Anterolateral Biplanar Proximal Tibial Opening-Wedge Osteotomy

Chase S. Dean, M.D., Jorge Chahla, M.D., Samuel G. Moulton, B.A., Marco Nitri, M.D., Raphael Serra Cruz, M.D., and Robert F. LaPrade, M.D., Ph.D.

Abstract: Proximal tibial anterolateral opening-wedge osteotomies have been reported to achieve successful biplanar lower-extremity realignment. Indications for a proximal tibial anterolateral osteotomy include symptomatic genu recurvatum with genu valgus alignment, usually in patients with a flat sagittal-plane tibial slope. The biplanar approach is able to simultaneously address both components of a patient's malalignment with a single procedure. The correction amount is verified with spacers and intraoperative imaging, while correction of the patient's heel height is simultaneously measured. A plate is secured into the osteotomy site, and the site is filled with bone allograft. The anterolateral tibial osteotomy has been reported to be an effective surgical procedure for correcting concomitant genu recurvatum and genu valgus malalignment.

Proximal tibial osteotomy (PTO) has been reported to successfully treat medial knee overload, early unicompartmental osteoarthritis, and chronic instabilities.[1-5] This procedure has been primarily advocated for treatment of varus misalignment, leaving the distal femur as the preferred site for correction of valgus deformity.[6]

When treating biplanar abnormalities (coronal and sagittal planes), distal femoral osteotomies fail to address the sagittal plane, specifically the tibial slope. Hence, the anterolateral PTO has been described and is reported to produce good results in patients with combined symptomatic genu recurvatum resulting from a flat sagittal-plane tibial slope and coronal-plane genu valgus malalignment.[7] The ability to perform corrections in the coronal and sagittal planes makes this a valuable tool for the surgeon. The purpose of this surgical technique description was to detail the surgical method to perform an anterolateral opening-wedge PTO fixed with a plate with allograft filling of the osteotomy gap for patients with genu recurvatum and valgus malalignment.

From the Steadman Philippon Research Institute (C.S.D., J.C., S.G.M., M.N., R.S.C., R.F.L.); and The Steadman Clinic (R.F.L.), Vail, Colorado, U.S.A.

The authors report the following potential conflict of interest or source of funding: R.F.L. receives support from Arthrex; Smith & Nephew; Ossur; Health East, Norway; and an NIH R13 grant for biologics. The Steadman Philippon Research Institute receives support by Arthrex, Ossur, Siemens, and Smith & Nephew.

Received October 6, 2015; accepted February 2, 2016.

Address correspondence to Robert F. LaPrade, M.D., Ph.D., Steadman Philippon Research Institute, The Steadman Clinic, 181 W Meadow Dr., Ste 400, Vail, CO 81657, U.S.A. E-mail: drlaprade@sprivail.org

2212-6287/15966/$36.00

http://dx.doi.org/10.1016/j.eats.2016.02.015

Surgical Technique

Indications for Surgery

Precise patient selection is crucial for the success of this surgical procedure. The main indication for this procedure is a symptomatic patient with combined genu recurvatum and genu valgus malalignment.

The double deformity can also occur as a result of malunion of a previous tibial fracture, physeal arrest, or previously overcorrected varus deformity evolving with concomitant recurvatum. Genu recurvatum can result from a decreased posterior tibial slope in patients with posterior structure injury.[8]

Given its ability to perform coronal- and sagittal-plane corrections, this technique can also be useful in treating chronic complex knee ligament instabilities. Usually, opening-wedge osteotomies are preferred when an increase in the posterior tibial slope is desired. Both sagittal-slope and coronal-plane alignment may be required to protect a concurrent or future planned posterior cruciate ligament (PCL) or medial knee ligament reconstruction.

Objective Diagnosis

Observing the patient in the standing position from the front and lateral views can show a valgus-recurvatum combined deformity. Moreover, physical

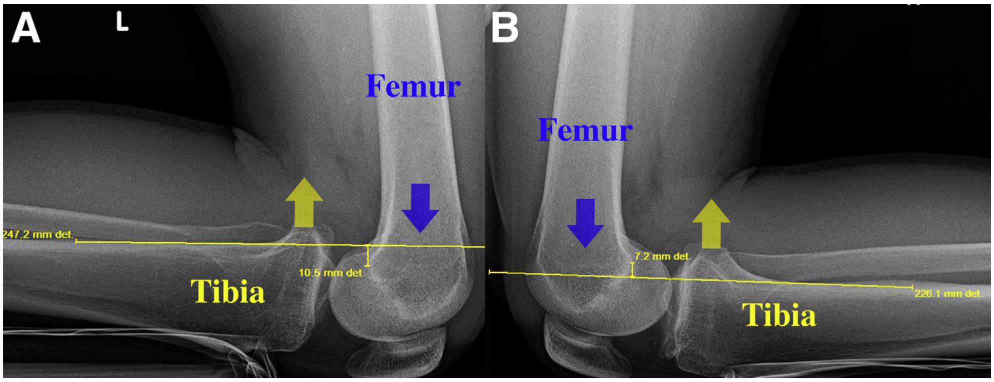

Fig 1. Preoperative kneeling posterior stress radiographs provide an objective and reproducible evaluation of posterior tibial translation. The operative leg (left) (A) and the nonoperative leg (right) (B) are both imaged, providing a side-to-side difference of 17.7 mm.

examination can show asymmetrical heel height, as measured by the distance from the examination table to the patient's elevated heel. This maneuver is performed with the patient in the supine position, with one hand placed above the knee to secure the upper leg to the table while the other hand holds the great toe and lifts the lower leg. The heel height should be compared with that of the contralateral leg because a wide range of physiological recurvatum has been reported among patients.[9]

Imaging should include a lateral radiograph to calculate the tibial slope, a standing long-leg radiograph to assess the mechanical axis, and kneeling posterior stress radiographs to compare side-to-side posterior tibial translation (Fig 1, Video 1). Varus and valgus stress radiographs may be obtained if a collateral ligament tear is suspected. Magnetic resonance imaging is not necessary for the diagnosis of malalignment but can be useful if other pathologies, such as cartilage damage or meniscal or ligamentous tears, are suspected.

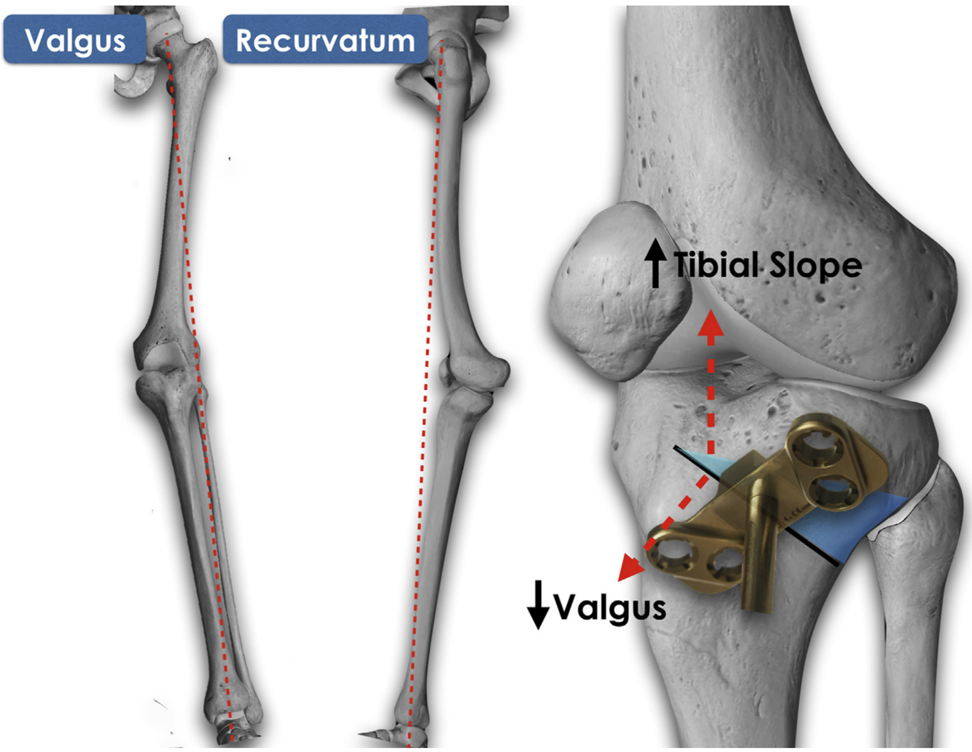

Fig 2. Genu valgus, which is assessed from the anteroposterior view, is shown on the left. The red line represents the mechanical axis and is drawn from the center of the femoral head through the center of the talar dome. If this line passes lateral to the lateral tibial eminence, genu valgus exists. Genu recurvatum, which is assessed from a lateral view, is shown in the middle, with the mechanical axis roughly represented by a line drawn from the center of the femoral head through the center of the talar dome. A left knee with an anterolateral opening-wedge osteotomy, showing biplanar correction (increasing tibial slope and diminishing valgus alignment), is shown on the right. The distal aspect of the plate should correspond to the anterior tibial cortex.

To determine the mechanical axis, a straight line is drawn from the center of the femoral head through the center of the talar dome (Fig 2). The preoperative mechanical axis should be calculated as a percentage across the tibial plateau with the medial edge considered 0% and the lateral edge considered 100%. Affirmation of valgus malalignment occurs when the mechanical axis lies lateral to the apex of the lateral tibial eminence or more than 56%[1] across the tibial plateau in the coronal plane.

Tibial slope is evaluated on the lateral radiograph by drawing 2 circles in the tibial shaft that extend from the anterior to posterior cortices and drawing a straight line extending between the central point of the circles to find the anteroposterior midpoint of the tibia (Fig 3). A second line perpendicular to the first one is drawn at the tibial plateau, and a third line is drawn along the tibial slope, using the medial femoral condyle. The angle measured between the second and third lines is the preoperative angle of the tibial slope. The degree of correction will be dictated by measurement of intraoperative heel heights, which is repeatedly performed until the corrected heel height is comparable with the contralateral knee.

Preoperative planning aims to restore the mechanical axis through the apex of the medial tibial eminence (41% across the tibial plateau[1]). To calculate the appropriate angle of correction in the coronal plane, a line is drawn from the center of the femoral head through the apex of the medial tibial eminence. Another line is drawn from the center of the talar dome through the same point on the tibia. The angle formed by the intersection of these 2 lines provides the osteotomy correction angle needed to achieve the desired correction. This angle is transposed to the location of the most medial cut of the planned osteotomy on the proximal aspect of the tibia and expanded to the lateral proximal tibia. This calculated angulation creates a triangle with the height (in millimeters) at the lateral cortex representing the amount of correction required for the osteotomy (Fig 4). It is important to leave 1 cm of the medial cortex intact to avoid medial cortical fracture.

Patient Positioning

The patient is placed supine on the operating table, and general anesthesia is used for induction. A bilateral knee examination under anesthesia is performed. A

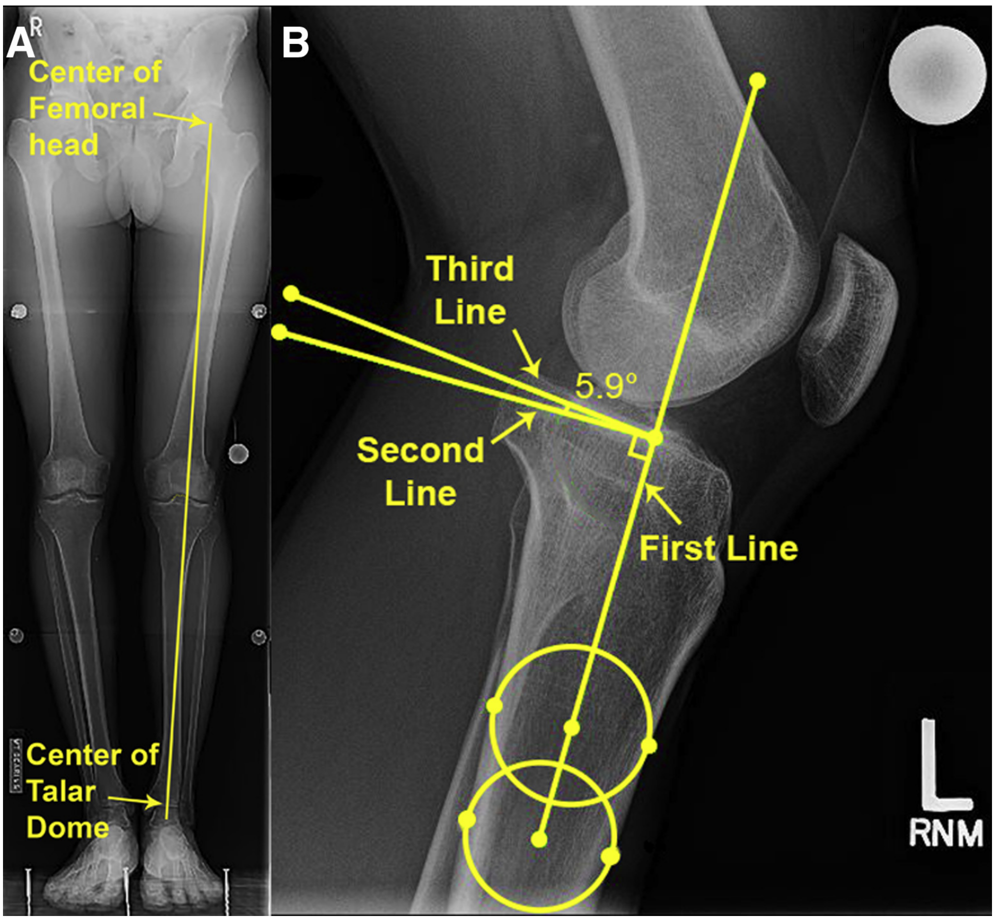

Fig 3. (A) Standing long-leg anteroposterior radiograph of the inferior limbs to determine the mechanical axis. A straight line is drawn from the center of the femoral head to the center of the talar dome. When this line passes lateral to the tip of the lateral tibial eminence, valgus alignment is confirmed. (B) Lateral view of a left knee showing an inverted tibial slope of 5.9°. Two circles are drawn tangent to the anterior and posterior tibial cortices, and their centers are connected by a straight line, which will determine the tibial axis. A second line perpendicular to the first line is drawn at the tibial plateau, and a third line is drawn along the margin of the tibial plateau. The angle measured between the second and third lines is the angle of the tibial slope.

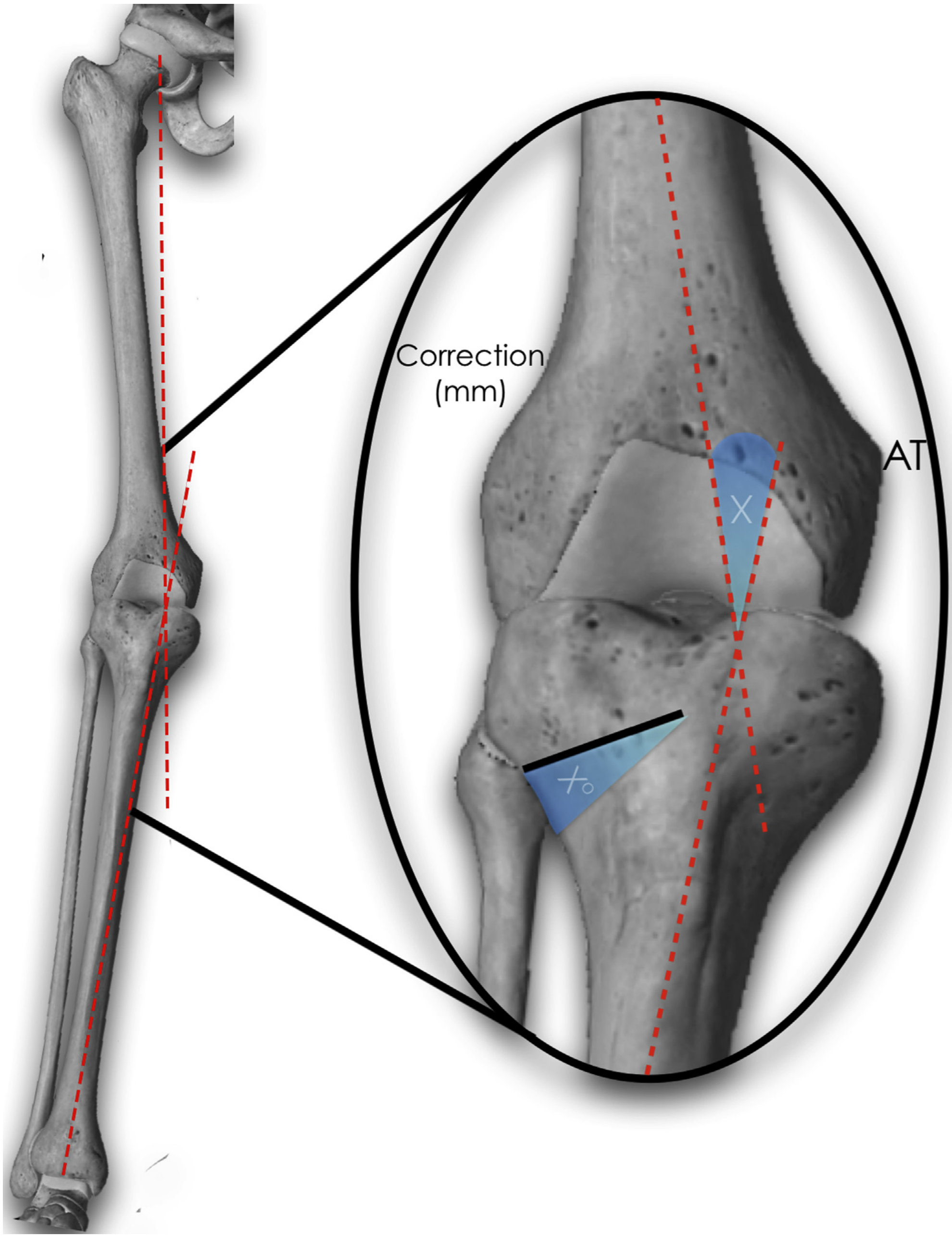

Fig 4. To calculate the appropriate angle of correction, a line is drawn from the center of the femoral head through the apex of the medial tibial eminence. Another line is drawn from the center of the talar dome through the same point on the tibia. The angle formed by the intersection of these 2 lines provides the osteotomy correction angle needed to achieve the desired correction. This angle is transposed to the location of the most medial cut of the planned osteotomy on the proximal aspect of the tibia and expanded to the lateral proximal tibia to provide the height (in millimeters) of the lateral cortex that should be expanded. (AT, adductor tubercle)

well-padded high-thigh tourniquet (Zimmer, Warsaw, IN) is placed on the operative leg, and then a bump is placed under the knee so that it rests at approximately 30° of flexion. The contralateral leg is secured to the table in full extension with a leg holder (Mizuho OSI, Union City, CA), and a pneumatic compression device (Covidien Medtronic, Irvine, CA) is placed around the lower leg.

Operation

Standard anterolateral and anteromedial parapatellar portals are created, and routine arthroscopy is performed to evaluate and treat any concurrent knee pathology. After completion of the arthroscopy, an anterolateral incision is made beginning at the Gerdy tubercle and extending approximately 7 cm distally, midway along the anterior compartment (Fig 5).

The anterior compartment is identified along the anterior crest of the tibia and proximally along the Gerdy tubercle to the anterior margin of the proximal tibiofibular joint. By use of sharp dissection (Fig 6), the musculature is dissected subperiosteally off the tibial cortex.

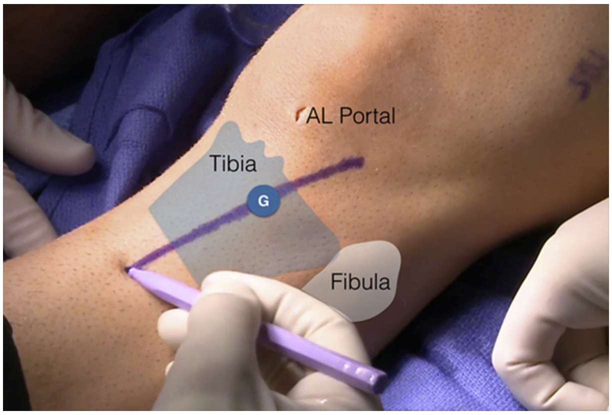

Fig 5. The anterolateral (AL) incision is outlined on a left knee centered at the Gerdy tubercle (G) and extending approximately 7 cm distally along the midportion of the anterior compartment.

Fig 7. A retractor is placed within the deep infrapatellar bursa and deep to the left patellar tendon to protect this structure from the saw and osteotome.

With this approach, the common peroneal nerve is not disturbed. A plane is created along the Gerdy tubercle, the soft tissues are elevated, and a retractor (Arthrex, Naples, FL) is placed under the infrapatellar bursa and deep to the patellar tendon (Fig 7).

Before the osteotomy is performed, a radiolucent retractor (Arthrex) is placed posteriorly to protect the neurovascular structures. The osteotomy is initiated at the proximal extent of the lateral tibial flare while medially maintaining a minimum of 1.5 cm of bone between the osteotomy and articular cartilage to minimize the risk of an intra-articular fracture and to ensure adequate bone stock for hardware fixation. One 2.4-mm guide pin (Arthrex) is placed, and an osteotomy guide (Arthrex) is assembled over the top of the guide pin. The osteotomy guide is adjusted to an oblique angle to establish the biplanar osteotomy trajectory. Once the desired angle is achieved, the second guide pin (Arthrex) is inserted to secure the guide (Fig 8).

To begin the osteotomy of the lateral cortex, an oscillating saw (Hall Instruments; ConMed, Utica, NY) is used along the border of the osteotomy guide. Under the guidance of direct fluoroscopic imaging, an osteotome is used to complete the anterior and anteromedial cuts, leaving an approximately 1-cm bone bridge of the medial tibial cortex intact (Fig 9).

The posterolateral cortex is cut for approximately 10 to 15 mm with the use of a small osteotome against the radiolucent retractor under constant fluoroscopic imaging. Next, an osteotomy spreader device (Arthrex) is inserted and slowly and meticulously opened (Fig 10).

During this process, the heel height is intermittently assessed and compared with the preoperative and contralateral heel heights to assess for the recurvatum correction (Fig 11). Anteroposterior imaging is used to assess varus correction (Fig 12).

Once the desired correction of heel height is achieved, the spreader device is left in place for approximately 5 minutes to allow for stress relaxation of the medial cortex. A tine device (Arthrex) is progressively advanced and a series of plates are inserted to assess the extent of correction needed to decrease the patient's

Fig 6. The anterior compartment is accessed through an inverted hockey-stick incision on the anterior fascia in a left knee.

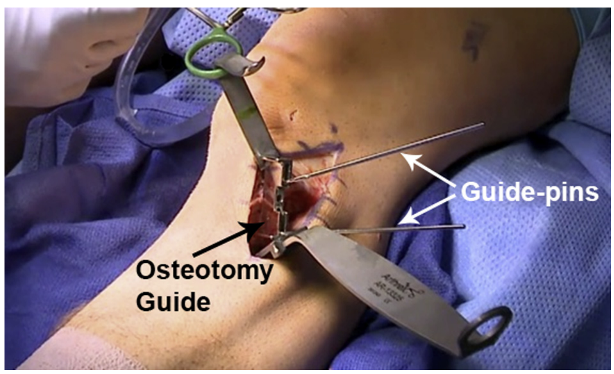

Fig 8. An osteotomy guide is fitted over the guide pins to create a straight line between the pins to perform the osteotomy cut at the desired angle in a left knee.

Fig 9. An osteotome is used to complete the anterior and anteromedial cuts under the guidance of direct fluoroscopic imaging in a left knee.

Fig 11. Intraoperative photograph of a left leg undergoing heel height assessment. The heel height is intermittently assessed and compared with the preoperative and contralateral heel heights to assess for correction.

recurvatum. Lateral fluoroscopic imaging is then used to assess the tibial slope.

When the surgeon is satisfied with the degree of coronal-plane, sagittal-plane, and recurvatum correction, a Puddu plate (Arthrex) is inserted. Often, the plate will need to be bent to ensure it conforms well to the proximal tibia. The plate is secured distally with two 4.5-mm bicortical screws (Synthes, West Chester, PA) and proximally with two 6.5-mm fully threaded cancellous screws (Synthes) (Fig 13). Opteform demineralized bone allograft (RTI Biologics, Alachua, FL) is then packed into the osteotomy site (Fig 14).

Fluoroscopic images are used to verify the screws are of appropriate length, the posteromedial and medial cortices should remain intact, and the bone graft is thoroughly packed (Fig 15). Lastly, the change in the patient's heel height is verified again.

Postoperative Rehabilitation

After the procedure, the patient is to remain non—weight bearing for 8 weeks. During the first 2 weeks, passive range of motion should be limited from 0° to 90° of knee flexion. A knee immobilizer brace (Össur, Foothill Ranch, CA) should be worn for the first 8 weeks. Starting on postoperative day 1, a supervised physical therapy program is initiated, with emphasis on quadriceps activation. Quadriceps sets and straight-leg raises are to be performed 3 to 5 times daily. After 8 weeks, weight bearing is gradually increased based on clinical and radiographic evidence of bone healing. Kneeling posterior stress bilateral radiographs should be taken at 6 months postoperatively to perform side-to-side comparison and to compare with the preoperative images (Fig 16). An example of the rehabilitation protocol can be found in Table 1.

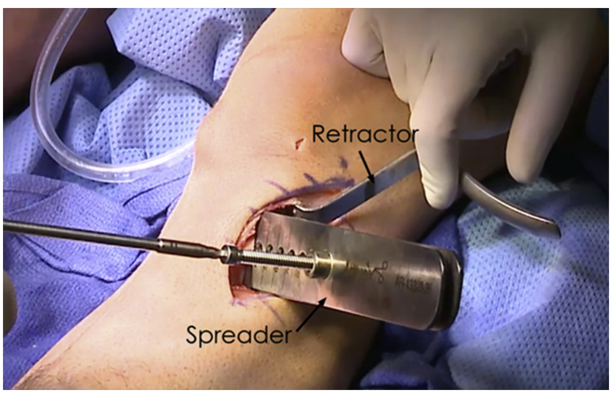

Fig 10. A spreader device is used to slowly create the wedge and maintain the gap in a left knee.

Discussion

The varus-producing proximal tibial anterolateral opening-wedge osteotomy has been reported to achieve successful biplanar lower-extremity realignment.[7] The indication for this type of osteotomy is symptomatic genu recurvatum combined with genu valgus alignment. The possibility to address both entities with a single procedure makes this option a valuable tool.[7] One concern regarding lateral-based high tibial osteotomy procedures is the risk of peroneal nerve injury. However, it can be safely performed by carefully protecting the nerve and leaving the head and neck of the fibula intact.

Although distal femoral osteotomy is the preferred method among most authors to address valgus malalignment,[6] it does not offer the possibility to correct sagittal-plane abnormalities. A prospective study on medial opening-wedge PTO by LaPrade et al.[10] showed that greater increases in tibial slope occurred when using an anteromedial plate position compared with those with a posteromedial plate position. Theoretically, the same general principle should apply when performing an anterolateral opening-wedge PTO.[10] Moreover, another advantage of a tibial osteotomy is

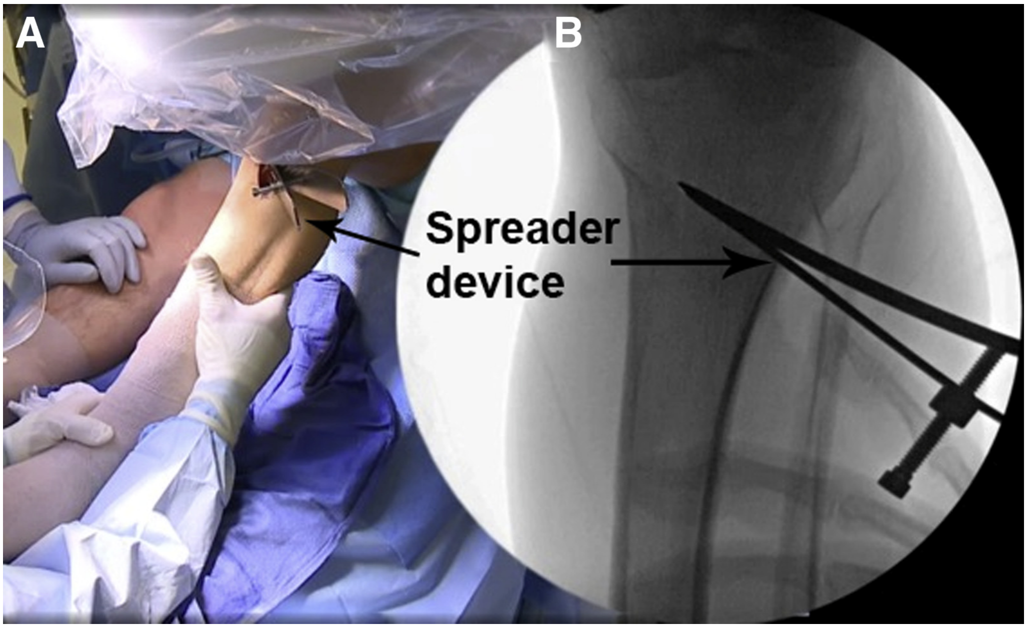

Fig 12. Anteroposterior imaging is used to assess varus correction and the status of the medial cortex. (A) Intraoperative photograph depicting the positioning (neutral rotation and 45° of flexion) of the left leg, with the fluoroscope angled toward the patient's foot for the anteroposterior fluoroscopic image. (B) Corresponding fluoroscopic image with the spreader device inserted into the osteotomy site.

that it aids in both flexion and extension, whereas a distal femoral osteotomy is biomechanically effective only in extension.[11]

The most commonly performed PTO is a valgus-producing proximal tibial medial opening-wedge osteotomy for genu varus limb malalignment. Indications have recently expanded to the treatment of several entities such as medial compartment overload or early degenerative changes,[12] chronic instability (such as posterolateral corner,[13] PCL, and anterior cruciate ligament instability),[5] and ligament reconstruction failure due to malalignment,[12] as well as the protection of a concurrent ligament reconstruction.[3] Likewise, this anterolateral high tibial osteotomy may be useful when both sagittal tibial slope and valgus coronal alignment corrections are required to protect a PCL or medial knee ligament reconstruction, as well as in cartilage procedures.

To fill the gap produced by the osteotomy, different materials can be used, such as autograft, allograft, cement spacers, and bone substitutes.[14] However, it has been reported that gaps of less than 10 mm can be left unfilled for medial opening-wedge PTO—a concept that can be extrapolated to anterolateral PTO.[15]

Further long-term studies are needed to assess the subjective and objective patient outcomes regarding the use of proximal tibial anterolateral opening-wedge osteotomy in patients with valgus malalignment and genu recurvatum. We recommend our approach to achieve successful biplanar lower-extremity realignment and encourage further studies by other groups to evaluate our surgical technique (Tables 2 and 3).

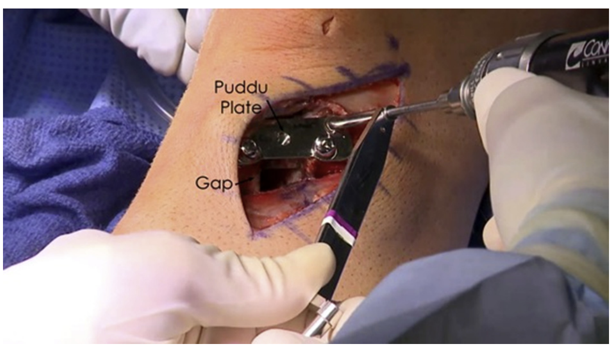

Fig 13. When the desired amount of correction is achieved, a plate that spans the gap is secured with cancellous screws proximally and cortical screws distally (left knee).

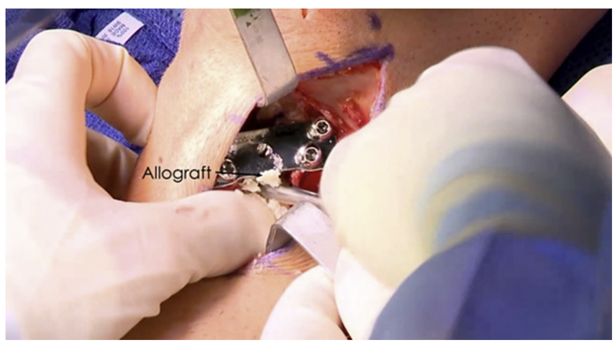

Fig 14. With the plate secured, the allograft is packed into the osteotomy site in a left knee.

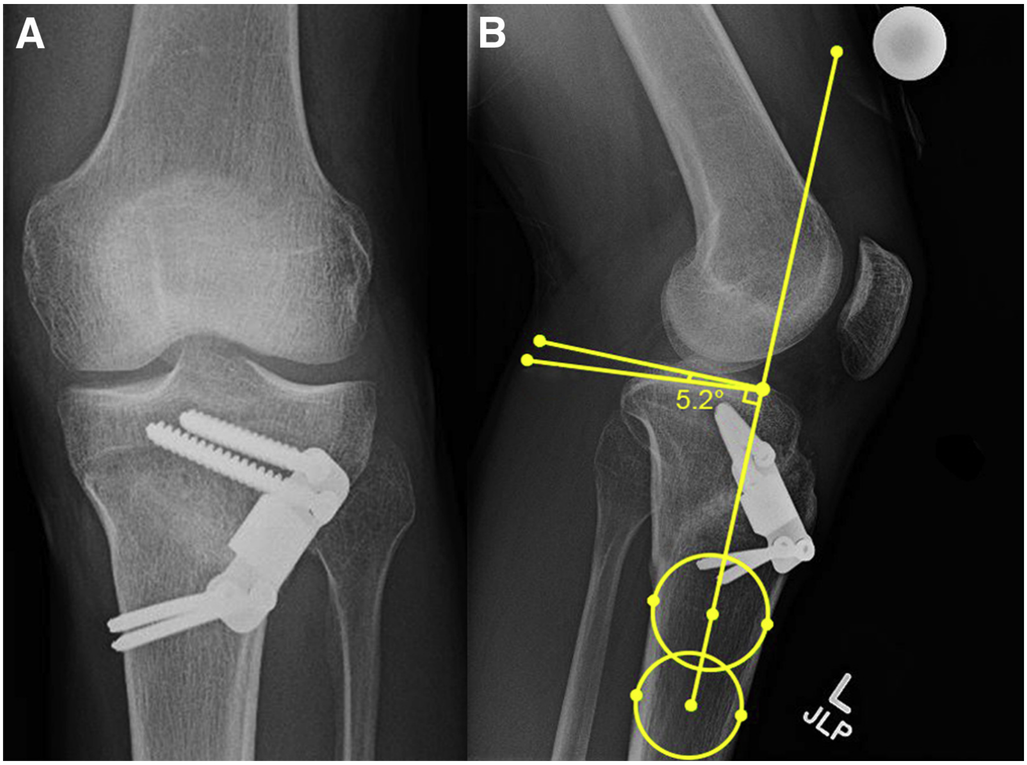

Fig 15. Postoperative radiographs of an anterolateral opening-wedge proximal tibial osteotomy in a left knee: anteroposterior (A) and lateral (B) views. The sagittal tibial slope has increased from an inverted 5.9° preoperatively to a posterior slope of 5.2° postoperatively, for a total change of 11.1°. One should observe the positioning of the Puddu plate in both incidences and how the gap is completely filled with the allograft.

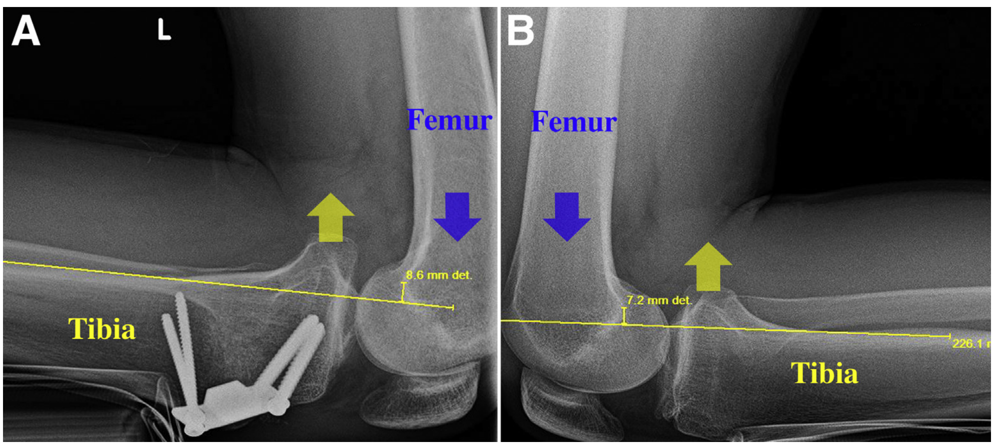

Fig 16. Kneeling posterior stress radiographs are obtained at 6 months postoperatively. The operative leg (A) and the nonoperative leg (B) are both imaged, providing a side-to-side difference of 3.6 mm.

Table 1. Physical Therapy Protocol After Proximal Tibial Osteotomy

	Week																
	1	2	3	4	5	6	7	8	9	10	12	16	20	24	28	30	36
Initial exercises																	
Flexion extension																	
Wall slides	●	●	●	●	●	●	●	●									
Seated	●	●	●	●	●	●	●	●									
Patellar tendon mobilization	●	●	●	●	●	●	●	●									
Extension mobilization	●	●	●	●	●	●	●	●									
Quadriceps series	●	●	●	●	●	●	●	●									
Hamstring sets	●	●	●	●	●	●	●	●									
Sit and reach for hamstrings (towel)	●	●	●	●	●	●	●	●									
Ankle pumps	●	●	●	●	●	●	●	●	●								
Crutch weaning									●	●	●						
Toe and heel raises										●	●	●					
Balance series										●	●	●	●	●			
Cardiovascular exercises																	
Bike with both legs																	
No resistance								●	●	●							
Resistance									●	●	●	●	●	●			
Aqua jogging									●	●	●	●	●	●			
Treadmill walking with 7% incline												●	●	●			
Swimming with fins											●	●	●	●			
Elliptical trainer												●	●	●			
Rowing												●	●	●			
Stair stepper												●	●	●			
Weight-bearing strength																	
Double knee bends											●	●	●				
Double leg bridges											●	●	●				
Reverse lunge with static hold											●	●	●				
Beginning cord exercises												●	●				
Balance squats												●	●				
Single-leg dead lift												●	●	●			
Leg press												●	●	●			
Sports test exercises													●	●			
Agility exercises																	
Running progression														●	●		
Initial—single plane														●	●		
Advanced—multidirectional															●		
Functional sports test															●		
High-level activities																	
Golf																●	●
Outdoor biking, hiking, snowshoeing																●	●
Skiing, basketball, tennis, football, soccer																	●

NOTE. A bullet point indicates that the patient should perform the listed exercise for that week. The range-of-motion restrictions were 0° to 90° for 2 weeks, followed by full passive range of motion. Regarding brace settings, an immobilizer was used for 8 weeks. Regarding weight-bearing status, progression to weight bearing was held until follow-up radiographic approval. The patient was non—weight bearing for 8 weeks and then progressed to one-fourth body weight per week to wean off crutches. The time lines were as follows: week 1, postoperative days 1 through 7; week 2, postoperative days 8 through 14; week 3, postoperative days 15 through 21; and week 4, postoperative days 22 through 28.

Table 2. Pearls and Pitfalls

Pearls	
	The affected limb should always be compared with the contralateral limb because physiological recurvatum can confound establishment of the precise diagnosis and planning.
	The use of a radiolucent retractor to protect the posterior neurovascular structures allows the surgeon to fluoroscopically access the osteotomy without having to remove it.
	Opening of the osteotomy should be performed slowly using a spreader device. It should be left in place for 5 min to allow for stress relaxation of the cortices to prevent fracture.
	The heel height should be frequently checked during the procedure to address the amount of change in posterior tibial slope. This should be confirmed with lateral fluoroscopic imaging.
	The fixation plate may need to be bent to better conform to the proximal tibia.
Pitfalls	
	A lateral approach to the proximal tibia has an intrinsic risk to the peroneal nerve. Careful neurolysis and protection of the nerve reduce the risk of injury.
	Consolidation problems may occur with opening-wedge osteotomies. Preserving local biology and filling the gap with bone graft when it is >10 mm minimize the risk of this complication.
	Avoiding smoking and the use of nicotine products prevents consolidation problems.
	An intra-articular tibial fracture is a possible complication with this technique. Keeping at least 1.5 cm of bone between the osteotomy and the cartilage minimizes this risk.
	An extra-articular fracture extending to the medial tibial cortex may occur. Leaving a 1-cm bone bridge on the medial side will avoid this complication. If the medial cortex is breached, a staple can be used to help stabilize the fracture.

Table 3. Advantages and Limitations

Advantages	
	Biplanar proximal tibial osteotomy allows correction of coronal and sagittal deformities with a single procedure.
	Tibial osteotomy is biomechanically effective in both flexion and extension, whereas femoral osteotomy only helps with extension.
	Opening-wedge osteotomy allows for better control of the correction.
Limitations	
	Technically demanding procedure
	Need for 8-wk period of non—weight bearing
	Risk of tibial fracture or nerve injury

References

1. LaPrade RF, Spiridonov SI, Nystrom LM, Jansson KS. Prospective outcomes of young and middle-aged adults with medial compartment osteoarthritis treated with a proximal tibial opening wedge osteotomy. *Arthroscopy* 2012;28:354-364.
2. Brouwer RW, Huizinga MR, Duivenvoorden T, et al. Osteotomy for treating knee osteoarthritis. *Cochrane Database Syst Rev* 2014;12:CD004019.
3. Zaffagnini S, Bonanzinga T, Grassi A, et al. Combined ACL reconstruction and closing-wedge HTO for varus angulated ACL-deficient knees. *Knee Surg Sports Traumatol Arthrosc* 2013;21:934-941.
4. Kim SJ, Moon HK, Chun YM, Chang WH, Kim SG. Is correctional osteotomy crucial in primary varus knees undergoing anterior cruciate ligament reconstruction? *Clin Orthop Relat Res* 2011;469:1421-1426.
5. Arthur A, LaPrade RF, Agel J. Proximal tibial opening wedge osteotomy as the initial treatment for chronic posterolateral corner deficiency in the varus knee: A prospective clinical study. *Am J Sports Med* 2007;35:1844-1850.
6. Hetsroni I, Lyman S, Pearle AD, Marx RG. The effect of lateral opening wedge distal femoral osteotomy on medial knee opening: Clinical and biomechanical factors. *Knee Surg Sports Traumatol Arthrosc* 2014;22:1659-1665.
7. Gaskill TR, Pierce CM, James EW, LaPrade RF. Anterolateral proximal tibial opening wedge osteotomy to treat symptomatic genu recurvatum with valgus alignment. A case report. *JBJS Case Connector* 2014;4:e71.
8. Morgan PM, LaPrade RF, Wentorf FA, Cook JW, Bianco A. The role of the oblique popliteal ligament and other structures in preventing knee hyperextension. *Am J Sports Med* 2010;38:550-557.
9. LaPrade RF, Ly TV, Griffith C. The external rotation recurvatum test revisited: Reevaluation of the sagittal plane tibiofemoral relationship. *Am J Sports Med* 2008;36: 709-712.
10. LaPrade RF, Oro FB, Ziegler CG, Wijdicks CA, Walsh MP. Patellar height and tibial slope after opening-wedge proximal tibial osteotomy: A prospective study. *Am J Sports Med* 2010;38:160-170.
11. Dejour H, Walch G, Deschamps G, Chambat P. Arthrosis of the knee in chronic anterior laxity. *Orthop Traumatol Surg Res* 2014;100:49-58.
12. Bonasia DE, Governale G, Spolaore S, Rossi R, Amendola A. High tibial osteotomy. *Curr Rev Musculoskelet Med* 2014;7:292-301.
13. LaPrade RF, Engebretsen L, Johansen S, Wentorf FA, Kurtenbach C. The effect of a proximal tibial medial opening wedge osteotomy on posterolateral knee instability: A biomechanical study. *Am J Sports Med* 2008;36: 956-960.
14. Chahla J, Arroquy D, Rodriguez GG, et al. Osteotomía valguizante tibial alta: Comparación de resultados con el uso de aloinjerto y sustituto óseo. *Artrosc (B Aires)* 2014;21:89-94.
15. Lobenhoffer P, Agneskirchner JD. Improvements in surgical technique of valgus high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc* 2003;11:132-138.