Total Knee Arthroplasty After High Tibial Osteotomy

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ABSTRACT

High tibial osteotomy may be indicated in the treatment of varus knee in young, active patients. The preservation of proprioception and native joint and biomechanics is crucial for functional recovery in these patients. However, deterioration of initial good results can occur with time. In such cases, revision with total knee arthroplasty is indicated. However, this is a more surgically demanding option compared with a primary prosthesis. Accurate preoperative planning is mandatory to decrease the risk of intraoperative com-

edutational objectives

As a result of reading this article, physicians should be able to:

1. Delineate the indications for high tibial osteotomy (HTO) and report on its functional results in relation to the conversion to total knee arthroplasty (TKA).
2. Outline the principles and anatomic implications of opening- and closing-wedge HTO.
3. Describe how to undertake soft tissue balance in the knees of patients who previously underwent HTO.
4. Analyze tibial malunions after HTO and their implications for further HTO and TKA.

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Received: February 5, 2013; Accepted: September 30, 2013; Posted: March 11, 2014
doi: 10.3928/01477447-20140225-08
High tibial osteotomy (HTO) is a reliable option in the management of constitutional varus deformity of the knee in young adults and in arthritic varus knees. High tibial osteotomy is considered the best choice in young, active patients in whom the preservation of proprioception and native joint and biomechanics is crucial for functional recovery. Moreover, there are legitimate concerns regarding the results and survivorship of total knee arthroplasty (TKA) in young, high-demand patients. Recently, HTO has been proposed in association with ligament reconstruction and the management of cartilage defects. In such patients, HTO protects the cartilage and/or ligament graft by changing the lower limb mechanical axis. Historically, the literature has reported good results in terms of pain relief and function in 80% to 90% of patients after dome, opening-wedge, or closing-wedge HTO. However, these encouraging early results generally deteriorate with time. When this occurs, 3 options exist: unicompartmental knee arthroplasty (UKA), total knee arthroplasty (TKA), and a new osteotomy. Total knee arthroplasty is a safe option, especially when the lateral compartment is affected. At 10-year follow-up, TKA was necessary in 23% of patients previously treated with HTO.

More recently, Flecher et al reported that 14% of patients underwent revision for progression of osteoarthritis after HTO, whereas in the series by Hui et al, the revision rate after HTO was 31% (mainly to TKA). Finally, Mont et al reported that, following HTO, 36% of patients experienced a fair or poor result or necessitated further surgery, with 8% of patients requiring TKA. Similar data were reported in other studies where debilitating pain was the main indication for revision to TKA. When considering TKA after HTO, several aspects must be taken into account in preoperative planning and intraoperatively. Patients must be informed of the less satisfactory functional and clinical results of these procedures compared with primary arthroplasties. Staehele et al reported similar results with primary implants and TKA after HTO. To clarify these aspects, the current authors performed a literature review and analyzed the potential pitfalls of preoperative planning and surgical technique.

**Materials and Methods**

A PubMed search was performed using the key words “total knee arthroplasty,” “after,” and “high tibial osteotomy.” Technical notes, letters to editors, instructional courses, and book chapters were screened by hand to improve the quality of this narrative review.

**Results**

A total of 108 articles were identified. All abstracts were independently screened by 2 surgeons (S.C., M.V.). All articles not focusing on the issue at hand were excluded. Eventually, 56 articles and 4 book chapters, including prospective and retrospective studies, reporting the outcomes of patients undergoing TKA after dome, opening-wedge, or closing-wedge HTO were identified. However, a methodology evaluation of the studies was not performed.

**Discussion**

**Closing-wedge High Tibial Osteotomy**

This time-tested technique has been widely adopted. Its major advantages are stable fixation, low risk of nonunion, and the possibility of early weight bearing because it does not necessitate bone grafting at the site of osteotomy. Healing generally occurs within 6 to 8 weeks. These may lead to peroneal nerve palsy or proximal tibiofibular instability. In more severe deformities, medial hinge fracture and loss of correction may occur. When planning a closing-wedge HTO, the thickness of the blade and the double bone cut must be taken into account to avoid hypercorrection. Moreover, the common algorithm of a 1-mm wedge to achieve 1° correction is not precise and usually results in undercorrection. Theoretically, closing-wedge HTO distalizes the joint line, thus increasing patellar height. However, clinical evidence of patella baja is more common. This is likely the consequence of postoperative immobilization and scarring or patellar tendon slackness consequent to the reduction of metaphyseal thickness. A devastating but uncommon complication that may occur after all HTOs is compartment syndrome, reported in less than 1% of patients.

**Opening-wedge High Tibial Osteotomy**

This procedure was initially introduced in Europe and later in the United States. It facilitates precise correction on both the frontal and lateral planes. Moreover, modifications of the tibial slope are possible with this procedure. The main advantages are preservation of the proximal tibiofibular joint and the fact that peroneal osteotomy is not required. Simultaneous additional procedures, such as anterior cruciate ligament reconstruction, are also possible. However, an opening-wedge HTO requires partial detachment of the superficial layer of the medial collateral ligament (MCL), which may therefore be damaged. Moreover, if larger corrections are planned, then filling the bone gap with autologous bone graft or bone substitutes must be considered to enhance the healing process. Both options have disadvantages, including donor...
site morbidity and longer healing time, respectively. Thus, weight bearing is usually allowed later than in closing-wedge HTOs. Fracture of the lateral hinge may occur as a result of technical errors, with an increased risk in deformities greater than 10° to 15°. Other disadvantages are slight tibial lengthening and patella baja, the latter of which is relatively common.

**Technical Aspects of Total Knee Arthroplasty After High Tibial Osteotomy**

Conversion of HTO to TKA requires careful surgical planning. Some potential pitfalls are related to previous surgery and include hardware removal, joint exposure, dealing with tibial deformities from the previous osteotomy, and managing soft tissue imbalances. These aspects must be evaluated preoperatively, and their solutions must be clear before beginning surgery. Although some surgeons consider TKA after HTO to be no more technically demanding than routine TKA, the current authors believe that most surgeons find it more demanding.

**Hardware Removal, Incision, and Joint Exposure.** The first step is often hardware removal. Because of the risk of impingement with the tibial stem, the authors agree with those who suggest their removal regardless of their type (eg, staples or plates). However, there is no consensus on the timing of the removal; some authors suggest a 2-stage procedure, whereas others prefer a 1-stage procedure. The former has the advantage of a more predictable operative time. Moreover, it is possible to take samples for microbiology at the time of removal. However, 2-stage procedures increase anesthesia time, patient discomfort, and costs (2 hospitalizations and 2 procedures). In cases of bulky hardware, the necessity of detachment of the anterior tibialis muscle for closing-wedge HTOs or disruption of the MCL and pes anserinus tendons for opening-wedge HTOs may require slower rehabilitation. In such instances, as well as when infection is suspected, a 2-stage procedure is preferable.

When planning the skin incision, previous scars must be carefully considered because skin necrosis is a major issue in this surgery. Because blood vessels come from the lateral branches of the genicular arteries, the most lateral incision is preferred. When this is not possible and a new incision is required, it should be at least 6 cm away from older incisions, and incision convergence must be avoided. Arthrotomy depends at least partially on the skin incision. To decrease the risks of skin necrosis, wide subcutaneous dissection should not be performed. In case of hypocorrection after HTO and recurrence of varus, a medial arthrotomy is indicated. In cases of hypercorrection and valgus knee, a lateral approach is preferred. When the arthrotomy is performed on the opposite side of a previous osteotomy, this increases the risk of patellar necrosis and fracture. Due to scar tissue, patella baja, and proximal tibial malunion (more frequent in cases of closing-wedge HTO), accurate joint exposure can be difficult. Care should be taken to increase joint exposure and avoid patellar tendon damage or avulsion. Although cutting the femur first can make exposure easier, at times additional steps must be considered. Quadriceps snip and V-Y plasty are commonly adopted and were necessary in 23% of patients reported by Gill et al and 40% of patients reported by Toksvig-Larsen et al. Unfortunately, they weaken the extensor mechanism and may lead to even greater patella baja or extension lag. Tibial tubercle osteotomy is a more demanding option. It was necessary in 12% of patients reported by Badet et al. A precise surgical technique is mandatory to avoid potentially devastating complications. The tibial tubercle fragment must be at least 7 cm long, and, to avoid the risk of nonunion, it should be fixed with 2 bicortical horizontal screws.

**Tibial Resection.** After HTO, alterations of the tibial mechanical axis are possible. They can be located either within the soft tissue envelope for wear and deformity caused by arthritis or outside this envelope for tibial malunions (Figure 1). Malunions include angulation and translation of the metaphysis on the diaphysis and can often be corrected intra-articularly at the time of TKA. However, in severe deformities, this could lead to soft tissue unbalance, and additional osteotomies can be required to correct the angulation and displacement of the proximal fragment.

On the frontal plane, 2 scenarios are possible: (1) hypocorrection and varus recurrence or (2) hypercorrection and valgus deformity. In both of these scenarios, an additional problem is the absence of reliable anatomical landmarks for the height of tibial resection. This is the consequence of medial tibial plateau wear and lateral tibial plateau lowering after the initial osteotomy. Although joint line variations of up to 8 mm are tolerated, soft tissue unbalance could occur with larger variations. Joint line raising leads to lower patella and collateral ligaments slackness, whereas its lowering causes patella...
Neer 1,11 suggest a tibial resection 5 mm below the medial plateau in case of hypercorrection and 6 mm below the medial plateau in case of hypocorrection when using a 9-mm polyethylene insert. In case of hypercorrection and major tibial deformity, the risk of deep MCL release or cut at the time of tibial resection should be considered. The axis of tibial resection is strictly correlated to its height. This axis can be either perpendicular to tibial mechanical axis, as in primary implants, or adapted to the local anatomy. The latter option is extremely challenging and can result in lower-limb malalignment and soft tissue unbalance. Tibial resection perpendicular to the mechanical axis is more reliable but can cause impingement between the tibial stem (when used) and the lateral tibial cortex (Figure 2).11,13 This occurs in almost 15% of patients and is more frequent after closing-wedge HTO.28 Impingement can be avoided by implanting undersized tibial trays and leaving the lateral tibial plateau partially uncovered or positioning the tibial tray more medially, with the risk of overhang and MCL impingement. Custom-made prostheses, offset stems, or simultaneous osteotomies represent the only options in cases of severe deformity. Metaphyseal malunions are possible even in the sagittal plane, with anterior or posterior shifting of the proximal end of the tibia over the diaphysis. This may lead to impingement of the tibial stem with the anterior or posterior cortex. However, this is easily predictable and can be solved by slight anterior or posterior translation of the tibial tray or by using offset stems.

Slope variations are encountered even more frequently (Figure 3), especially after closing-wedge HTO. Normally, the tibial slope ranges between 5° and 7°. An increase in the slope causes anterior tibial translation, increase in knee flexion, and possible instability in flexion; a decrease in the slope leads to posterior tibial translation, posterior capsule contraction, and decrease of flexion. This must be carefully evaluated preoperatively with accurate clinical evaluation and imaging studies. Tibial slope correction is mandatory for a good prosthesis outcome. However, this correction is performed through intra-articular resections, although the deformity is extra-articular. This is dangerous because it can result in flexion instability in cases of thick resection. In these situations, Winsor et al13 proposed linking the femoral resection to the tibial resection using thicker polyethylene inserts to compensate for this flexion laxity, as well as considering an overresection of the distal femur to balance the knee in full extension. Malunions are extremely difficult to detect in the axial plane; however, because they can lead to patellofemoral maltracking and instability, they must be carefully evaluated.10,11 The gold standard is computed tomography scan assessment, although clinical examination may detect asymmetry with the unaffected side in external or internal rotation. The correction of tibial malunions by modifying the position of the tibial tray is dangerous because it affects both tibiofemoral and patellofemoral kinematics. For large malunions, derotation osteotomy can be proposed. However, in cases of tibial tubercle osteotomy at the time of joint exposure, the tibial tubercle can be fixed more medially to improve patellofemoral kinematics.

Soft Tissue Balance. After tibial resection, the medial and lateral sides may not be balanced. A tibial osteotomy produces an extra-articular deformity that influences soft tissue tension. At the time of prosthesis implantation, a tibial bone cut perpendicular to the mechanical axis leads to asymmetric resection with a thin side and a thick side. This produces the so-called

Figure 2: Postoperative anteroposterior radiograph of a stemmed total knee arthroplasty. In severe tibial malunion, the use of stemmed tibial trays can lead to impingement between the stem and lateral cortex.

Figure 3: Lateral radiograph of the proximal tibial metaphysis after high tibial osteotomy. An increase in tibial slope must be corrected when implanting a total knee arthroplasty to avoid implant instability in flexion.
resection laxity, which increases the pre-existing imbalance.

In cases of hypocorrection after prior osteotomy and varus recurrence, medial plateau wear and moderate tibial metaphyseal malunion (similar to bony deformity in a constitutional varus knee) are present. The tibial resection creates a trapezoid space, which is thicker on the lateral compartment. Sometimes, a medial release is necessary, but because the lateral structures are generally only slightly retracted, this release is minimal. In these situations, a posterior cruciate ligament (PCL)-retaining prosthesis can be implanted. In cases of more severe deformities, there are additional problems. The correction of a metaphyseal deformity of 10° through tibial resection leads to an asymmetry of 1.5 cm if the mediolateral tibial distance is approximately 10 cm. This requires extensive medial compartment release that increases the tibiofemoral space and may lead to medial instability. Unfortunately, the cutoff value for correctable deformities is not always predictable during preoperative evaluation, even if stress radiographs are extremely helpful. Neyret et al reported that angulations of 9° or more are difficult to correct through soft tissue release. Generally, the closer the extra-articular deformity to the joint, the greater its influence on knee kinematics. In such cases, PCL retention is challenging, and proper extension balance may require its sacrifice. Moreover, the role of the PCL is even more important in flexion, and its section leads to an increase of the flexion space of approximately 4 mm. However, combined PCL sacrifice and wide medial release often result in increased instability. More constrained implants are then required. Sometimes slight medial overtension or lateral laxity can be accepted to avoid even more constrained implants. For more severe deformities (beyond 10°-15°), complete release of the MCL is required to obtain a proper rectangular space. Because this leads to severe instability, it must be avoided, and simultaneous corrective osteotomies or hinged implants must be considered.

In cases of hypercorrection after HTO and valgus knee, tibial resection is thicker on the medial side, leading to medial compartment laxity. In such conditions, a medial parapatellar approach can be used. In cases of lateral structure retraction after closing-wedge HTO or medial collateral ligament insufficiency after opening-wedge HTO, this unbalance is even more severe. To improve joint exposure, a Keablesh approach should be performed, as well as iliotibial tract release and/or tibial tubercle osteotomy. The fat pad should be preserved to facilitate joint closure at the end of the procedure. To compensate mediolateral unbalance, Krackow et al proposed MCL and PCL retensioning through their transposition. Nevertheless, the current authors are mindful of the effects of these transpositions on knee kinematics. Thus, they perform minimal tibial resection and compensate soft tissue unbalance through PCL release or sacrifice and pie crust of the lateral capsule. The popliteus tendon and posterolateral corner release should be carefully evaluated and their section gently performed only when soft tissue balance is unsatisfactory. For more severe deformities (beyond 10°), more constrained implants and tibial stems (to ensure uniform metaphyseal loads distribution) must be considered. However, the correction of the deformity through lateral release may be dangerous and cause peroneal nerve damage. In these cases, some laxity persists after the procedure. Thus, some authors suggest simultaneous corrective metaphyseal osteotomy. A medial closing-wedge HTO is preferred for its lower risk of peroneal nerve damage. If these HTOs are performed proximal to the tibial tubercle, metaphyseal necrosis can occur. To avoid it, Badet et al suggested performing a combined tibial tubercle osteotomy that allows for a more distal metaphyseal osteotomy and for a patella height correction.

**LITERATURE REVIEW**

High tibial osteotomy is a reliable option in the treatment of varus knee arthritis if strict selection criteria are followed. Recently, they have been partially replaced by unicompartamental prostheses. This is open to debate because the indications for these procedures are different. High tibial osteotomy is indicated in patients younger than 65 with symptomatic varus knee as a consequence of cartilage wear or with bony deformity. In such patients, unicompartamental prostheses are not indicated for the increased risk of failure. Moreover, some reports show better results of TKA after HTO than after unicompartamental prostheses. Gill et al reported International Knee Society scores of 87 and 78 after HTO and unicompartmental prosthesis, respectively. In their opinion, unicompartamental prosthesis revision is more technically demanding because bony reconstruction is often needed. In select patients, HTO guarantees excellent results in terms of pain relief and functional recovery. Unfortunately, these results generally deteriorate with time. Odenbring et al reported excellent survivorship at 13-year follow-up. In that series, failure was almost always related to hypocorrection. Mont et al found some risk factors for HTO failure and further replacement. However, if revision with a prosthetic implant is planned, all possible challenging steps must be considered and solutions planned. These include the consequences of a multioperated knee, such as joint exposure, tibial malunions, and soft tissue mismatches. Tibial malunions are a common source of mistakes at the time of tibial resection; they depend on the type of osteotomy rather than on the amount of correction. However, Whitehead et al and Kendoff et al reported a higher rate of malunions after closing-wedge HTO. Similarly, soft tissue balance is crucial to avoid early failure of the prosthesis. Haslam et al and Bathis et al reported soft tissue balance to be more difficult in
Parvizi et al\textsuperscript{58} report poorer International Knee Society pain score results in the TKA after HTO group. Moreover, this group had a higher incidence of aseptic loosening, possibly the consequence of younger, heavier, and more active patients. These findings are in contrast with the results of Toksvig-Larsen et al,\textsuperscript{12} who reported in a stereophotography study the same rate of loosening in the 2 groups. In a clinical study, Kazakos et al\textsuperscript{59} reported comparable results at 4.5-year follow-up, even with a statistically significant higher rate of intra- and postoperative complications, including impingement between the tibial stem and lateral tibial cortex, patella baja, and patellar subluxation. Similarly, Haddad et al\textsuperscript{50} reported comparable results at 6-year follow-up, although patella baja was present in 50\% of patients in the TKA after HTO group. Patella baja is one of the most common complications in TKA after HTO (Figure 4),\textsuperscript{10-13,27} with a prevalence up to 24.1\%.\textsuperscript{28} It is more common after closing-wedge HTO and makes joint exposure more difficult, especially if associated with a stiff knee preoperatively. Moreover, it affects functional result if not corrected at the time of surgery. Another common finding in these patients is range of motion limitation. This problem has several causes, such as bracing after HTO.\textsuperscript{27}

These contradictory results can be explained by analyzing the level of evidence of these studies. Most of them compare different implants from different surgeons and do not take into account the degree of initial deformity. This makes groups inhomogeneous and comparison impossible.\textsuperscript{13} Considering these aspects and the excellent results of TKA in young patients,\textsuperscript{61} HTO should be performed according to strict indications. In these cases, patients must be informed of the possible failure of this procedure and the further need for TKA. Finally, they should be instructed that revision surgery will be more difficult and give inferior results than primary TKA.

CONCLUSION

Total knee arthroplasty after HTO is uncommon because of the relatively low number of HTOs performed and their good functional results and long-term survivorship. In cases of HTO failure, prosthetic replacement is indicated. However, this is a difficult procedure. Surgeons must deal with a multioperated joint and proximal tibial malunions. Even when all of these aspects have been considered and surgery has been performed in a technically competent fashion, clinical results are usually unpredictable and generally inferior to those of primary TKA. According to these considerations, the authors believe that informing the patients is crucial. Patients should know that HTO is a reliable surgery if the correct indications are met. They should be aware of the possible deterioration of clinical and radiographic results with time. Moreover, they should know that, in some instances, further replacement could be required. Finally, patients should be informed of the additional technical difficulties and of the generally unpredictable results of this procedure.

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