Arthroscopic and Computer-Assisted High Tibial Osteotomy Using Standard Total Knee Arthroplasty Navigation Software

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Abstract: Opening-wedge high tibial osteotomy is an increasingly performed procedure for treatment of varus gonarthrosis and correction of malalignment during meniscal transplantation or cartilage restoration. Precise preoperative planning and meticulous surgical technique are required to achieve an appropriate mechanical axis correction. We describe our technique of arthroscopic and computer-assisted high tibial osteotomy using commonly available total knee arthroplasty navigation software as an intraoperative goniometer. We believe that our technique, by providing intraoperative real-time guidance of the degree of correction that is accurate and reliable, represents a useful tool for the surgeon who uncommonly performs high tibial osteotomy.

High tibial osteotomy is a well-accepted procedure for treatment of varus gonarthrosis. However, interest in performing high tibial osteotomy as an adjunctive procedure has increased recently, because of advances in meniscal transplant and cartilage restoration techniques for which malalignment would otherwise represent a contraindication. Whether high tibial osteotomy is performed as a primary or secondary procedure, the goal remains the same: to correct the mechanical weight-bearing axis and alter the loading pattern of the knee.

To achieve this correction, one must adhere to precise preoperative planning and meticulous surgical technique. Surgical imprecision of only a few degrees may result in poor surgical outcomes as a result of failing to adequately alter the mechanical weight-bearing axis. Long-term radiographic studies have shown that precise correction is mandatory for satisfactory outcomes.

Given the importance of accurate correction, we sought an improved technique over currently described methods for performing an opening-wedge high tibial osteotomy. Computer-assisted surgery offers the ability to precisely determine the mechanical weight-bearing axis intraoperatively and has been shown in a prospective, randomized study to result in improved postoperative alignment after total knee arthroplasty.

Accordingly, we have adapted our high tibial osteotomy technique with adjunctive arthroscopy to employ the use of a total knee arthroplasty navigation system as an intraoperative goniometer to permit a more accurate and reproducible alteration in the mechanical weight-bearing axis.

Technique

Preoperative Assessment

Before surgery, radiographic evaluation is performed on all patients. In addition to standard views about the knee, a full-length alignment view in double stance is obtained. This permits evaluation of the weight-bearing axis of both legs to determine the degree of deformity and to plan surgical intervention.

Despite the use of intraoperative navigation, it is nevertheless important to calculate the desired angular correction preoperatively. We use a trigonometric modification of the Noyes technique for determining tibial wedge size (Fig 1). This calculation ultimately serves as a reference during surgery and can be relied upon should intraoperative navigation fail.

Setup

The patient is placed supine with a tourniquet about the thigh and raised for the duration of the case. Spinal anesthesia is used. Bony prominences and superficial...
neurovascular structures are well padded. The portable fluoroscopy image intensifier C-arm is placed on the operative side of the patient, and the scrub nurse is positioned at the foot of the bed.

We use the Stryker Navigation System with precisioN Knee module (Stryker, Kalamazoo, MI). This system is positioned on the contralateral side of the patient, approximately 4 ft away from the bed and centered at the knees (Video 1, Fig 2). This system is an image-free infrared system that uses arrays positioned in the femur and tibia to calculate the axial, rotational, and translational position of the tibia with respect to the femur.

**Diagnostic and Therapeutic Arthroscopy**

Knee arthroscopy must be performed when one is using intraoperative navigation, because intra-articular...
landmarks must be registered with the software for accurate limb axis measurements. This also permits treatment of associated degenerative meniscal tears that may be causing mechanical symptoms and confirms that the lateral and patellofemoral compartments are relatively well preserved.

**Arthroscopically Assisted Navigation Registration**

After arthroscopy, arrays are positioned in the femur and tibia percutaneously with the use of partially threaded Steinmann pins. The femoral pin is positioned approximately 1 hand’s breath proximal to the superior pole of the patella from anterior to posterior. The tibial pin is inserted into the mid diaphysis of the tibia, approximately 1 hand’s breath distal to the planned incision. Once the anchor pins are inserted, the patient tracker arrays are attached (Fig 3). The center of the femoral head is determined through hip flexion and circumduction of the lower leg. By use of a pointing device, the medial and lateral epicondyles are digitized.

The arthroscope is reintroduced into the knee through the inferolateral portal, and the pointing device is introduced through the inferomedial portal. The center of the trochlear sulcus, which is the same point at which one would place the intramedullary rod during conventional total knee arthroplasty, is digitized with the pointing device (Fig 4). The femoral anteroposterior axis, also known as the Whiteside line, is also digitized with the pointing device. The tibia center is next identified by placing the pointing device at the footprint of the anterior cruciate ligament. The arthroscopy instruments are then removed from the knee. Lastly, the tibial tubercle and the medial and lateral malleoli are digitized. This completes the registration process and permits the software to calculate the mechanical femoral and tibial axes.

The software next displays the angular deformity in the coronal (varus-valgus) and sagittal (flexion-contraction) planes (Fig 5). The knee is taken through a full range of motion to produce an initial alignment curve. Often, as knee flexion increases, the coronal deformity decreases, but this curve may be variable. The navigation system is now functioning as an intraoperative goniometer. The arrays are removed from the anchor pins, because they are not needed until after the osteotomy has been completed.

**High Tibial Osteotomy**

**Initial Steps.** A 7-cm vertical incision is made halfway between the tibial tubercle and the posteromedial border of the tibia, beginning at a point just distal to the medial joint line. The incision may be moved slightly more midline to preserve exposure for possible total knee arthroplasty in the future. Sharp dissection is continued to the level of the sartorial fascia, where the tendons of the pes anserinus are identified. A vertical
Incision of the pes anserinus is made immediately lateral to the anterior tibial crest. The tendons of the pes anserinus and superficial medial collateral ligament are subperiosteally elevated to the posteromedial border of the tibia.

The retropatellar fat pad is identified and incised to permit insertion of a bent right-angle retractor to protect the patellar tendon during the osteotomy. The most proximal 1 cm of the patellar tendon insertion on the tibial tubercle can be sharply elevated to improve exposure. Posteriorly, a blunt-tipped Hohmann retractor is placed immediately adjacent to the posterior cortex of the tibia to protect the neurovascular bundle.

With adequate visualization, the entire proximal tibial metadiaphysis can be visualized and attention turned to performing the osteotomy. Two guide pins are used to mark the osteotomy under image intensifier guidance. A percutaneous guide pin is placed perfectly parallel to the joint line in the coronal plane approximately 1 cm distal to the tibial articular surface in a medial-to-lateral direction. The second guide pin is inserted obliquely along the planned osteotomy line from medial to lateral, starting approximately 4 cm distal to the joint line medially, but immediately proximal to the level of the tibial tubercle. The second guide pin should end 1 cm distal to the joint line laterally and the tip of the first guide pin (Fig 6).

The plane of the osteotomy is marked with electrocautery. In the sagittal plane, it should parallel the posterior tibial slope, approximately 7° from perpendicular. An initial osteotomy is performed distal to the oblique guide pin only through the medial cortex with an oscillating saw. Sharp, flexible, thin osteotomes are used to perform the osteotomy through the anterior cortex, cancellous bone, and posterior cortex. These must be repeatedly inserted and removed to complete the osteotomy along the guide pin. The osteotomy should not extend beyond the tip of the guide pin to prevent perforation of the lateral cortex and destabilization of the proximal tibial fragment. Frequent imaging is performed to ensure that the osteotomes are in the correct position.

**Navigated Opening.** Instruments from the Arthrex Opening Wedge Osteotomy System Set (Arthrex, Naples, FL) are used to complete and open the osteotomy. The Osteotome Handle and 35-mm Blade (Arthrex) are inserted to complete the osteotomy, again under fluoroscopy. It is critical to verify that the anterior and posterior cortices have been osteotomized before opening.

The arrays are replaced on the anchor pins, and the coronal and sagittal planes are verified.

Next, the blades of the Osteotome Jack (Arthrex) are inserted sequentially into the osteotomy site. By use of

**Fig 5.** Screenshot from navigation software, displaying angular deformity in coronal and sagittal planes. (A, anterior; L, lateral; M, medial; Max, maximum; Min, minimum; P, posterior.)

**Fig 6.** Intraoperative radiograph showing guide pin placement and insertion of osteotome.

**Fig 7.** The Osteotome Wedge Trial is inserted and advanced with the guidance of the navigation software to the desired correction point.
the 3.5-mm hex screwdriver, the jack is slowly opened to approximately 8 mm. This opening is carefully performed under fluoroscopic visualization. The degree of correction may be initially checked on the navigation system.

Once the osteotomy site has been initially opened and made slightly mobile, the Osteotome Wedge Trial (Arthrex) is inserted (Fig 7). The depth of insertion is guided both navigationally and fluoroscopically. By use of the navigation software, the Osteotome Wedge Trial is advanced until the varus alignment is eliminated and a genu valgum of at least 2° to 3° is achieved (Fig 8). The resting knee flexion angle is also carefully observed to ensure that changes in posterior slope are not altered. If the flexion angle increases, a single Osteotome Wedge Trial construct can be used, with the Wedge Trial inserted more posteriorly. This is because of the triangular cross-sectional shape of the proximal tibia.

Once the desired correction has been achieved, the Arthrex ContourLock with sloped wedge is inserted as posteriorly as possible into the osteotomy site. A single 6.5-mm cancellous screw is inserted proximally and a 4.5-mm cortical screw is inserted distally to provide initial fixation of the osteotomy and prevent inadvertent alterations in the degree of opening. The mechanical axis is again verified with the navigation software. The remaining proximal and distal holes of the plate are filled with cancellous and cortical screws, respectively.

Final navigational and fluoroscopic verification is performed to ensure correct mechanical axis alteration and hardware positioning. The knee is taken through a gentle range of motion, and the final alignment curve is compared with the initial alignment curve obtained at the outset of surgery. Generally, the curve representing alignment in the coronal plane is shifted such that the knee is in approximately 2° of mechanical valgus in full extension. The shape of the curve, however, generally does not change after the osteotomy. As the knee flexes, the degree of valgus should increase and the slope of increase should be similar to the slope of the initial alignment curve (Fig 9). Morselized bone chips are impacted into the osteotomy site. The wound is closed in layers, the anchor pins are removed, and closure is performed in an interrupted fashion. The leg is placed into a hinged knee brace, locked in extension. A drain is not routinely used.

Postoperatively, the patient is admitted to the hospital for neurovascular observation and intravenous analgesia. Partial weight bearing with crutches is permitted during the first 6 weeks. At 6 weeks, radiographs are obtained, and if consolidation is evident, full protected weight bearing with crutches is permitted for the next 6 weeks. Complete weight bearing is typically allowed at 12 weeks.

**Discussion**

We have performed an arthroscopic and computer-assisted high tibial osteotomy technique in 25 patients in the past 2 years. Preliminary radiographic results show appropriate lateral deviation of the weight-bearing axis into the lateral compartment in all cases. There has been 1 complication in which the osteotomy was noted to propagate through the lateral cortex, resulting in a minor loss of correction.

![Fig 8. Screenshot from navigation software. The coronal-plane angular deformity has been corrected, but slope has been increased (because flexion has increased). The Osteotome Wedge Trial is inserted more posteriorly to avoid slope correction. (A, anterior; L, lateral; M, medial; Max, maximum; Min, minimum; P, posterior.)](image1)

![Fig 9. Screenshot from navigation software. As the knee flexes, valgus increases.](image2)
Advantages of our technique include accurate determination of the weight-bearing axis intraoperatively without use of a hip-to-ankle extramedullary alignment guide to evaluate the correction. The procedure can be performed quickly if one adheres to the key points (Table 1). An increased tourniquet time of approximately 15 minutes is well tolerated by the patient. Disadvantages include separate incisions in the femur and tibia, as well as the added cost of using navigation and inability to directly measure changes in the posterior tibial slope.

The results of similar computer-assisted high tibial osteotomy techniques have recently been published. In a prospective randomized trial of 27 knees, navigation techniques were associated with a more accurate and reproducible correction of deformity compared with standard techniques. We believe that our technique, by providing intraoperative real-time guidance of the degree of correction that is accurate and reliable, represents a useful tool for the surgeon who uncommonly performs high tibial osteotomy.

Table 1. Key Points

Preoperative templating is mandatory should intraoperative navigation fail.
A large operating room is required with the arthroscopy and navigation towers placed on the contralateral side of the patient, the scrub nurse at the foot of the bed, and the C-arm on the ipsilateral side.
Extra-articular navigation registration is the same as that performed for a standard total knee arthroplasty. The center of the trochlear sulcus and the footprint of the anterior cruciate ligament are the key landmarks that must be digitized arthroscopically.
The technique for the high tibial osteotomy may be performed as preferred by the treating surgeon. Once the osteotomy is created, the navigation system is turned on and can be used as an intraoperative goniometer.
One should carefully note the preoperative flexion contracture (if any). The postoperative flexion contracture should match this number. If it is increased, the tibial slope has been increased and the correction should be re-evaluated.

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