High tibial osteotomy (HTO) is a good alternative to arthroplasty in selected cases of medial compartment osteoarthritis because it enables high activity levels for the patient and delays the need for total knee arthroplasty (TKA). With the passage of time these results deteriorate, and the most common means of treating a failed HTO is with revision to a TKA. As a result, the surgeon performing an HTO must be mindful of the potential need for subsequent TKA and avoid compromising its outcome. The available literature on this issue is divided. There are studies that show favorable results similar to primary TKA1–5 and other studies that show inferior results6–8 similar to those associated with revision TKA. There is an overall consensus, however, that an HTO does often make TKA more technically demanding, with a higher level of postoperative complications and less postoperative range of movement.1 This chapter reviews the literature on TKA after a failed HTO, the factors that influence the outcome of the TKA, and the associated intraoperative technical factors and complications.

HIGH TIBIAL OSTEOTOMY

The first reported HTO for osteoarthritis of the knee was in 1958.9 This procedure was then popularized by Coventry10 and Jackson and Waugh.11 Since this time there have been many reports in the literature documenting the success of this procedure.12–14 In the short term there is a high level of satisfaction, with reports of 80% to 90% satisfactory results.15–18 However, at 6 to 10 years only 45% to 65% of patients are reported to have satisfactory results.5,15,18 Those patients requiring further surgical intervention usually require a TKA. The results of a TKA post HTO are therefore an important consideration, as are the factors that influence the outcome of a TKA in this situation.

Coventry reported that the factors that influenced a successful outcome of HTO were correction of anatomical alignment, the maintenance of this correction in at least 8 degrees of anatomical valgus, and a body mass index (BMI) less than 132% of the patient’s ideal body weight.19 Berman et al. reported favorable results in those younger than 60 years of age, with less than 12 degrees of angular deformity, pure unicompartmental disease, ligamentous stability, and a preoperative range of motion of at least 90 degrees.20

The factors that had no effect on the outcome of HTO were age, height, gender, preoperative weightbearing pain, preoperative varus angulation, and severity of degenerative change in the patellofemoral and medial compartments, and previous surgical intervention.19

The reported early complications associated with HTO include peroneal nerve palsy, malunion, nonunion, intraoperative fracture, compartment syndrome, and infection. The incidence of reported complications varies considerably from 10%–50%.17–19 Late adverse sequelae include joint line distortion, patella infera, offset tibial shafts, problematic prior incisions, and retained hardware.

A well-corrected and maintained HTO in the ideal patient has a high likelihood of long-term success, is less likely to require a TKA, and would pose the least troublesome scenario at the time of conversion to a TKA. An HTO that fails early, due to malunion or nonunion, is most likely to present technical difficulties.

There is an ongoing controversy about the frequency with which the results of TKA are compromised after HTO. There are studies that show favorable results similar to primary TKA1–5 and other studies that show inferior results, similar to results associated with revision TKA.6–8
The majority of research on this issue uses matched pair analysis comparing the results of primary TKA with those having TKA after failed tibial osteotomy. Mont et al. recommended more appropriate comparison groups, such as patients who have undergone revision TKA or ideally a group matched on multiple criteria.

Several authors have reported good or excellent results in 64% to 81% of their post-osteotomy patients at 2.9- to 6-year follow-up. These results are significantly less than their control groups of primary TKA with 88% to 100% good or excellent results at the same follow-up. Katz reported an increased average operating time due to an increased incidence of technical difficulties, including difficulty with exposure and patellar eversion. A decrease in the average arc of motion with a flexion contracture and limited flexion post-osteotomy has been reported. Nizard et al. reported a statistically significant difference in the Knee Society Score and pain relief, but not in the function score between the primary TKA group matched with the post-osteotomy group. Using the Western Ontario and McMaster Universities (WOMAC) Osteoarthritis Index, which is a reliable and validated instrument to assess the functional outcome in knee arthritis, Karabatsos et al. found a trend toward a significant difference in pain (p = 0.07), function (p = 0.18), and stiffness (p = 0.14), suggesting a poorer outcome in patients undergoing TKA for a failed HTO.

By including the cases with significant complications in the osteotomy group there should be a tendency toward an overall less favorable outcome with TKA. Even with these cases excluded from the post-osteotomy group, Laskin reported statistically inferior results and an increase in tibial radiolucent lines compared with primary TKA patients. This is in contrast to several studies that showed no increase in adverse outcome in the post-osteotomy arthroplasty patients. Meding et al. acknowledged that in those patients with a previous osteotomy there were important differences preoperatively, including valgus alignment, patella infera, and decreased bone stock in the proximal part of the tibia. However, the clinical and radiographic results of TKA with and without a previous HTO were not substantially different. Amendola et al. found comparable percentages of successful outcomes in those patients having a primary TKA (90%) and those having a TKA after a failed HTO (88%) at an average of 37 months. Staeheli et al. reported an 89% successful outcome, at 4 years follow-up, in an unmatched group of 35 patients with TKA post-osteotomy, but also somewhat surprisingly reported that the intraoperative and postoperative rates of complications were not higher, and no untoward technical difficulties were encountered at surgery.

Mont et al. report that for 60% to 80% of patients requiring a TKA for a failed HTO, the arthroplasty presents no significant difficulty. However, for the remaining 20% to 40% of patients, there are a variety of intraoperative challenges that require careful preoperative clinical and radiological evaluation, as well as intraoperative technical difficulties that need to be understood and addressed by the attending surgeon (Figure 18-1).

The key issues that potentially influence the outcome of a TKA post-osteotomy are reviewed. These issues include previous surgical incisions, intraoperative exposure, retained hardware, patella infera (baja), limited range of motion, joint line angle distortion, lateral tibial plateau deficiency, tibial rotational deformity, an offset tibial shaft, malunion, nonunion, collateral ligament imbalance, flexion and extension gaps, implant choice, peroneal nerve palsy, and reflex sympathetic dystrophy and infection.

### Previous Surgical Incisions

Planning for surgery and avoiding potentially catastrophic skin necrosis require an awareness of the previous incisions used at previous knee surgery. A laterally based incision from the previous HTO should not provide

![FIGURE 18-1. An AP radiograph of a previous HTO with nonunion, retained broken hardware, proximal tibial bone loss, and a sloping joint line.](image)
significant difficulties as long as a skin bridge of at least 8 cm can be achieved. This may require a slightly medially based skin incision rather than a true midline incision. A previous transverse incision should pose no problem as long as the new incision is perpendicular to it. Where parallel incisions are present, the more lateral incision is recommended, as the blood supply to the extensor surface is medially dominant. Very rarely, a sham incision can be used before the definitive surgery, to more safely assess the potential wound healing. Jackson et al. noted a 30% rate of primary wound healing in TKA after failed HTO, with a 20% incidence of deep infection (Figure 18-2).

**Intraoperative Exposure**

Scar tissue between the patellar tendon and the proximal anterior tibia often makes eversion of the patella after a previous HTO more difficult. Release of this scar tissue and excision of a thickened fat pad can improve exposure. The patellofemoral ligament should be routinely released to improve lateral exposure. Meding et al. reported that this was adequate to complete the tibial exposure in each case.

If difficulty with exposure is still encountered, then an early lateral release can be performed. Personal experience of the senior author (RDS) in 74 consecutive conversions of failed HTO to TKA is of a lateral release rate of 38% compared with a 30% lateral release rate in 1000 consecutive arthroplasties from the same era. Nizard et al. reported a lateral release rate of 24% in their post-osteotomy group compared with just 2% in their control group. If exposure is still compromised, then a quadriceps snip is recommended. A tibial tubercle osteotomy should rarely be required for exposure, although Nizard et al. used a tibial tubercle osteotomy in 7 of 63 post-osteotomy cases. Finally, a pin through the patella tendon insertion intraoperatively is strongly recommended, as a prophylactic measure to protect it from avulsing (Figure 18-3).

**Retained Hardware**

Various fixation devices are usually used in HTO. Options include staples, a compression plate and screws, a blade plate, and other similar hardware. Preoperative planning is required to assess whether the hardware will interfere with the TKA (Figures 18-4 and 18-5). If not, then the HTO fixation device does not require removal unless its presence is symptomatic to the patient.

If the hardware will interfere with the tibial jigs or implant, then the decision as to whether to perform the TKA in one stage or two would depend on whether a separate incision is required for hardware removal, the size and placement of the hardware, and the site of previous incisions.

For 2-stage arthroplasty, an interval of 6 to 12 weeks after hardware removal should be used to enable good wound healing before the TKA. Also, cultures of the osteotomy site should always be obtained at the first-stage procedure.

**FIGURE 18-3.** A pin inserted in the tibial tubercle (arrow) to protect against patella tendon avulsion.
Patella Infera

Patella infera is often seen after a closing wedge osteotomy where shortening of the distance between the tibial tubercle and the tibial plateau occurs, which results in secondary shortening of the patella tendon. Patella infera is defined as a ratio of 0.8 or less. This can easily be assessed with preoperative radiographs using the Insall-Salvati ratio, which is the ratio of the patella height to the length of the tibial patella tendon. Patella infera is also a problem with respect to elevation of the joint line. The easiest way to compensate for this intraoperatively is to resurface the patella with a smaller than templated patella button placed as proximally as possible. Alternatively, up to 5 mm of extra proximal tibia can be resected, while minimizing the bone resection from the distal femur. This lowers the joint line, or at least insures that the joint line is not elevated, which can improve the patella infera. Finally, at capsular closure, an attempt should be made to advance the medial capsule distally on the lateral capsule, pulling the patella proximally. Patella infera is associated with a decreased arc of motion and potential impingement between the inferior pole of the patella against the anterior flange of the tibial prosthesis. Several studies have shown the presence of patella infera is not necessarily associated with a less successful outcome of TKA for failed HTO (Figure 18-6).

Limited Range of Motion

Many studies, including reports that show no significant difference between primary TKA and TKA after failed

FIGURE 18-4. Postoperative A-P (A) and lateral (B) radiographs of a TKA with retained hardware.

FIGURE 18-5. Weightbearing AP radiographs of bilateral closing wedge HTOs with retained fixation devices.
HTO, report less flexion in the postosteotomy group.\textsuperscript{1,3,6} Amendola et al.\textsuperscript{1} reported an average 14-degree decrease in flexion in the post-osteotomy group, but believed that this did not compromise the overall functional outcome. Poor preoperative flexion and/or poor intraoperative flexion against gravity after capsular closure warns of this possibility.

A fixed flexion deformity (FFD) can occur in patients after an HTO. The majority of cases of FFD can be addressed intraoperatively. Care must be taken if the patient has patella infera and a FFD, because the former requires a minimal distal femoral resection to avoid elevating the joint line, while a FFD is often addressed by resecting more distal femur than usual. Careful removal of all posterior osteophytes with the addition of capsular stripping from the femur and tibia can be helpful.

**Joint Line Angle Distortion and Deficient Lateral Tibial Bone**

The post-osteotomy joint line is invariably distorted. First, after a closing wedge osteotomy, there is a valgus angulation of the tibia on the coronal view. Second, there is sometimes a loss of the normal posterior slope of the proximal tibial joint line on the sagittal view. In contrast to the anatomical deformity expected with a varus knee, the post-osteotomy valgus angulation of the joint line results in a thicker medial tibial resection than on the lateral side. The tibial cut should resect minimal or no bone from the lateral tibia, with any remaining bony defect managed with lateral augmentation or a structural bone graft if the defect is uncontained. A contained defect can be managed with morsellized graft or cement as required. With preoperative radiographic templating for the appropriate tibial cut this should be identified hence eliminating intraoperative error (Figure 18-7).

An osteoarthritis-induced valgus deformity of the knee will be due to a valgus deformity in both the femur and the tibia, whereas a valgus deformity post-osteotomy will be solely due to the tibial deformity. The tibial valgus deformity is compensated for by the varus deformity of the femur due to the initial medial compartment osteoarthritis that necessitated the original HTO. Mont et al.\textsuperscript{21} stress the practical implication of this for the surgeon who, after making the routine valgus femoral cut, will make the valgus deformity worse.

The loss of the normal posterior tibial slope can present as either a neutral slope or in fact as an upsloping joint line (Figure 18-8). The posterior slope must be recreated, necessitating minimal bony resection from the anterior proximal tibia to avoid excess posterior bony resection. Otherwise the potential for flexion and extension gap mismatch can occur, with resultant flexion instability. Once again, radiographic templating will prepare the surgeon for this unusual situation.

**FIGURE 18-6.** A lateral radiograph of patella infera.

**FIGURE 18-7.** An AP radiograph of a sloping lateral joint line (arrow).
Tibial Rotational Deformity
A closing wedge osteotomy has no inherent rotational stability other than that provided by the internal fixation. Inadvertent intraoperative tibial rotation or loss of fixation can result in either internal or external rotation of the tibia. As a result the medial one-third of the tibial tubercle may not necessarily be an accurate or reliable guide to tibial rotation. This will necessitate rotation to be determined from more distal landmarks, including the tibialis anterior tendon, the bony ridge of the tibial diaphysis, or the midpoint of the talus. It should be noted that external rotation of the distal tibia increases the Q-angle, which accentuates abnormal patellofemoral mechanics. Difficulty of surgical exposure also produces a tendency to internally rotate the tibial component, which increases the likelihood of patellofemoral subluxation.

An Offset Tibial Shaft
A closing wedge HTO will result in a lateral step-off at the osteotomy site due to the resultant disparity in the medial-lateral metaphyseal bone width. This will be accentuated if there is any secondary lateral collapse. Careful preoperative templating will help determine whether the chosen prosthesis will impinge on the lateral tibial cortex. Cutting the proximal tibia in slight valgus can help accommodate for a standard tibial prosthesis (Figure 18-9).

If a stemmed implant is required, then it is important to confirm that medial offset stems are available to prevent potential medialization of the tibial tray, or a potential iatrogenic fracture of the proximal tibia (Figure 18-10). Whether an intramedullary or extramedullary alignment guide is used is at the discretion of the surgeon. However, an extramedullary guide is recommended because the medullary canal may be offset medially, such that an intramedullary guide will have difficulty being positioned correctly.

Malunion of Osteotomy Site
A malunion at the osteotomy site is less common with rigid internal fixation. It is more common for a malunion to result in excess valgus than excess varus, due to the propensity of a closing wedge osteotomy to collapse on the lateral side at the level of the truncated metaphysis. Preoperative planning will determine whether correction of the mal-union can be incorporated into the TKA. If not, then a one- or two-stage procedure incorporating an osteotomy of the tibia with a stemmed tibial prosthesis will be required. A dome or opening wedge osteotomy of the tibia is preferred over a closing wedge osteotomy in

FIGURE 18-8. A lateral radiograph of an upsloping joint line.

this situation to preserve lateral tibial metaphyseal bone stock before performing a TKA. However, a dome osteotomy is a difficult option if correction is required in 2 planes, as is seen in Figure 18-11 (See also Figure 18-12).

**Nonunion of the Osteotomy Site**

Nonunion of the osteotomy is a rare complication, but poses a difficult challenge to the arthroplasty surgeon. The management of the nonunion and the arthroplasty can be performed separately or incorporated into a single procedure. It is imperative to determine whether the nonunion is septic or aseptic and atrophic or hypertrophic. A single-stage correction of the malalignment, bone grafting of the defect, and the use of a long-stem tibial prosthesis can address this difficult problem (Figure 18-13).

**Collateral Ligament Imbalance**

The potential for lateral ligament balancing to is to be expected during a TKA postosteotomy. This is especially the case if there has been a malunion into further valgus or severe overcorrection. Meding et al. reported no significant increase in the rate of lateral ligament release in post osteotomy TKA compared with a contralateral TKA in 39 consecutive patients. However, if there is a trapezoidal extension space that is tight laterally, then a lateral release in extension at the level of the joint line is performed. Conversely, a trapezoidal flexion space that is tight laterally would require extension of the lateral release proximally above the level of the superior genicular artery.

If a valgus deformity of more than 20 degrees is present, then a complex ligamentous reconstruction of advancing the lax medial collateral ligament, the medial hamstring tendons, and the posterior cruciate ligament or a more constrained prosthesis may be required. However, despite the benefit of a lateral release in cases with difficult exposure, the lateral release rate is not significantly higher in TKA post-osteotomy than in primary TKA.

**Flexion and Extension Gaps**

The general principles of balancing flexion and extension gaps apply in post-osteoamy TKA (Figure 18-14). However, the routine external rotation of the femoral component, as referenced from the anteroposterior axis or the transepicondylar axis, does not routinely produce a quadrangular flexion space, because of the abnormal valgus angulation of the joint line.
FIGURE 18-11. (A) AP and (B) lateral radiographs of a left knee showing tibial malunion subsequent to a previous HTO using an external fixation device.

FIGURE 18-12. Postoperative (A) AP and (B) lateral radiographs of a one-stage TKA and osteotomy for proximal tibial malunion.
When the tibial resection is made perpendicular to the longitudinal axis, the flexion gap will potentially be asymmetrical. To correct this, the femur must sometimes be internally rotated to create a symmetrical flexion gap; alternatively an extensive lateral release in flexion could be considered, but this complicates flexion and extension gap balancing.

As previously mentioned, an upsloping tibial joint line post-osteotomy needs to be converted into the normal joint line slope. Even with a minimal anterior proximal tibial resection this can result in a thick posterior proximal tibial resection that can potentially create a larger gap in flexion than in extension. In these cases, a less pronounced initial posterior slope on the tibial cut is recommended. If the flexion gap is still larger than the extension gap, then the principles of using a larger femoral component with posterior augmentation or resecting more distal femur to increase the extension gap to match the flexion gap are required. The latter option requires a thicker polyethylene insert, which raises the joint line and exacerbates patella infera if present.

**Implant Choice**

Preoperative planning helps determine whether the surgeon’s preferred implant will result in any impingement between the prosthesis and the lateral cortex. The selected implant should have standard and offset stem options available. Whether to substitute or preserve the posterior cruciate is the surgeon’s decision. The senior author (RDS) has used a cruciate retaining prosthesis in 74 consecutive cases of TKA for failed osteotomy.

**Peroneal Nerve Palsy**

The reported incidence of post-osteotomy peroneal nerve palsy is approximately 5%. A failed osteotomy with an unresolved peroneal nerve palsy needs careful clinical
assessment to differentiate neurogenic from mechanically induced pain. The surgeon then needs to consider whether decompression of the nerve is warranted. Thereafter, the decision is whether to primarily decompress the nerve or to do this at the same time as the TKA.

**Reflex Sympathetic Dystrophy**

Total knee arthroplasty in the presence of reflex sympathetic dystrophy (RSD) increases the likelihood of a fair or poor outcome. Cases in which features of RSD are present or in which there was no pain relief from the HTO should make the surgeon cautious to proceed with TKA. Even if previous RSD symptoms are quiescent, there is a high risk of recurrence (47%) of symptoms with further surgery.6

**Infection**

Although the incidence of deep infection in TKA after failed HTO is not significantly higher than in primary TKA,2,5 there is a tendency toward an increase in deep infections.22 Of concern is a report by Jackson et al.23 that noted 6 out of 20 patients with a TKA for a failed osteotomy had a failure of primary wound healing resulting in 4 cases of deep infection. In contrast, no wound healing problems or deep infections occurred in 23 patients requiring a TKA for a failed unicompartmental arthroplasty.

**CONCLUSION**

The available literature is divided as to the effect that a previous HTO has on the overall outcome of TKA. However, it is hard to refute that TKA after a failed HTO does present potential challenges to the surgeon. The key issues that potentially influence the outcome of a TKA post-osteotomy have been reviewed. An HTO is a good alternative to arthroplasty in selected cases of medial compartment osteoarthritis; however, with the passage of time these results deteriorate, and the most common means of treating a failed HTO is with revision to a TKA. As a result, the surgeon performing an HTO must be mindful of the potential need for subsequent TKA and avoid compromising its outcome.

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