High Tibial Osteotomy
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**Abstract:** High Tibial Osteotomy is a valuable tool for young active patients with osteoarthritis that is isolated to a single compartment. Recently, more surgeons have migrated to the use of the medial opening wedge technique in the hope that some of the complications associated with the lateral closing wedge can be avoided. This article describes the preoperative evaluation, surgical procedure, postoperative rehabilitation, and its potential pitfalls. Our goal is to provide a concise easy-to-read manual for the procedure.

**Key Words:** high tibial osteotomy, proximal tibial osteotomy, knee osteoarthritis, opening wedge osteotomy

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**HISTORIC PERSPECTIVE**

Osteoarthritis of the knee is a common condition. When localized disease corresponds with malalignment, high tibial osteotomy (HTO) is a valuable surgical management option. The concept of HTO was introduced by Jackson and Waugh and had gained acceptance after their reports in 1961. In the United States, the procedure was later popularized by Coventry. The basis of the realignment procedure has remained the same. The goal is to redistribute the mechanical forces from an arthritic knee compartment to one with more viable articular cartilage. The lateral closing wedge osteotomy popularized by Coventry, although widely accepted, was also fraught with complications (peroneal nerve problems, limb shortening, patella baja, etc). The medial opening wedge using external fixation became popular in an attempt to avoid these complications. However, the use of the external fixation technique was not without its own set of complications (pin tract infection, patient satisfaction/compliance). With Giancarlo Puddu’s introduction of the “Puddu” plate, the medial opening wedge HTO gained further popularity. This mode of fixation allowed for varying degrees of tibial realignment, reestablishment of tibial length, and more precise correction with elimination of some of the inherent risks of the lateral approach and avoided some of the disadvantages of external fixation.

Currently, given the excellent results seen in total knee arthroplasty and increased popularity of unicompartamental arthroplasty, HTOs are being used less frequently. However, HTO remains the more appropriate procedure for younger, active patients with unicompartamental arthritis and a malaligned limb.

**INDICATIONS AND CONTRAINDICATIONS**

There is no clear consensus regarding the choice between an osteotomy and joint replacement; however, selecting the proper patient is one of the most important factors determining successful outcome after osteotomy. Generally accepted indications for a high tibial osteotomy are primary degenerative arthritis involving a single compartment in a mal aligned limb of a young individual. Unicompartmental osteoarthritis most often involves the medial compartment and is usually associated with varus alignment of the leg. The “ideal” patient should be active and of ideal body weight with localized, activity-related pain in the diseased compartment. The knee should have good range of motion with a well-functioning ipsilateral hip. A ligamentously stable knee was classically required. However, HTO is indicated in the triple varus knee (ie, ACL tear, LCL injury, and malalignment). In such cases addressing malalignment before ligamentous reconstruction or repair is vital to an acceptable outcome. Although there is no specific age cutoff, it has been suggested that osteotomies for unicompartmental arthritis be limited to patients less than 65 years. More importantly, ideal candidates for osteotomy are those patients in whom the predicted stress on the tibiofemoral joint based on their activity requirement or expectations would carry a high risk of premature implant loosening or accelerated polyethylene wear with total joint arthroplasty. Absolute contraindications include diffuse arthritis, inflammatory arthritis, tibiofemoral subluxation, earlier meniscectomy in the compartment intended to be loaded, and unrealistic patient expectations. Advanced physiologic age (≥65), obesity (≥1.32 × ideal body weight), poor range of motion (contractures more than 15 degrees and flexion of less than 90 degrees), generalized knee pain, and patellofemoral pain are considered relative contraindications.

**PREOPERATIVE PLANNING**

It is well documented that to ensure adequate clinical results, high tibial osteotomy must restore alignment to the lower extremity and shift the load distribution toward the unaffected compartment. In the usual case, this means correcting the leg into valgus alignment that shifts the load to the lateral compartment. To achieve this goal, a common method of preoperative planning involves selecting a correction wedge angle that is equal to the amount of angular deformity plus any desired overcorrection. A correction of greater than 7 degrees of valgus is known to reduce load across the tibiofemoral joint with an 8 to 10 degree valgus anatomic axis having been shown to offer the best results for high tibial osteotomy. There has been no agreement on the amount of overcorrection, only that at least some overcorrection is necessary.

To properly select the appropriate wedge angle, the forces acting about the tibiofemoral joint must be evaluated. Many dynamic forces and mechanical variables occur at the knee joint during ambulation. These include muscle and ligamentous forces, adduction moment magnitude, upper body position, and walking speeds. The forces and variables involved in a
patient’s gait and their effect on the magnitude of medial compartment loads cannot be quantified on static analysis of plain radiographs. However, the use of plain full-length, weight-bearing radiographs offers the best clinical approximation of high tibial osteotomy preoperatively (Fig. 1). Double stance radiographs offer an advantage over single stance views in that comparison between the 2 knees allows for sufficient determination of whether or not lateral joint space opening is contributing to the varus angulation. Determination of the weight bearing line (WBL) at the knee joint represents the most precise method of preoperative planning. The weight bearing line represents the intersection of the mechanic axis at the knee joint. In the normally aligned knee, 60% of the mechanic axis load is located in the medial compartment. Best results of HTO occur when the WBL passes through the lateral plateau. It has been reported that the optimal location is at 62% to 66% of the width of the tibial plateau, which will typically be at the base of the lateral tibial spine (Fig. 2). Additionally, it is also important to avoid over distraction of the medial compartment, which could lead to medial collateral ligament failure and possible progressive valgus deformity. Lateral compartment overload may also lead to early failure of the osteotomy, although long-term outcome studies correlating the amount of overcorrection with failure rates have shown mixed results. However, all these studies have correlated undercorrection with early failure. Therefore, by placing the WBL just lateral to the tibial spine, it ensures transfer of load to the lateral compartment without over distraction. Preoperative radiographs include a complete leg length study, standing AP of the knee, and a true lateral of the knee.

TECHNIQUE

The medial opening wedge high tibial osteotomy can be carried out through use of a plate fixation technique or an external fixation technique. Before either procedure, a knee arthroscopy is done to evaluate for any intraarticular pathology not appreciated on physical exam or radiographs. If there are significant degenerative changes in either of the 2 other compartments, the operation will fail; so, there is no point in continuing on to the osteotomy.
Plate Fixation

Patients are placed supine on a radiolucent table that allows intraoperative imaging of the hip, knee, and ankle. An incision is made approximately 3 cm medial to the tibial tubercle, and blunt dissection is used to reach the level of the pes anserinus tendons. At approximately 1 cm below the joint line, horizontal to the patellar tendon, an inverted “L” incision is made across the pes insertions. The pes tendons are then subperiosteally dissected off the tibia and reflected posteriorly. This posteriorly reflected sleeve of tissue typically contains the anterior fibers of the superficial medial collateral ligament. By limiting the extension of the horizontal limb of the incision and keeping the dissection subperiosteal, you can preserve function of the MCL and avoid potential issues with MCL repair. The posterior border of the tibia is identified and a retractor is placed to protect the MCL and neurovascular structures. Anteriorly, a retractor is used to protect the patellar tendon. The leg should then be placed on a bump to raise it above the level of the opposite leg for purposes of easily obtaining fluoroscopic images. Adjust the C-arm into position until a true AP of the knee is visualized. It is important to make sure the x-ray beam is parallel to the tibial plateau. Using freehand technique and fluoroscopic image intensification, a 2.5-mm guidewire is placed in subchondral bone parallel to the joint line.

To identify the posterior slope of the tibia, a second guidewire is placed posterior and coplanar to the first guidewire. It is particularly important at this point to ensure that the fluoroscopic image shows overlapping of the anterior and posterior tibial plateaus to ensure that the cut will not change the slope of the tibial plateau. A distal osteotomy guidewire is then placed at the junction of the anterior and middle thirds of the tibia approximately 4 cm distal from the joint line aimed proximally toward the top of the proximal tibia-fibula joint. A second osteotomy guidewire is inserted posterior to the first and should be seen to “disappear” on image intensification, again reproducing the posterior tibial slope. A lateral radiograph is obtained to double check that the pins are in the correct plane with the joint line. Once satisfied with positioning of the guidewires, the osteotomy can be carried out with an oscillating saw using the distal osteotomy guidewires as a cutting jig. Some surgeons prefer to use break-off pins to allow for easier sliding of the saw on the pins, and it is at this point that the pins should be broken off. Whether using standard pins or break-off pins, the most important aspect is to make sure that the saw cut is following the pins as it crosses the tibia. At this point, a subperiosteal elevation should be done anterior and posterior to protect the patellar tendon attachment anteriorly and the neurovascular structures posteriorly. The saw is placed distal to the guidewires and is passed approximately two-thirds of the way across the tibia avoiding penetrating the lateral cortex. During the cutting, retractors should be placed anterior and posterior between the periosteum and bone to protect the patellar tendon attachment and neurovascular structures, respectively. An osteotome is then used to separate the anterior and posterior cortices and is advanced laterally within 1 cm of the lateral cortex. Using a large osteotome posteriorly will be less likely to plunge. A gradual distraction instrument, of which there are several commercially available, or a lamina spreader then may be inserted into the osteotomy site to assist with achieving the appropriate amount of correction. The amount of correction to be carried out is assessed at this point with the use of an electrocautery cord and image intensification. By placing the electrocautery cord in line with the mechanic axis, it is possible to adjust the opening wedge so that the weight bearing line passes just lateral to the base of the lateral tibial spine. Once the appropriate amount of correction is achieved, the corresponding plate is selected and inserted. Several vendors make plates specific for high tibial osteotomies. These include plates with small wedges, such as the Puddu plate and its derivatives, and/or plates that use locking screws that attach to the plate and provide fixed-angle screws. After the plate is inserted, predrilling is done, and the correct size screw is inserted. You should start with the distal most screw. A screw is then placed in the proximal plate cluster to

FIGURE 3. Postoperative AP (A) and Lateral (B) of the knee after plate fixation and bone grafting.
avoid any anterior or posterior shifting of the plate. The plate should be inserted as far posterior as possible to minimize the risk of increasing posterior tibial slope or having screws penetrate the posterior cortex. To prevent the distal segment from flexing, the proximal screw is drilled with the knee in hyperextension. After final plate fixation, bone graft is placed in the osteotomy site. Allograft, autograft, or a combination thereof may be used and individualized based on the patient and the amount of correction achieved. Figure 3 shows plate fixation after correction and bone grafting. As long as the incision in the pes anserine is made in a longitudinal direction, there is limited horizontal extension of the inverted L, and the remainder of the dissection stays subperiosteal, an MCL repair is usually not necessary.

External Fixation

Use of external fixation for opening wedge high tibial osteotomy is generally recommended for the moderately obese patient or in those that may have difficulty complying with weight bearing restrictions. In a similar fashion, as the plate fixation technique, once a true AP of the knee is obtained, the first step of applying the external fixator is placing a tapered bone screw parallel to the joint line under image intensification. Once the first bone screw is in place, the external fixator clamp can be positioned and used as a template for placement of the second bone screw. It is important to have the second screw coplanar with the first and parallel to the tibial plateau to avoid changing the tibial slope. The fixator body is then connected and the entire assembly can be manipulated in the anterior/posterior and medial/lateral planes to locate the proper position for placement of the distal diaphyseal bone screws. The external fixator must be removed temporarily to carry out the osteotomy. In much the same way as the plate fixation technique, a corticotomy is carried out parallel to the joint line at the desired level of bone separation. Once the corticotomy is complete the external fixator is reapplied and distracted with visualization under fluoroscopy to ensure the corticotomy is complete (Fig. 4). The fixator is then compressed to its original position for 10 to 14 days to permit callous formation. Distraction then is started at one-quarter turn 3 times per day to correct the varus deformity. Long leg alignment films are obtained weekly until the desired correction is reached. The external fixation is then tightened in the static position until healing occurs. The fixation can generally be removed approximately 6 weeks after distraction is stopped. The biggest advantage to external fixation is the ability to fully weight bear through the entire course of treatment.

LITERATURE RESULTS

High tibial osteotomy has been shown to have good early results which deteriorate over time. Virolainen and Aro did a metaanalysis of high tibial osteotomy outcomes as reported in the literature over a 28-year period. High tibial osteotomy had an average probability of a good or excellent result in 75.3% of patients after 60 months, and 60.3% after 100 months. The overall failure rate, defined as reosteotomies, arthroplasties, meniscectomies, ligament reconstructions, infections. and non-unions, was 24.6% at 10 years. Several others studies have shown similar long-term outcomes. However, these studies are for lateral closing wedge osteotomies. Long-term results of medial opening wedge osteotomies are not yet available.

COMPLICATIONS

There are both short-term and long-term rates of complication for high tibial osteotomy. Intraarticular extension of the osteotomy can occur by fracture, if the cut is not made far enough across the tibia, and/or the osteotomy is placed too close to the joint. If intraarticular extension of the fracture is suspected, evaluation with arthroscopy is recommended to look for displacement along with compression screw fixation of the fracture. Coventry recommended placement of the proximal cut at least 1 cm to 2 cm distal to the articular surface to help avoid this complication. Another common intraoperative complication is fracture and instability of the lateral cortex. This would cause the osteotomy to become unstable. Intraoperative correction of this can be achieved by either lateral plate or staple fixation to reestablish the lateral hinge. Some early postoperative complications include infection, thromboembolism, intraoperative fracture, and undercorrection. Late complications may include loss of correction, failure of fixatio and delayed union or nonunion. Undercorrection is a result of inappropriate or inaccurate preoperative planning and/or surgical errors. Undercorrection of the malalignment fails to achieve unloading of the joint and likely will result in a
lack of the desired reduction in pain. Increasing the posterior tibial slope has also been reported.

FUTURE OF THE TECHNIQUE

Achieving appropriate alignment is crucial to the success of medial opening wedge HTO. Increasing the posterior tibial slope is a major technical problem associated with medial opening wedge HTO. This has been shown to influence knee kinematics, stability, and tibiofemoral contact pressure. These findings stress the importance of obtaining proper coronal and sagittal alignment. Computer-assisted 3-dimensional navigation systems have been used in an attempt to monitor coronal and sagittal alignment. Yamamoto et al\textsuperscript{16} reported on the success of this technology and its ability to provide surgeons with reliable information to determine the appropriate alignment.

REHABILITATION PROTOCOL AFTER HIGH TibIAL OSTEOTOMY

After high tibial osteotomy, the rehabilitation includes immediate protected range of motion and quadriceps isometric exercises. For the opening wedge plate fixation, a knee immobilizer is used postoperatively for comfort and to maintain full extension. The patient can wean from the immobilizer as tolerated. For the first week, patients are encouraged to ice and elevate the leg to prevent swelling. Deep Venous Thrombosis prophylaxis includes low molecular weight heparin initially, followed by a transition to a full strength daily aspirin, once the patient becomes mobilized. For the opening wedge plate fixation technique, patients are able to ambulate with toe-touch weight bearing for the first 6 to 8 weeks. If the patient shows healing and maintenance of the HTO position, the patient is gradually increased to full weight bearing by 8 to 10 weeks postoperatively. Some authors are now beginning to show good results with early weight-bearing-to-tolerance at 2 to 3 weeks, particularly for the locking plates, but this is by no means universal.\textsuperscript{17,18} For the external fixation technique, the patient is permitted to weight-bearing-to-tolerance immediately after the surgery. For the external fixation technique, the fixator is locked in the closed position for 1 week. At 1-week follow-up, the fixator is unlocked and the patient begins distraction with one-quarter turn 3 times per day. Weekly long leg alignment films are obtained until the desired correction is obtained, which should be a weight-bearing axis passing through the base of the lateral tibial spine. This usually takes between 10 days and 3 weeks. Once the correct alignment is obtained, the external fixator is locked until healing occurs. At that point, the external fixator can be removed. This is usually between the 8 to 12 week postoperative period. Strengthening exercises are begun, once significant healing has been shown on radiographs usually at about 3 months postoperatively. The protocol includes closed chain exercises emphasizing quadriceps, hamstring, gastroc-soleus complex, and hip flexor strengthening. Return to activity is recommended only when strength testing shows near equal strength to the contralateral leg, and when no significant pain or swelling occurs with or after activity.

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