Surgical Approach

The first incision is created utilizing the previous primary PCL tibial incision and is made from the joint line to approximately 6 cm distal to the medial joint line (Fig 3). A subperiosteal dissection is performed anteriorly under the patellar tendon and deep infrapatellar bursa (Fig 4). Subperiosteal dissection is continued posteriorly under the medial collateral ligament and popliteus musculature. The posteromedial aspect of the fibular head and styloid should be palpable posteriorly.

Arthroscopy

Next, medial and lateral parapatellar arthroscopic portals are created. The camera is inserted, and the joint is insufflated with normal saline. An arthroscopic assessment of the joint is performed, and intra-articular pathology is addressed as necessary. The previous PCL reconstruction graft should be assessed. In many cases with a failed PCL reconstruction graft, the anterior cruciate ligament will have a slack sign, which is confirmed by examining the laxity of the PCL. If present, the laxity is reduced by pulling the tibia anteriorly. To prepare for bone graft placement, the PCL graft is debrided with a shaver, and the PCL femoral tunnel is debrided utilizing a shaver, curette, and rasp (Fig 5).

A posteromedial arthroscopic portal is then made, and debridement of the PCL tibial tunnel is performed. After locating and visualizing the PCLR tibial tunnel and nonfunctional PCL graft, a guide pin is placed in the PCL tibial tunnel by hand, and a large curette is placed posteriorly to protect the posterior knee from potential damage due to overpenetration. The guide pin is then overreamed by hand using 6-mm, 8-mm, and 10-mm reamers progressively. Hand reaming is preferred to drilling to prevent further damage when the bone quality is questionable. The tibial tunnel is cleaned of scar tissue with a shaver and a rasp until bleeding edges are seen.

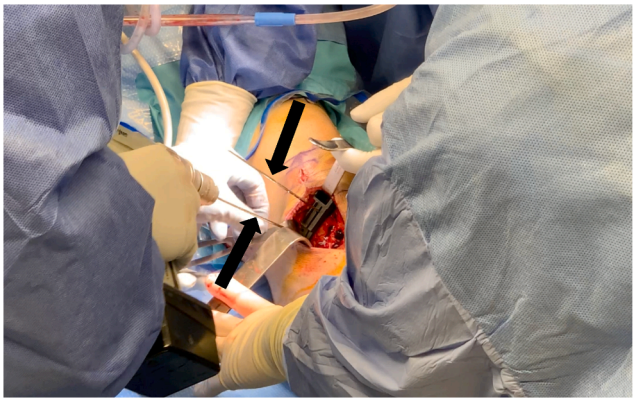

Fig 6. With the patient in a supine position, 2 guide pins (black arrows) are placed along the anterior left proximal tibial metaphysis in preparation for a medial opening-wedge proximal tibial osteotomy. The guide pins are aimed toward the fibular head, ensuring there is 1.5 cm of bone superior to the guide pins to reduce the risk of tibial fracture.

Medial Opening-Wedge Proximal Tibial Osteotomy

Attention is then turned to the slope increasing MOWPTO as 2 guide pins are placed parallel to the joint along the proximal tibial metaphysis, aiming toward the fibular head and maintaining a minimum of 1.5 cm of bone superior to the guide pin to ensure there is a minimal risk for an intra-articular fracture (Fig 6). Fluoroscopy is used to confirm proper pin placement.

An oscillating saw is then used to cut to a depth of 5 mm along the medial aspect of the proximal tibia (Fig 7). Completion of the anterior and posterior

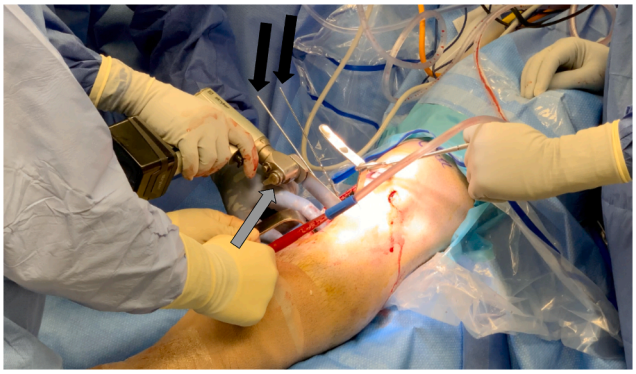

Fig 7. While the patient is in a supine position, guide pins (black arrows) are placed parallel to the left knee joint along the anterior left proximal tibial metaphysis. The oscillating saw (gray arrow) is used to begin proximal tibial osteotomy by cutting to a 5-mm depth through the medial proximal tibia.

portions of the osteotomy utilizes a small osteotome, while the midportion requires a medium osteotome (Fig 8). The osteotomes are slowly advanced posteriorly, and a finger is used to palpate the edge of the osteotome to protect the neurovascular structures.

Once the osteotomy is completed, the opening spreader device is used to open the osteotomy to the desired correction amount (Fig 9). The spreader is left in place for 5 minutes to allow for stress relaxation of the 1-cm lateral cortical hinge. Calibrated osteotomy tines are put into place to confirm the osteotomy measurement (Fig 10). The posteriorly sloped osteotomy plate is then used to fix the correction amount, using two 4.5-mm cortical screws distally and 2 fully threaded 6.5-mm cortical screws proximally (Fig 11). To prevent propagation, an incision is made over Gerdy's tubercle and dissected to expose the osteotomy

Fig 8. Osteotome advancement into the anterior left tibial metaphysis with the patient in the supine position to proceed with medial opening-wedge proximal tibial osteotomy. A medium-sized osteotome (black arrow) is carefully placed into the proximal tibia using a surgical mallet (gray arrow). A finger is then used to advance the osteotome deeper in order to protect the posterior knee neurovasculature.

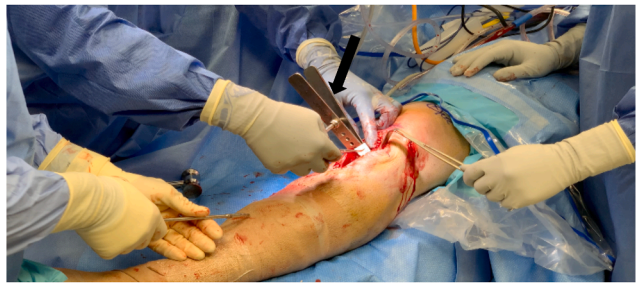

Fig 9. An opening spreader device (black arrow) is placed along the anterior left proximal tibial osteotomy site for the desired correction with the patient in the supine position. The opening spreader device is opened to the calculated correction measurement found preoperatively by using the angle of a line drawn from the center of the femoral head to the center of the lateral tibial eminence and a second line down the center of the tibia. Once in place, the spreader is left for 5 minutes to allow for stress relaxation of the 1-cm lateral cortical hinge before hardware can be implanted.

site, and a large staple is placed to provide further fixation. The osteotomy and PCL tunnels are then bone grafted with allograft bone graft (Fig 12).

Rehabilitation

Patients are nonweightbearing on the surgical limb for 8 weeks. Knee flexion is limited to 90° for the first 2 weeks and may increase as tolerated. After 3 months, the patient is encouraged to transition off of crutches and continue rehabilitation efforts. At 6 months postoperatively, a second operation for ligament repair would be considered due to the time needed for the bone allograft to heal sufficiently for stage 2. For progress management, baseline anterior-posterior and lateral x-rays should be completed after physical therapy on postoperative day 1 and repeated at 8 weeks, 3 months, and 6 months.

Fig 10. Calibrated osteotomy tines placement along left tibial osteotomy site while the patient is in a supine position. The osteotomy tines (black arrow) are used to confirm preoperative osteotomy measurements before continuing with plate placement.

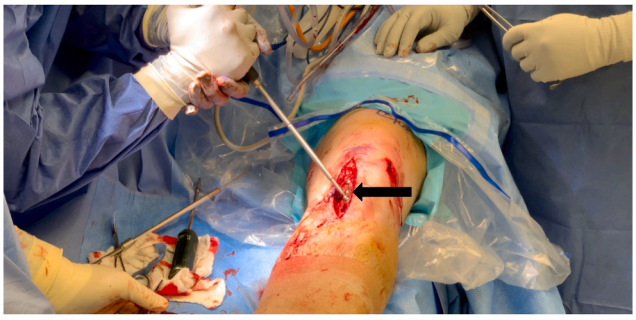

Fig 11. In a supine position, the osteotomy screws are fixed into the osteotomy plate on the left anterior tibia. The posteriorly sloped osteotomy plate (black arrow) is placed using two 4.5-mm cortical screws distally and 2 fully threaded 6.5-mm cortical screws proximally to fix the slope increasing medial opening-wedge osteotomy at the desired correction amount.

Discussion

A slope increasing MOWPTO is an effective option for a first-stage procedure in the setting of chronic PCL injury or failed PCLR and varus malalignment. Studies have shown that an increasing slope with a MOWPTO preceding ligament reconstruction can have a protective effect against loading forces on PCL grafts.[1] Rehabilitation is an important aspect of this operation, as time between surgeries is crucial to maintain mobility and allow for bone healing.[2] A biplanar correction is an effective approach in cases of varus malalignment to allow for correction in the coronal plane, as well as in cases when the PTS may be increased to help offload the PCL tension, which is addressed in the sagittal plane.[8,9] A complete list of the advantages and disadvantages of this procedure is outlined in Table 2. The 2-staged approach allows for increased knee stability through altering the mechanical axis and, second, by correcting chronic ligamentous injury to best maximize graft viability.

Fig 12. To complete the medial opening-wedge proximal tibial osteotomy procedure, the left knee osteotomy site is packed with bone allograft (black arrow) with the patient in the supine position. The allograft bone graft (from the cup-gray arrow) is packed into the osteotomy site and debrided posterior cruciate ligament tunnels to prepare for new tunnels to be drilled in the potential second-stage ligament revision reconstruction.

Table 2. Advantages and Disadvantages of a Slope Increasing Medial Opening-Wedge Proximal Tibial Osteotomy for Preventive Offloading of the Posterior Cruciate Ligament and to Correct Varus Malalignment in the Setting of a Failed Posterior Cruciate Ligament Reconstructions

Advantages	Disadvantages
Can decrease the risk of revision PCL reconstruction rerupture	This procedure may add increased tension to the MCL
May reduce posterior tibial translation alone without PCL reconstruction	Nonweightbearing for 8 weeks
Can precede ligament reconstruction to increase graft viability and graft stretching	Risk of tibial fracture due to tibial PCL guide pin placement and osteotomy
Weight is redistributed evenly to remove stress on subsequent ligament repairs	Changes to the posterior tibial slope and patellar height may alter knee biomechanics
Restores knee stability	Increase in posterior tibial slope may increase inherent risk of ACL injury
Can slow progression of osteoarthritis in the medial compartment	Wait period of at least 6 months before second-stage procedure to allow for bone graft and osteotomy healing

ACL, anterior cruciate ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: R.F.L. has received funding grants from Ossur, Smith & Nephew, Arthroscopy Association of North America, and American Orthopaedic Society for Sports Medicine; is a consultant or advisor for Ossur, Smith & Nephew, and Responsive Arthroscopy; has received travel reimbursement from Smith & Nephew; has received speaking and lecture fees from Foundation Medical, LLC; and has a patent with royalties paid to Ossur. All other authors (K.H.S., N.K.R., B.J.W., L.V.T., M.T.R., D.R.L.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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