Technical Note

The Barrel Vault Tibial Osteotomy of Maquet for Medial Compartment Arthritis of the Knee

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Abstract: The barrel vault tibial osteotomy performed for knee varus osteoarthritis avoids the complications of the opening wedge osteotomy and minimizes the potential complications of the lateral closing wedge osteotomy. It allows correction of large varus deformities in knee medial compartment osteoarthritis.

Proximal tibial osteotomy is most commonly performed for varus malalignment secondary to medial compartment knee osteoarthritis. Several methods of performing a valgus tibial osteotomy have been described. The closing wedge tibial osteotomy was originally described by Jackson.[1] He followed up with a paper in 1974 in which he described both barrel vault osteotomies and closing wedge osteotomies.[2] The closing wedge osteotomy was later popularized by Coventry.[3,4] The barrel vault osteotomy was subsequently published in 1976 by Maquet[5] (Fig 1A). More recently, opening wedge[6] and combination (opening/closing) valgus[7] tibial osteotomies have been described.

Multiple methods of postoperative fixation for closing wedge osteotomies have been advocated including staples,[3] a cast,[8] external fixation,[5] and plates.[9]

The purpose of this paper is to present our current surgical technique and to the describe the advantages and disadvantages of the Maquet barrel vault osteotomy technique for valgus high tibial osteotomy for medial knee compartment arthritis.

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Surgical Technique

Instruments and Exposure

The specific required instrumentation is very simple and consists of a goniometer, 2 external fixators, small and large barrel vault cutting guides, and a locking lateral tibial plateau plate (Fig 2) (Video 1). The patient is placed supine on a fluoroscopy table and routinely prepped and draped with a tourniquet. A 10-cm longitudinal midline anterior incision is made (a typical total knee incision moved slightly distally) extending from the middle of the patella distal to the tibial tubercle. Using a midline anterior incision does not compromise any subsequent revision to a total knee. A fasciotomy of the anterior compartment is routinely performed with a Mayo scissors through the distal end of the incision. The anterior compartment musculature is dissected off of the proximal lateral tibia, and dissection is carried posteriorly and laterally along the proximal lateral tibia to identify the anterior aspect of the tibiofibular joint through the same longitudinal incision.

Tibiofibular Osteotomy and Application of the Barrel Vault Guide

An oscillating saw is used to take a 2- or 3-mm wafer of bone out of the tibiofibular joint to dissociate the upper end of the fibula from the tibia to allow mobilization of the osteotomy (Fig 3). Dissection is carried medially to create a subcutaneous flap, and the small or large curvilinear guide is placed behind the patellar tendon just proximal to the tibial tubercle (Fig 4). The curvilinear guide is pinned with 2 anterior to posterior smooth Steinmann pins to stabilize it (Fig 5). Multiple holes are then made through the curved guide from anterior to posterior (Fig 6). The barrel vault guide is removed.

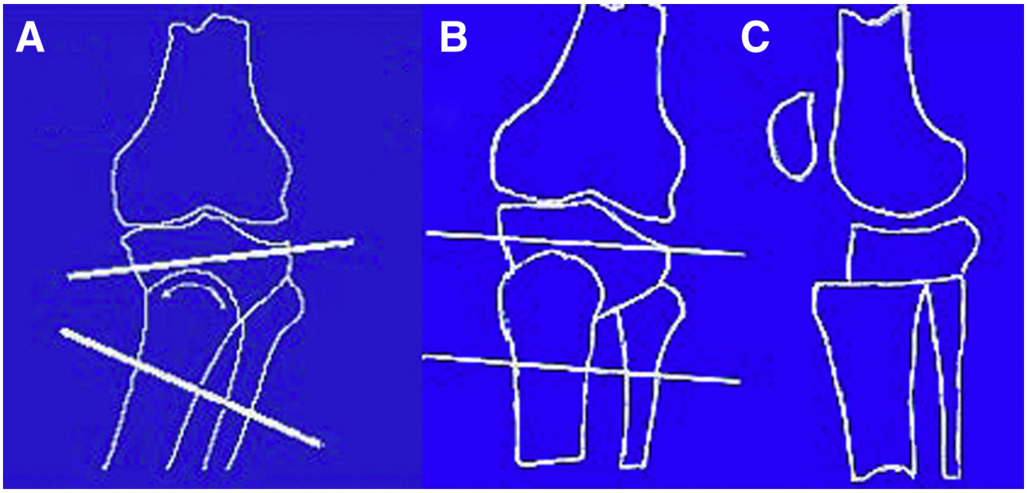

Fig 1. (A) Diagram of the Maquet barrel vault osteotomy with pins, left knee, premanipulation. (B) Diagram of the Maquet barrel vault osteotomy with parallel pins, left knee, postmanipulation. (C) The Maquet barrel vault osteotomy with tibial tubercle elevation (left knee).

Insertion of Steiman Pins for Alignment Correction

A Synthes 3- or 4-hole lateral compression tibial plateau plate (locking or nonlocking) is then positioned along the lateral tibia, and a 1/8-inch smooth Steinmann pin (3.2 mm) is drilled through the most proximal anterior hole parallel approximately 6 or 7 mm distal to the articular surface (Fig 7). This creates the proximal "base" for measurement of correction. The plate is removed, and a thin narrow osteotome is used to "connect the dots" of the drill holes through the anterior cortex and metaphyseal bone only. At this stage of the procedure, the posterior cortex is left intact to maintain the undisrupted alignment of the tibia. The plate is reapplied over the proximal pin. Based upon the preoperatively standing x-rays used to determine correction, the goniometer is then preset to the planned correction angle (Fig 8) and placed over the proximal pin, and the second pin is drilled through the goniometer's distal guide between the plate and the anterior tibial cortex (Fig 9). This places 2 pins at the planned correction angle (e.g. 14°). The distal pin typically is a few millimeters posterior to the anterior tibial crest and therefore does not affect the final position of the plate (see Video 1). Avoid placing the distal pin through a screw hole in the plate because it would limit accurate angular correction after the osteotomy is completed.

Fig 2. Instrumentation: goniometer, 2 external fixatures, small and large barrel vault cutting guides, and left locking lateral tibial plateau plates (right to left).

Osteotomy Completion

Once the 2 pins are in place, the goniometer and the plate are removed and a thin osteotome is used to complete the barrel vault osteotomy through the posterior cortex, being careful to keep the osteotome perpendicular

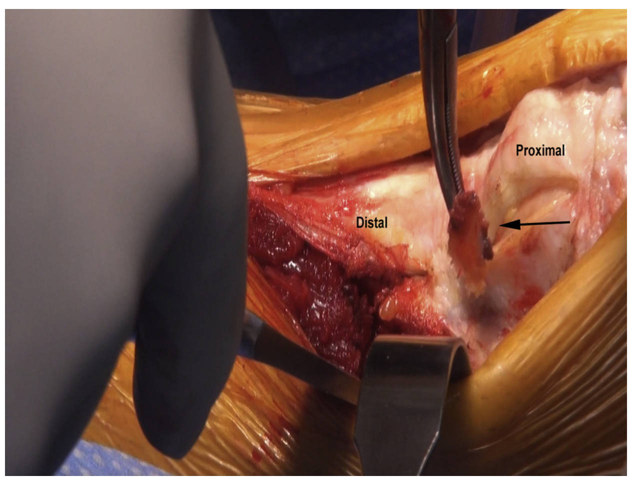

Fig 3. Removal of the tibiobular joint wafer (black arrow, left knee, proximal to the right).

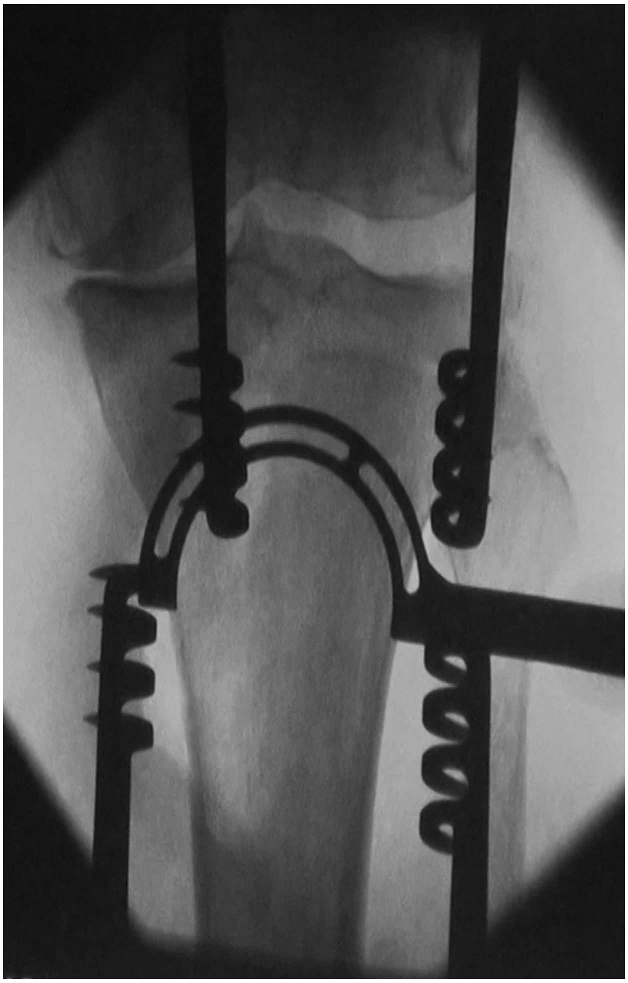

Fig 4. X-ray of the barrel vault osteotomy guide in place (left knee). Note the marked narrowing of the medial joint line.

to the axis of the tibia so that the tibial slope is not affected (Fig 10). Avoid going through the posterior cortex directly behind the patellar tendon to prevent damage to the popliteal vessels. The osteotomy through the extreme medial and lateral cortex needs to be specifically completed as this is a common area of residual bone that prevents mobilization of the osteotomy. No specific disruption of the medial soft tissue structures is performed other than at the distal medial extent of the curvilinear osteotomy. This area is well distal to the distal insertion of the deep medial collateral ligament and is effectively distal to almost all of the pes anserine tendons and the distal insertion of the superficial medial collateral ligament (Fig 11).

Alignment Correction and Plate Application

Manual valgus stress completes the mobilization of the osteotomy, and the pins are brought to parallel, completing the angular correction (Fig 12). The original AO external fixator is used to hold the correction (Video 1), but any external fixator can be used to maintain parallel alignment of the pins until the screws can be inserted into the plate. The screw mechanism of the external fixator allows the correction to be easily "fine-tuned" up or down. A ruler is used to make one measurement of the distance between the pins close to the bone and one at the tips of the pins to assure that the pins are parallel and the desired angular correction has been achieved (Fig 1B). The plate is bent with a plate bender to contour to the new valgus alignment of the proximal tibia and placed over the proximal pin. With the external fixator in place, cancellous locking screws are inserted through the proximal posterior screw holes, leaving the proximal anterior measurement pin in place. Cortical locking screws are inserted distally, locking in the correction. The 2 pins are then removed, and the remaining holes in the plate are filled with appropriate length screws as desired by the surgeon. An appropriate length cancellous screw is inserted into the proximal anterior (3.2-mm proximal Steinmann pin) hole (Fig 13). Range of motion is checked to make sure that there is no residual instability.

Closure

One or 2 2-0 Vicryl sutures are used to tack the proximal fascia over the tibiofibular joint, but the distal fasciotomy is left open. No bone graft is required, and

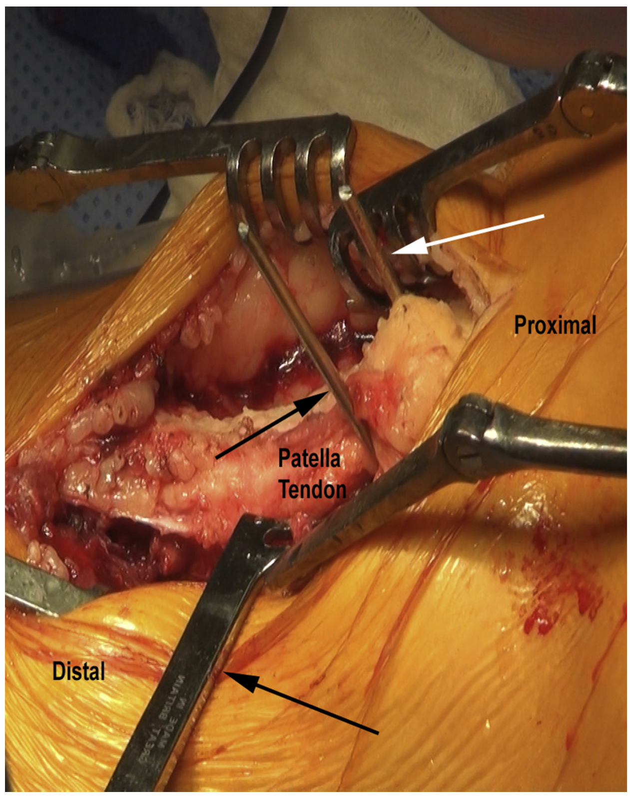

Fig 5. The barrel vault osteotomy guide is pinned (white and black arrows) in position behind the patellar tendon (left knee).

Fig 6. X-ray of multiple drill holes prior to osteotomy (left knee). Note the marked narrowing of the medial joint line.

Fig 8. Goniometer set for a 14° valgus correction (left knee).

corrections as large as 25° have been performed. If desired, anterior displacement of the distal tibia can be performed prior to insertion of the distal screws to unload the patellofemoral joint (Fig 1C). A routine wound closure is performed.

Postoperative and Rehabilitation

Postoperatively, the patients are allowed ad lib range of motion and weight bearing as tolerated with crutches

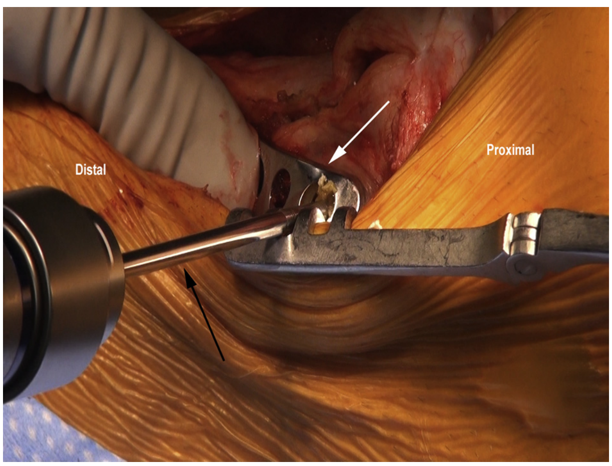

Fig 7. Insertion of 3/32-inch proximal Steinmann pin (white arrow) through the proximal anterior hole of the lateral tibial plateau plate (left knee, proximal to the right).

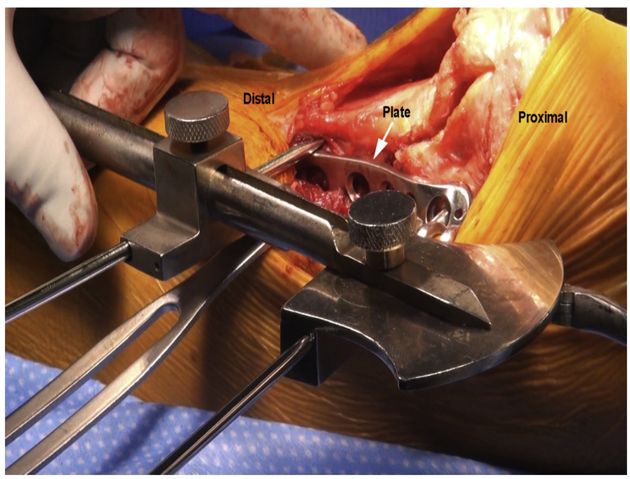

Fig 9. Distal pin insertion with goniometer (set for 14° valgus correction) anterior to the plate (left knee, proximal to the right).

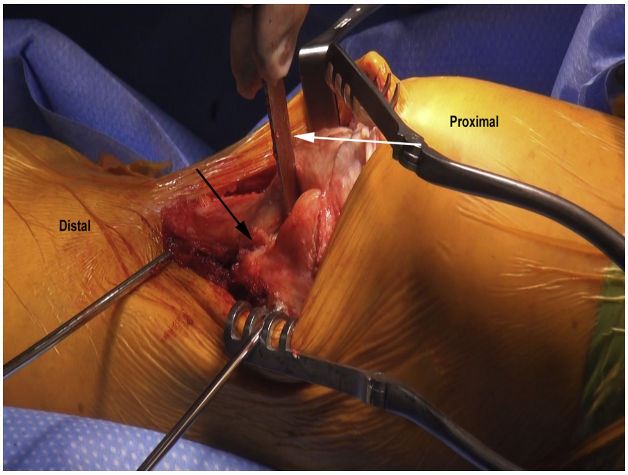

Fig 10. Completion of the osteotomy (black arrow) with a narrow osteotome (white arrow) through the posterior cortex prior to correction. Note the pins are not yet parallel.

Fig 11. Pins and plate in place, osteotomy completed, no manipulation yet. Pins are not yet parallel.

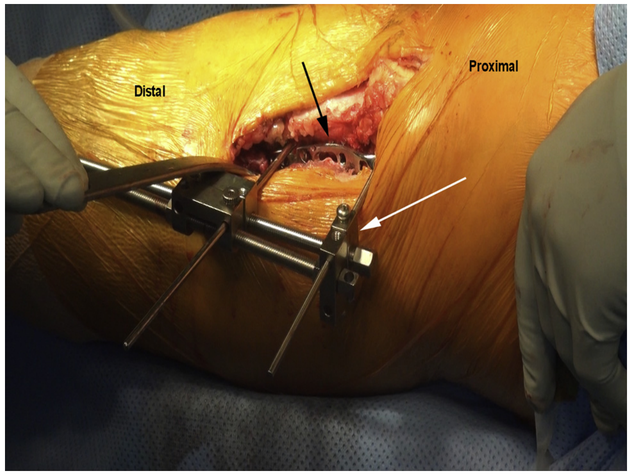

Fig 12. Valgus correction complete, pins are parallel, and the correction is held with the 2 external fixatures (white arrow) prior to insertion of the screws into the distal plate (black arrow).

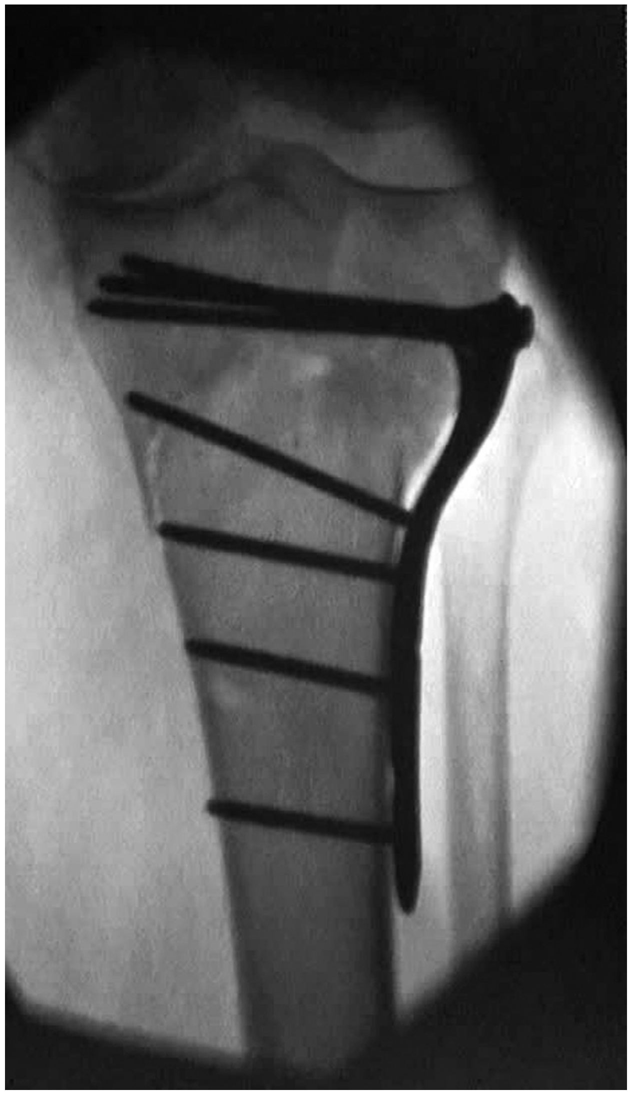

Fig 13. X-ray of completed procedure (left knee).

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
Always do a compartment fasciotomy.	Incomplete osteotomy of the medial and lateral cortex makes correction extremely difficult.
Use a narrow saw blade for the tibiofibular joint resection.	Thin osteotomes can be difficult to remove, and you may need a pliers (see Video 1).
Use a narrow osteotome for the tibial osteotomy.	Be sure the external fixature is used only to maintain the correction and is not used to achieve the correction; the pins can bend and result in undercorrection.
Cut only through the anterior 2/3 of the tibia until just prior to correction.	
Be sure to complete the osteotomy of the medial and lateral cortices before attempting to manipulate the correction.	
Avoid completing the osteotomy in the posterior midline with the osteotome; fracture the posterior bridge manually at the time of correction.	
A locking or nonlocking tibial L-plate can be used.	
Use the plate as a guide to insert the 3.2-mm Steinmann "base pin" through its most proximal and anterior hole.	
After correction, contour the plate to the new angle with a plate bender, apply over the proximal Steinmann pin, and insert the 2 posterior screws in the proximal plate prior to the fixature application so that once the correction is performed you can immediately insert a distal screw in the plate to maintain the correction.	
Use a ruler to measure the distance between the pins at the bone and at the pin tips to confirm they are parallel and the desired correction has been achieved.	
Be sure the fixature is used only to hold the correction and the pins are truly parallel from bone angular correction and not from pin tension on the bone.	

and a simple Velcro knee immobilizer until quadriceps control is achieved. Most patients have a full range of motion and are full weight bearing with minimal, if any, external assistance at 6 weeks when postoperative x-rays are taken.

Discussion

A "standard" straight longitudinal anterior incision is used, and there is no medial incision as used in medial opening wedge osteotomies to create narrow skin bridges that potentially could generate wound healing issues at the time of conversion to total knee arthroplasty. To expose the proximal medial tibia, only the most distal medial soft tissue structures are affected and no stripping is necessary medially. Because no bone defects are created, no bone graft is required, and there is an extremely large surface of metaphyseal bone, which heals readily and more rapidly than with the bony defects inherent in opening wedge osteotomies. The risk of tibial nonunion is much lower than in an opening wedge technique. I have not encountered any nonunion in 75 cases. Because no bone is removed, if the tibial osteotomy ever fails, conversion to total knee arthroplasty is not affected. The tibial plate combined with the configuration of the osteotomy provides excellent stability, which allows immediate weight bearing and full range of motion. The only immobilization necessary is a Velcro knee immobilizer for quadriceps control during weight bearing. Because this is still a "laterally based" procedure, the risk of peroneal nerve injury is still hypothetically present. The excision of the tibiofibular wafer is much simpler than with more distally based fibular shaft osteotomies. It can easily be performed through the same incision used to perform the osteotomy and inserting the plate. No separate fibular shaft osteotomy is necessary, and no specific dissection of the peroneal nerve is required. Although the osteotomy is curvilinear, it is performed with a standard osteotome, and no "complicated carpentry" is needed as in the opening/closing wedge tibial osteotomies. The angle of correction is infinitely variable and does not require fixed specific angles of correction as with the Puddu plates. In addition, because the subchondral support of the medial and lateral tibial plateaus is not disrupted by removal of bone, a much larger correction can be performed with the barrel vault osteotomy compared with an opening wedge osteotomy. Because hypothetically the posterior neurovascular bundle is at risk, we are careful to limit the use of the osteotomes to the anterior two-thirds of the tibia until the final steps just prior to manipulation, at which time the osteotomes are used to complete medial and lateral posterior cortex osteotomy, but the posterior middle tibial cortex is simply fractured without direct instrumentation of the posterior cortex in front of the

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
Uses a standard longitudinal anterior incision.	Posterior neurovascular potentially at risk.
Instrumentation is very simple and no there are "complicated carpentry" cuts.	Disruption of the tibiofibular joint could aggravate lateral or posterolateral laxity.
No disruption of the medial tissues or ligaments.	
Large metaphyseal surface for bone healing.	
No bone removed and no bone graft necessary.	
"Infinitely" variable correction.	
Large corrections are easily performed.	
Rigid fixation with a standard locking or nonlocking lateral tibial plateau plate.	
Immediate postoperative weight bearing and range of motion.	
No fibular shaft osteotomy is necessary.	
Anterior/posterior slope of the tibia not affected.	
No effect on leg length.	
Anterior displacement of the tibial tubercle is possible.	
No loss of alignment with time has been seen.	
No alteration of relative patellar tendon length.	
Concomitant anterior cruciate ligament reconstruction is possible.	

neurovascular bundle. Because the osteotomy is performed in a straight anterior/posterior direction, there is no risk of affecting the tibial slope as has been shown in opening wedge osteotomies.[10] Similarly, because no bone is removed, there is no effect on the leg length, the tibial slope, or the relative length of the patellar tendon. However, the distal tibia, with the attached patellar tendon, can be translated anteriorly to produce a tibial tubercle elevation with ease in the face of significant patellofemoral disease. The risk of loss of fixation is much lower than with an opening wedge. Loss of correction with time has not been seen with this technique as has been shown in an opening wedge osteotomy.[11]

Concomitant anterior cruciate ligament reconstructions can be performed because there is no hardware in the medial tibia. If an anterior cruciate ligament reconstruction is required, only the proximal posterior 1 or 2 screws are inserted and only the distal 1 or 2 screws are used to maintain the correction until after the tibial tunnel has been drilled. After the tibial tunnel has been drilled, the remaining screws can be inserted. Hypothetically, because the tibiofibular joint is disrupted, it could increase laxity if posterolateral rotatory instability is present. This could relax the lateral collateral ligament, but because only the tibiofibular articular surface is excised, the ligaments themselves do not appear to be affected and the joint seems to stabilize by scar with the support of the interosseus membrane. I have not seen any lateral instability in any knees with osteoarthritis.

The medial wedge opening osteotomy was developed in an attempt to avoid some of the complications from the lateral closing wedge osteotomy. It was originally felt that the complication rates would be lower. However, recent studies have not confirmed a lower rate of complications, and the opening wedge osteotomy has its own limitations and unique complications.[10-13] In my opinion, the barrel vault osteotomy avoids the complications of the opening wedge osteotomy and minimizes the potential complications of the lateral closing wedge osteotomy. The barrel vault osteotomy allows correction of large varus deformities in knee medial compartment osteoarthritis. Pearls and Pitfalls of this technique are described in Table 1, and Advantages and Disadvantages are described in Table 2.

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