Technical Note

Tibial Supra-tubercular Deflexion Osteotomy in the Management of Failed Anterior Cruciate Ligament Reconstruction: A Surgical Technique

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Abstract: Excessive posterior tibial slope (PTS) is a recognized risk factor for failure of anterior cruciate ligament reconstruction (ACLR) and should be considered when planning a revision ACLR. A tibial supra-tubercular deflexion osteotomy can correct excessive PTS with simultaneous or staged ACLR. There are only a handful of technical descriptions offering insight on the respective authors' approach at reducing PTS, all of which vary greatly in their methods. The authors describe a surgical technique using a proximal tibial supra-tubercular deflexion osteotomy in patients with persistent knee instability, a history of at least one failed ACLR, and a PTS greater than 12°. This surgery is not recommended in patients with significant genu recurvatum (>10°), significant varus, or severe tibiofemoral osteoarthritis.

Introduction

The rates of primary anterior cruciate ligament (ACL) graft failure have been reported to be as high as 25%,[1] and there are more than 200,000 primary ACL reconstructions (ACLR) performed annually.[1,2] Most patients with revision ACLR return to a lower level of function when compared to their pre-revision state.[1] Increasing attention has been paid to intrinsic bony architecture, such as posterior tibial slope (PTS), as a predisposing risk factor for ACLR failure. This is a factor that has historically been overlooked in the revision setting until more recently.[3,4] Excessive PTS greater than 12° is a recognized risk factor for both native ACL and ACL graft rupture.[3-6] The authors present our surgical technique for tibial supra-tubercular deflexion osteotomy, indicated in patients with persistent knee instability, a history of at least one failed ACLR, and a PTS greater than 12°. The osteotomy in our technique is approached above the patellar tendon insertion on the tibial tubercle, leaving the tubercle intact.

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The authors report the following potential conflicts of interest or sources of funding: D.L.R. reports funding support from Arthrex and Stryker. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received January 31, 2022; accepted March 16, 2022.

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2212-6287/22165

https://doi.org/10.1016/j.eats.2022.03.032

Surgical Technique

Preoperative Planning

Measurement of Preoperative PTS

Measurement of preoperative PTS is critical for determining the dimensions of the anterior bone wedge that will be removed.[3] We calculate PTS on lateral radiographs using the following established method.[7] Two circles are drawn in the tibial shaft, which lie tangent to the anterior to posterior cortices. The first line is drawn along the shaft connecting the central point of the circles, and the second line is drawn perpendicular to the shaft line at the level of the tibial plateau. The last line is formed from the line connecting the superior points at the anterior and posterior edges of the medial tibial plateau. The PTS is the angle between the last line and the second line.

Measurement of Osteotomy Wedge Height

The height of the osteotomy wedge resected has been a point of debate, with various authors recommending 1, 1.5, and 2 mm of wedge height per degree of correction desired. Since wedge height can be affected by the anterior to posterior width of the proximal tibia, as well as whether a supra-tubercular or trans-tubercular technique is chosen, we recommend using the sagittal magnetic resonance imaging (MRI) to directly measure the relationship between angle of correction and osteotomy wedge height for each patient. Our technique video illustrates this relationship between tibial sagittal width and osteotomy wedge height.

In Fig 1, A and B, both patient A and B have a PTS of 17°, as measured on standing lateral radiographs. Patient A has a wedge height of 16.9, while patient B, who has a narrower tibia in the sagittal plane, has a wedge height of 12.1 mm. The wedge height formed with the native slope is represented with orange lines, and the sagittal width of tibia is shown with green lines. We recommend calculating osteotomy wedge height (WH) using the following formula, which requires only measurement of the PTS and tibial width (TW):

Osteotomy WH $\mathbf{X}$ = (TW)* tan (resection ∠) where the resection angle (12° in these examples) is the angle of the wedge needed to be removed in order to achieve the desired final PTS (5° in these examples). This is depicted in slide three of the technique video.

An alternative way to calculate the osteotomy wedge height is based on the small angle approximation, which states that tangent of an angle in radians is equal to that angle in radians for small angles. This formula does not require knowledge of the tibial width, but rather requires the native slope angle wedge height, resection angle, and native slope angle. This is nicely illustrated in slide four of the technique video. This formula may be more complicated, but it is an interesting derivation to go through to understand the relationship more deeply between tibial slope and osteotomy wedge height.

$$\text{Osteotomy WH } \mathbf{X} = \text{Native Slope} \angle \text{ WH}\left(\frac{\text{Resection} \angle}{\text{NativeSlope} \angle}\right)$$

In both formulas, angles are reported in degrees. The resection wedge height for Patient A using the trigonometric formula was more (11.9 mm) than for patient B (8.4 mm) to correct both to 5° of posterior slope. For Patient A, this equates to approximately 1° of correction per millimeter of wedge height (ex- 12°/11.7 mm), whereas for Patient B, this equated to ∼1.4°/mm of wedge height (12°/8.4 mm). A final technique is determining the resection angle required, and then drawing a triangle, reflecting the desired resection angle on the MRI image where the resection wedge height can be measured directly. Please see the attached technique video to visualize these measurement calculations.

It should be noted that if a trans-tubercular osteotomy is planned, the base height of the wedge will decrease due to the natural narrowing of the tibia from proximal to distal and because tibial depth will be less once the tubercle is removed starting the wedge more posteriorly. Additionally, most trans-tubercular techniques recommend orienting the resection wedge proximal toward the metadiaphyseal junction, which changes the orientation of the triangle and further affects wedge height. Figure 1C illustrates this with a trans-tubercular wedge drawn on the MRI of patient A, corresponding to a smaller osteotomy wedge height compared to its supra-tubercular counterpart. Surgeons should be aware of these two issues when planning a trans-tubercle osteotomy.

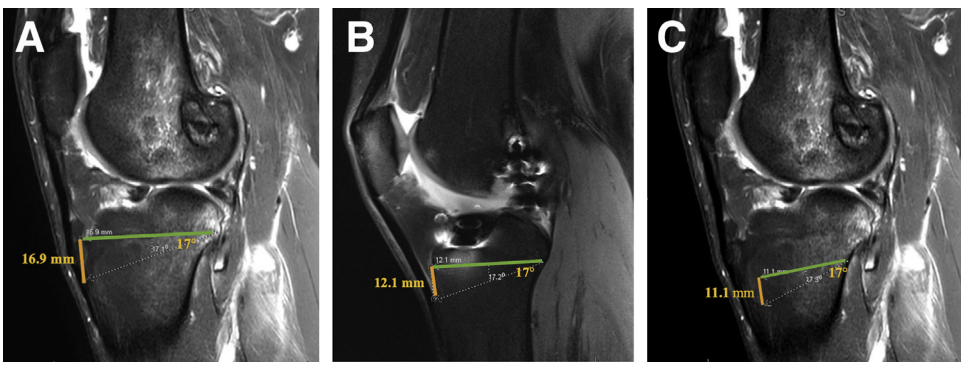

Fig 1. (A-C) Demonstration of how tibial sagittal width influences the osteotomy wedge height. A and B both show a supra-tubercular approach to deflexion. (A) Sagittal MRI of Patient A, who has a longer tibial width in the sagittal plane (green line) when compared to Patient B in B The orange line shows the wedge height, which corresponds to the native tibial slope. Both Patient A and B have a native posterior tibial slope of 17°. Patient A requires a larger anterior wedge resection than Patient B, which corresponds to 11.7 mm and 8.4 mm, respectively. (C) Trans-tubercular approach on Patient A, illustrating how this would require less wedge resection when compared to the supra-tubercular approach.

Patient Setup

Surgery is performed under general anesthesia with a regional nerve block. A padded thigh tourniquet is used for hemostasis. Tranexamic acid (TXA) is routinely used to allow improved visualization and decreased blood loss. The patient is positioned supine on a standard table. A side post is used if concurrent arthroscopy is planned.

Diagnostic Arthroscopy

Diagnostic arthroscopy can be done for multiple reasons, including to confirm graft failure, debride remaining ACL graft, evaluate cartilage, address meniscal tears, or graft tunnels. When performing simultaneous ACLR, the tibial tunnel is drilled prior to the osteotomy. Removal of prior hardware and bone grafting of femoral and tibial tunnels, if needed, is performed for staged operations.

Exposing the Osteotomy Site

A midline incision is created beginning at the inferior pole of the patella and extending distal to the tibial tubercle. Full-thickness skin flaps are developed, and the patella tendon is skeletonized and protected. Gentle elevation of the patella tendon from its attachment on the proximal portion of the tibial tubercle aids with visualization. Subperiosteal dissection is carried out medially underneath the superficial medial collateral ligament and laterally to the iliotibial band off Gerdy's tubercle. Figure 2 illustrates how PTS changes following deflexion osteotomy.

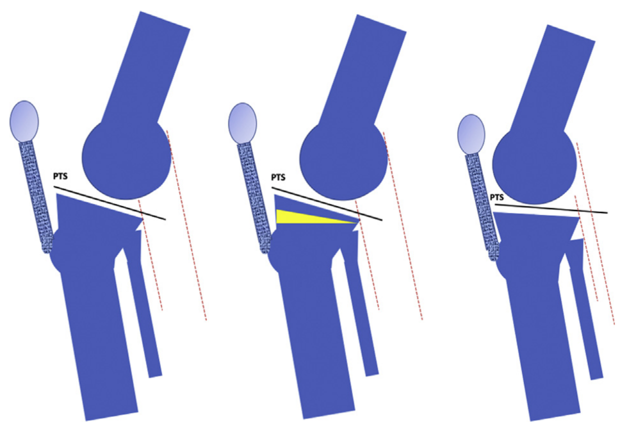

Fig 2. General overview of supra-tubercular deflexion osteotomy viewed in the sagittal plane. The osteotomy is performed about the tibial tubercle, leaving it intact. The far-left image shows increased posterior tibial slope before operative intervention. The yellow triangle in the middle image represents the anterior bony wedge that will be depicted. The far-right image depicts leveling of the tibial slope following deflexion. The parallel dashed red lines demonstrate how anterior tibial translation decreases with leveling of the tibial slope. PTS, posterior tibial slope.

Performing the Osteotomy

The technique video divides the osteotomy into 10 steps. Pins are driven from either side of the patellar tendon into the proximal tibia using fluoroscopy. The distal set of pins is placed just proximal to the patellar tendon insertion on the tibial tubercle. The proximal pins are placed at a predetermined distance based on desired correction. Placing the distal pins perpendicular to the axis of the tibia and the proximal pins parallel to the articular surface ensures a wedge-shaped bone cut (Fig 3, A-C). The pins are advanced until they contact the posterior cortex, making sure to avoid penetration. Fluoroscopy is used to ensure satisfactory pin placement in the coronal and sagittal planes. It is possible to purposefully take an asymmetric bone wedge (i.e., resect more medially than laterally) for minor corrections in varus or valgus malalignment.

Using the pins as a cutting guide, an oscillating saw is used inside the pins to perforate the anterior, medial, and lateral cortices. The oscillating saw is used on either side of the patellar tendon, which must be carefully protected. We carry our controlled cuts up to, but not through, the posterior cortex under fluoroscopic guidance. Thin osteotomes can be inserted to establish a cutting block, which can be used to complete the osteotomy; however, with an anatomic cut, the triangular wedge can be removed with minimal difficulty. We advise against use of standard thicker osteotomes, as they can deform the tibia and prevent osteotomy closure. As the bone cut is completed, fluoroscopy is used to ensure proper angle and depth, taking care to not violate the posterior cortex. Use of z-retractors under the medial collateral ligament and the iliotibial band laterally can be placed sequentially to avoid injury to posterior structures. The guide pins are then removed (Fig 4).

The bone wedge is removed (Fig 5), and a 2-mm drill bit is used to create several controlled perforations in the posterior cortex, facilitating atraumatic closure of the osteotomy (Fig 6, A and B). It is critical to use small curettes to remove any remaining subchondral bone posteriorly, while keeping the cortex intact (except for the stress-relieving drill holes in the posterior cortex). The knee is then gently brought into extension, closing the osteotomy. It is important to perform this maneuver carefully to minimize risk of fracturing the posterior cortex. We have not encountered any posterior cortical fractures and believe this is, in part, due to an accurate osteotomy, posterior cortical drilling, and cancellous bone removal.

The osteotomy is inspected to ensure good cortical contact and no rotational abnormalities. We prefer medial and lateral Richards® staples for final fixation (Smith and Nephew, Andover, MA), although we are exploring other constructs, such as an internal brace construct with FiberTape and knotless suture anchors

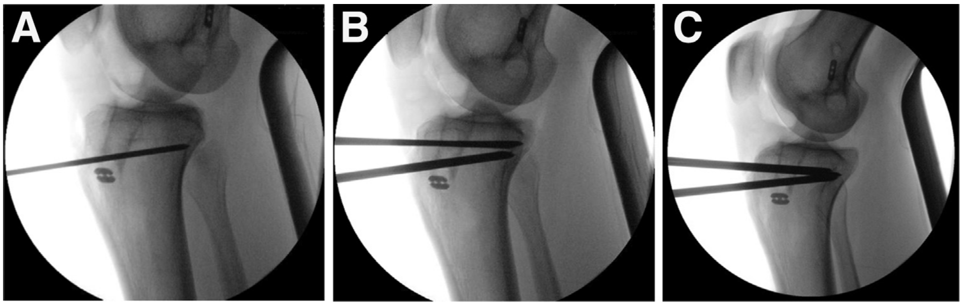

Fig 3. (A-C) Fluoroscopic lateral images of the knee intra-operatively, showing pin placement to guide osteotomy cuts. The osteotomy is performed between the pins (i.e., underside of proximal pins and on top of distal pins). The proximal set of pins are placed parallel to the articular surface, and the distal pins are placed perpendicular to the axis of the tibia.

(Arthrex) in addition to the eight-plate system. Finally, the knee is ranged to ensure no gapping across the osteotomy site (Fig 7, A and B). Recurvatum of the knee can occur; however, this can be managed by a period of immobilization short of full extension or by a posteromedial capsular advancement. It is noted that hyperextension preoperatively can be a contraindication to deflexion osteotomy, and in some scenarios, posterior capsular plication can be performed, but requires significant preoperative planning and surgical skill. Table 1 lists important surgical pearls for this procedure. Table 2 highlights advantages and disadvantages of the surgical technique.

ACLR Technique

In a single-stage procedure, we recommend using a soft tissue graft (autograft when possible) in the tibial tunnel as fixation of a bone plug across an osteotomy site can not only be technically challenging, but inadequate screw purchase and fracture risk are potential complications. One technique pearl involves drilling the tibial tunnel prior to the osteotomy and then re-reaming the tunnel either on power or by hand after fixation of the osteotomy to allow smooth graft passage.

In two stages, bone grafting of prior tunnels and removal of prior ACL hardware are done at the index procedure. We allow 2 to 3 months of osteotomy healing with clinical follow-up and radiographs. During the second stage, any prominent hardware that was used for osteotomy fixation is removed, and standard ACLR is performed using the surgeon's preference for graft selection. If not previously done, we recommend addressing all additional patho-laxity at the time of ACLR. In our experience, Richards staples are often prominent and require removal at this stage, which is one of the reasons we are exploring other fixation techniques.

Fig 4. Fluoroscopic intraoperative image of the sagittal knee after completion of triangular bone cuts following guide pin removal. This image is important, as it shows how the posterior cortex was not violated during formation of the triangular bony wedge.

Fig 5. Fluoroscopic intraoperative image of the sagittal knee upon removal of the bone wedge, keeping the posterior cortex intact. It is crucial to clean this area of the knee after removal of bone, so the osteotomy closes nicely when the knee is gently extended.

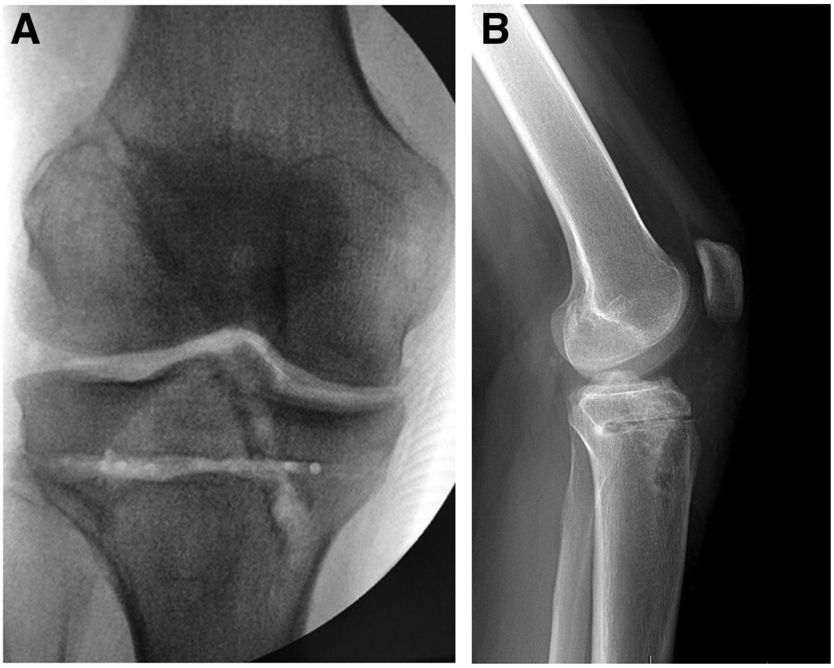

Fig 6. (A) An anterior-posterior intra-operative fluoroscopic image of the osteotomy site closed prior to final fixation.

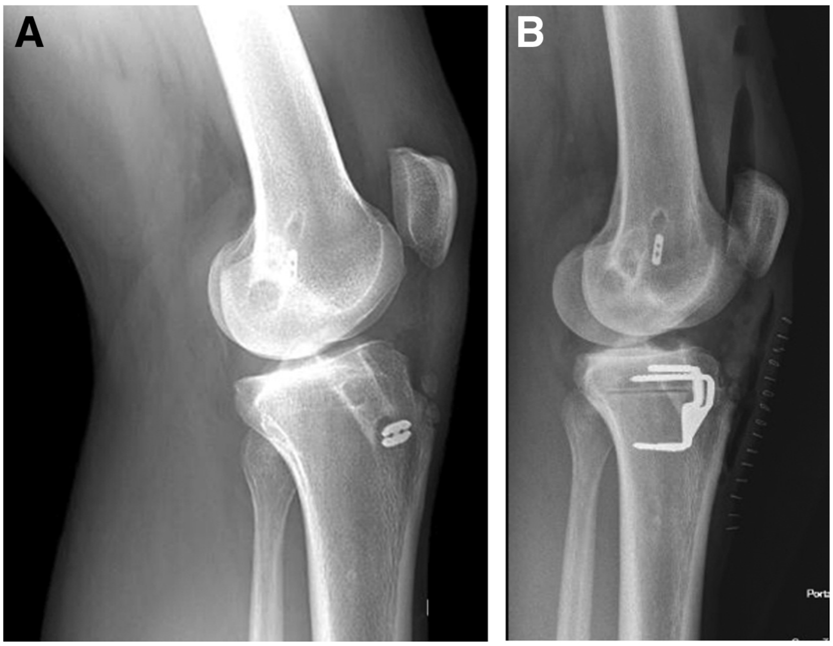

Fig 7. (A and B) Postoperative lateral radiographic images of the knee following final fixation using internal brace construct with FiberTape and knotless suture anchors (A), in addition to a different knee that was fixed using staples (B). No gapping is seen across the osteotomy site.

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
◇ Preoperative planning allows for accurate correction.	◇ Posterior cortex injury-popliteal vessels and nerves
◇ For simultaneous ACLR, drill tibial tunnel prior to osteotomy and redrill after fixation of osteotomy.	◇ Failure to recognize varus/valgus malalignment preoperatively
◇ Frequent use of intraoperative fluoroscopy	◇ Failure to recognize iatrogenic recurvatum
◇ Use of thin sawblades and osteotomes	◇ Healing complications, including delayed union and nonunion
◇ Posterior cortical drilling to allow for osteotomy closure with intact posterior hinge	
◇ Immobilize in 10-20° of flexion if recurvatum occurs	

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
◇ Reproducibly achieves accurate correction ◇ Preserving tibial tubercle allows early weight bearing ◇ Can correct small varus/valgus deformities with asymmetric wedge	◇ Need to work around patellar tendon ◇ Technically challenging to correct deformity in sagittal and coronal plane ◇ Causes minor limb shortening ◇ May cause recurvatum

Rehabilitation

Postoperatively, the patient is placed in a hinged brace locked in extension. While this is a stable construct, we prefer to make the patient touch-down weight bearing for 2 weeks, and then advance weight bearing, as tolerated, after the first postoperative visit. The brace remains locked in extension for ambulation for the first month, but gentle range of motion from 0° to 90° is permitted. After 1 month, weightbearing and range of motion restrictions are removed.

Discussion

Deflexion osteotomy is a tibial slope leveling procedure and is recommended for patients with significant knee instability undergoing second or third ACLR with a posterior tibial slope greater than 12°.[3,4,6,8-12] Surgical techniques described in the literature vary significantly, as this surgery can be performed supra-, infra-, or trans-tubercularly.[3-5,8-10] Our technique is supra-tubercular and avoids tibial tubercle osteotomy, and we have found this construct to be quite stable and reproducible. Our technique is adapted from that put forth by Dejour et al.,[3] which is similar to Neyret et al.[5] In contrast, Sonnery-Cottet et al. describes a trans-tubercular approach. Two of the more recent described techniques published in 2021 by Floyd et al. and Cruz et al. are both tibial tubercle sparing.[11,12] Besides the differences in the approach around the tubercle, another difference in published techniques is the target postoperative slope. Dejour et al. aims for a postoperative slope between 3° and 5°, Sonnery-Cottet et al. between 8° and 10°, Floyd et al. between 6° and 8°, and Cruz et al. between 7° and 9°.[3,4,11,12] As evidenced by this, the ideal correction is still to be determined, but our team targets a slope of 5°. Something unique about our described technique is that we include how to calculate osteotomy wedge height with trigonometric and nontrigonometric formulas. Most authors say ∼1 mm of anterior tibial resection equals 1° of tibial slope correction, but we have not come across technique videos that describe the derivation of why this is the case. Additionally, in our technique, we perform fixation with staples, an eight-plate, or an internal brace, whereas some others only advocate for staples. We believe the technique described here is safe and reproducible, while avoiding a biplanar or tibial tubercle osteotomy. All patients who we have performed deflexion on were managed in a team approach with two or three attending surgeons present to maximize safety and teaching.

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