Complications of closing wedge high tibial osteotomy

James A. W. Tunggal · Gordon A. Higgins ·
James P. Waddell

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Abstract Closing wedge high tibial osteotomy is a common, effective and well-established procedure to treat unicompartments osteoarthritis of the knee. It is, however, not without its complications. This article will discuss some of these complications and present an overview of the current literature. It will examine current thoughts on aetiology, techniques to try to avoid, and methods of treatment of these complications.

Introduction

Closing wedge high tibial osteotomy (HTO) is a common, well-established and effective procedure for the treatment of medial compartment knee osteoarthritis. Currently it appears to be gaining in popularity again and is seen to be making a resurgence. Good results have been achieved in the literature over both the medium and long term [1–8], with a gradual deterioration in function and outcome over time. All authors have emphasised the significance of appropriate patient selection and meticulous surgical technique in order to achieve optimal results. The closing wedge technique, as popularised by Coventry [9], involves an osteotomy above the tibial tubercle and removal of a wedge of bone laterally in order to realign the knee into valgus to offload the medial compartment thus relieving the symptoms of medial compartment osteoarthritis thereby improving function. The reported advantages of this technique include better initial stability due to the compressive nature of the osteotomy

leading to more immediate weight bearing and quicker healing. Also, there is no requirement for bone grafting or graft substitute. Disadvantages include the necessity for either a fibular osteotomy or proximal tibiofibular joint disruption, altered anatomy potentially complicating future arthroplasty, and difficulty in making fine angular corrections once the bony wedge has been removed. Given the nature of the procedure significant potential complications exist. The rate of complications ranges widely between different series with Wu et al. [8] reporting an overall rate of 5.6% whilst Naudie et al. [5] had an overall rate of 34% in his series. Bettin [4], Aglietti [6], Ivarsson [2] and Sprenger [7] fared better in their series with rates of 10%, 10%, 11% and 21%, respectively. These figures do not include the failures that required conversion to knee arthroplasty. As such, an understanding of the potential complications of this technique may be important in obtaining a better clinical outcome.

Infection

Rates of infection range from 0.8–10.4% [2, 4, 5, 7, 8]. Most are superficial wound infections that can be treated successfully with oral antibiotics. Deep infections are more problematic and may require irrigation and debridement with the use of intravenous antibiotics. Successful cases of debridement, intravenous antibiotics, bone grafting and compressive fixation have been reported with deep infections [5]. Fixation devices should be left in situ if at all possible.

Thromboembolic disease

The incidence of deep vein thrombosis ranges from 2–5% [1, 2, 4–7] in most series. However, Turner et al. [10]

J. A. W. Tunggal · G. A. Higgins · J. P. Waddell (✉)
Division of Orthopaedic Surgery, Department of Surgery,
University of Toronto, St Michael's Hospital,
30 Bond St, Toronto, ON M5B 1W8, Canada
e-mail: WaddellJ@smh.toronto.on.ca

undertook a venographic study after HTO and found the incidence to be 41%, the majority being only in the calf veins. He reported that of the three cases of proximal vein thromboses all three were only detected with venography and that only 15% of the cases were detected clinically. Both Insall et al. [1] and Aglietti et al. [6] have reported fatal pulmonary embolus in their series. Use of a tourniquet did not seem to have any significant effect on the incidence of thromboembolic disease [11]. Given the potentially large incidence of deep vein thrombosis it seems prudent to institute a postoperative thromboprophylaxis regime commonly along similar lines to that used in knee arthroplasty.

Compartment syndrome

This is an uncommon complication of closing wedge HTO. Gibson et al. [12] and Bauer et al. [13], however, have shown that there is an increase in compartment pressures with this technique, leading to the possibility of an anterior compartment syndrome. Gibson et al. [12] showed that there was significant elevation of the anterior compartment pressures to greater than 45 mmHg in the majority of the study group (7 out of 10) where the compartment was not drained, with five of them experiencing transient clinical signs. Insertion of a drain, however, resulted in the pressures dropping to below 30 mmHg in eight out of ten patients in this group. Particular attention also has to be paid to fluid extravasation leading to the possibility of a compartment syndrome in combined HTO and arthroscopic ligament reconstruction procedures [14]. If a tourniquet is used then this should be deflated and good haemostasis achieved prior to closure and, as shown by Gibson et al. [12], a drain should be used to decrease the compartment pressures.

Fractures

The aim of any osteotomy is to produce a controlled fracture in order to achieve the desired correction without destabilising the fragments. In general, the technique involves ending the osteotomy 5–10 mm from the opposite cortex and leaving a hinge on this side. Maintenance of the medial cortex has been recommended during closing wedge osteotomies to both provide stability and maximise the contact areas of the tibial segments [3, 15]. Two things must occur in the process of angular correction. Plastic deformation occurs in the hinge and microfractures occur in this region of bone as the osteotomy is closed. Propagation of the fracture as an extension either through to the opposite cortex or into the intra-articular region can occur as a complication of this process. This is undesirable as it may lead to the destabilisation of the proximal fragment and thus

affect overall angular correction—essentially a malunion [1, 16]—or result in a nonunion. Once a fracture is recognised then it is important to observe the correction under image intensification to determine whether the osteotomy remains stable or whether it requires additional fixation in order to achieve stability. Minimisation of this complication involves leaving a 5–10-mm bone hinge medially and to close the wedge slowly in order for stress relaxation of the bone to occur. Also, as shown by Kessler et al. [17], the addition of a 5-mm anteroposterior stress relieving drill hole 10 mm from the opposite cortex and 20 mm from the plateau (at the apex of the osteotomy) allowed for a significant increase in the amount of angular correction before cortical fracture (6.7° versus 10°, $P<0.001$). This may be an additional way to minimise the rate of fracture should large angular corrections be required.

However, a more recent study challenges the notion that medial cortical fracture leads to poorer outcomes, specifically loss of correction, and that the rate of fractures during closing wedge osteotomies may occur more commonly than suspected. Van Raaij et al. [18] conducted a retrospective study looking at opposite cortical fracture rates between closing and opening wedge osteotomies. They found that the rate of fracture in the closing wedge group was 82%, whereas the opening wedge group had a rate of 35%. However, at one year the closing wedge group with an opposite cortical fracture still maintained a valgus alignment whereas the opening wedge group had drifted back into varus. They concluded that even though fracture was more common in closing wedge osteotomies medial cortical disruption had no major consequences and that it did not generally lead to malalignment. In fact, the desired angular correction was achieved more often in the closing wedge group that was complicated by fracture. They surmised that ‘With the closing wedge technique, posteromedial bony remnants may act like a more lateral hinge when closing the wedge, and probably cause fracture and gaping at the medial osteotomy site with pronounced valgisation.’ [18]. This has been supported to some extent by Pape et al. [19] who also found no loss of valgus correction after unintentional fracture of the medial cortex in closing wedge osteotomies. His rate of unintentional fracture was close to 55%. Even so, he felt that prior to bone healing, the integrity of the medial cortex was crucial to both the clinical and radiological outcome of HTO.

Intra-articular fractures during closing wedge osteotomies have a reported incidence of 0–20% [4–7, 20]. This usually occurs when the osteotomy is too shallow and the medial hinge is too wide such that it offers too much resistance during closure of the osteotomy and preferentially directs the applied force into the joint resulting in an intra-articular fracture. Also, if the proximal fragment is made too close to the joint, resulting in a thin segment, then it will offer little resistance to fracture. In general the width of the medial bone

hinge should be less than the distance from the end of the osteotomy to the joint line [21]. It is critical to recognise the occurrence of this complication, as congruity of the articular surface must be preserved. Most intra-articular fractures remain reduced and require no additional fixation. Assessment can be made with fluoroscopy and/or directly with arthroscopy. Displacement of an intra-articular fracture necessitates reduction and fixation usually in the form of compression screws.

Delayed union and nonunion

Nonunion after closing wedge osteotomy is uncommon given the excellent healing potential due to the stability and metaphyseal bony apposition afforded by the technique. Moreover, it is in natural compression. Factors to consider in preventing nonunion of the osteotomy include general factors such as smoking, peripheral vascular status, nutritional status, strict adherence to postoperative protocols and comorbidities such as diabetes which all relate to the importance of proper patient selection. Specific factors relate to the general principles of an osteotomy and include creating a stable osteotomy, metaphyseal, rigid internal fixation and compressive in nature. The closing wedge osteotomy has the advantage that it meets most if not all of these specific requirements. However, nonunions still occur and in most series the incidence ranges from <1–5% [1, 4, 5, 7, 22, 23]. Treatment usually involves a revision procedure utilising a more rigid form of fixation such as locking plates or a compressive type of external fixation and the use of bone graft [24, 25]. Consideration should also be made as to the use of adjuvants such as bone morphogenic proteins and electrical stimulation [26]. Distraction osteogenesis has shown success in the treatment of nonunion whilst being able to maintain the desired angular correction [27]. There have also been reported cases of nonunion following HTO being treated successfully with conversion to total knee arthroplasty [7, 28].

Delayed union occurs with an incidence of 4–8.5% [5, 6, 8]. Vainionpaa et al. [23] showed that it occurred more frequently when the osteotomy was distal to the tibial tubercle as opposed to proximal (14% versus 3.6%). Management is mainly nonoperative and may involve prolonged restriction in weight bearing, casting of the limb and consideration as to the use of bone stimulators [26] to encourage union.

Neurovascular complications

Peroneal nerve palsy, whether sensory, motor or both, is the most commonly reported neurovascular complication after closing wedge HTO. The incidence ranges from 0–20% [1, 2,

4, 5, 7, 8, 29]. Wootton et al. [29], who had a 20% incidence in his series, demonstrated that 50% of those were left with some sort of a permanent deficit. The proximity of the nerve to the fibular head and neck is thought to be a causative factor as well as several other anatomical and surgical factors. Bauer et al. [13] identified two direct factors that contributed to this complication, namely, direct trauma to the nerve secondary to a high fibular osteotomy and high compartment pressure due to poor haemostasis or inadequate drainage. They also identified two related factors: use of a tourniquet, which sensitises the nerve, and stretching of the nerve during correction of the deformity. In order to limit the frequency of this problem they recommended limiting the surgical approach and limiting as far as possible any traumatic manoeuvres by using resection jigs that allow the correction to be performed without any forced manipulation. Also, due to the proximity of the motor branches from the deep peroneal nerve to the tibialis anterior and extensor hallucis muscles and the operative field, errant placement of and undue tension on retractors may result in a motor palsy [30].

Location of the fibular osteotomy appears to be a significant causative factor in the development of peroneal nerve palsy. More commonly, it is the extensor hallucis longus (EHL) muscle that is affected. Several anatomical studies [31, 32] have shown the proximity of the branches to this muscle to the fibular periosteum and its division from the deep peroneal nerve which occurs 70–150 mm distal to the fibular head [32]. Georgoulis et al. [30] showed that the EHL is innervated by two to three main branches, but in 25% of cases there was only one large branch to the muscle. Based on these studies and also clinical data, several authors have recommended either a disruption of the tibiofibular joint or performing the fibular osteotomy at the junction of the middle and distal thirds [29, 31] to avoid damage to the common peroneal nerve or to the main branches to EHL. Wootton et al. [29] in their study divided the fibula into four zones. Zone I being the proximal tibiofibular joint and zone IV being 16 cm or more below the fibular head. They found no complications in zones I and IV. Whereas all the complications occurred in zones II and III, the majority being in zone III (osteotomy between 8 and 15 cm below the fibular head). Not surprisingly, their recommendation was to either disrupt the proximal tibiofibular joint or to perform the osteotomy in zone IV. Similarly, Curley et al. [33] performed electrophysiological studies of the common peroneal nerve before and after HTO and noted greater electrical abnormalities in those that required a proximal fibular osteotomy (at the level of the fibular head or neck) with two of them developing nerve palsies. They also looked at other factors such as compartment pressures and creatine phosphokinase levels but could only conclude proximal fibular osteotomy as being a causative factor in the development of common

peroneal nerve palsy. Aydogdu et al. [31], in addition to recommending that the fibular osteotomy be performed at the junction of the middle and distal third, felt that it was important not to have any excessive anterior and medial displacement of the fragments and that a small segment be resected in knees with severe deformity requiring a significant angular correction in order to avoid neurological complications.

Injuries to the popliteal and anterior tibial arteries have been reported with closing wedge HTO but are rare. Both Georgoulis et al. [30] and Zaidi et al. [34] have each reported a case of division of the popliteal artery during this procedure. Pseudoaneurysm of the anterior tibial artery has also been reported [35]. Damage to the anterior tibial artery appears to be more common and may well be related to the significant prevalence of a high origin of this vessel resulting in the artery being in direct contact with the posterior cortex of the tibia [36] and being in harms way from poorly placed retractors or during the osteotomy. The popliteal artery and nerve is protected by both the popliteus and tibialis posterior muscles [30] and, as such, it is imperative that any retractors be placed subperiosteally on the posterior tibial cortex. Proper placement of retractors posteriorly adds a further layer of protection against damage to the popliteal artery and nerve. It has also been commonly believed that knee flexion is protective against injury to the popliteal artery as it allows it to fall back from the posterior tibial cortex. Zaidi et al. [34], however, found that in 12 of 20 knees the popliteal artery was closer to the posterior tibia in 90° of flexion than in full extension. Similarly, Smith et al. [37] in their MRI study had similar findings to that of Zaidi et al. Both concluded that knee flexion is not a guarantee of protection of the popliteal artery and that surgeons should be made aware of this. As such, particular attention should be paid to protection of the posterior neurovascular structures independent of knee position.

Under correction and recurrence of deformity

The goal of any HTO for varus malalignment is to shift the load from the medial to the lateral compartment. Biomechanically, 70% of the load is borne by the medial compartment when the mechanical axis passes through the centre of the knee. This load decreases to 50% in 4° of valgus with a further reduction to 40% in 6° of valgus [38]. Given this data most authors recommend an alignment range between 2° and 6° of mechanical valgus [3, 39–43]. Coventry et al. [3] advocated for 8° of valgus. Hernigou et al. [40] achieved best results at between 3° and 6° of mechanical valgus and showed deterioration when correction was in excess of 6°. Fujisawa et al. [39] approached it somewhat differently and aimed for the mechanical axis to pass through a point 30–40% lateral to the midpoint of the knee—the so-called

Fujisawa point. Much controversy still remains regarding the ideal mechanical alignment. Regardless of this, all agree that adequate valgus correction is necessary to achieve good clinical results and it has also been shown to be important in the longevity of HTO [8, 44, 45]. Myrner et al. [45] showed significantly better results in their over corrected than in their normal correction group. They aimed for 5° of over correction. Similarly, Wu et al. [8] and Pfahler et al. [44] noted that over correction was necessary for a successful outcome, as did Aglietti et al. [6] who, in their series, showed valgus angles of 8°–15° correlated with better results. Koshino and Tsuchiya [42] had recurrence of varus deformity three years after HTO with an inadequate correction and recommended correction to 10° of valgus.

Dynamic factors may also be important with regards to apparent under correction or more specifically recurrence of deformity. Prodromos et al. [46] using gait analysis studied two groups of people preoperatively and looked at their outcomes after HTO. The two groups consisted of those with either a high or low adduction moment preoperatively. All had good immediate postoperative correction. At 3.2 years post HTO the low adduction moment group had uniformly 100% good or excellent clinical results, whereas the high adduction moment group could only achieve half that at 50% excellent or good results. Moreover, the high adduction moment group had a significant recurrence of their varus deformity. This dynamic situation may well be an important consideration in helping to explain certain failures or recurrences despite good initial correction, as the static alignment of the knee cannot account for dynamic loading. It may also aid in producing a more uniform result for those undergoing HTO by improving patient selection.

Shaw et al. [47] goes further and questions the very anatomical and biomechanical basis of closing wedge HTO. In their study, they showed that osteotomy angles of greater than 10° rendered the lateral collateral ligament non-functional and allowed the knee to swing back to its native alignment with varus loading, thus negating much of the bony correction. Secondly, to achieve a mechanical alignment that passed through the lateral aspect of the joint would require a very large angular correction and be cosmetically and functionally unacceptable to most patients. They concluded that such dynamic factors and the flawed premise of the HTO procedure probably account for the high rate of recurrent varus deformity after HTO. As such the causes of under correction and recurrence are likely to be multi factorial in nature involving a combination of anatomy and biomechanics as well as static and dynamic factors.

However, with regard to the single issue of simply achieving the desired angular correction, the advent of computer navigation in surgery may help to address this. Despite the numerous conventional techniques available there is no single technique that can reliably determine the value of

the intraoperative correction achieved. Most corrections are based on preoperative planning data and the faithful reproduction of the preoperative plan intraoperatively in order to achieve the desired correction, hence the importance of accurate and meticulous preoperative planning [48]. Even so, Gaasbeek et al. [49] has shown a high variation in the postoperative correction angle achieved. This inaccuracy may well lead to postoperative malalignment and either under or over correction with resultant poor outcomes. The use of computer navigation in HTO surgery may well solve some of these issues. It affords real time data regarding mechanical axis and angular correction allowing the surgeon to control the correction more precisely. Several papers have looked at the accuracy of this technique and found it to be accurate, reliable and reproducible with a higher rate of precision in the corrections compared to conventional HTO [50–52]. Hankemeier et al. [52] also showed less use of fluoroscopy and a shorter operative time with the use of navigation. Image-free navigation measurements in the coronal plane at present seem to be more accurate than in the sagittal plane, thus prompting Pearle et al. [53] to recommend its use only in monitoring lower limb alignment in the coronal plane. Given the demanding nature of the procedure and the importance of achieving accurate correction navigation holds early promise in this regard. There is, however, no long-term clinical data to support its use.

Conversion to total knee arthroplasty

Significant controversy still exists with regard to the results of total knee arthroplasty after HTO. Whilst some authors have reported no adverse outcome with prior HTO [54–58], others have noted inferior results [59–65]. None of these studies have particularly long mean follow-up times however. The longest mean follow-up study was conducted by Haslam et al. [59]. They had a mean follow-up of 12.6 years and found that even though the Hospital for Special Surgery Scores showed no statistically significant difference, the HTO group tended to have poorer results with significantly reduced flexion, higher reoperation rates and more failures than the matched group with primary TKA. Most failures tended to occur in the medium to long term and they emphasised the importance of long-term follow-up. Regardless of their outcomes all authors agree that conversion of an HTO to a TKA is a much more technically demanding procedure than a primary TKA. Several issues account for this including the resultant patella baja after HTO, potential wound healing issues, anatomical deformity of the proximal tibia complicating TKA and the potential for any retained hardware to interfere with any subsequent procedure. Any or all of these factors may make the TKA more technically challenging and affect the long-term outcome.

Patella baja after closing wedge HTO occurs as a result of scarring of the patella tendon and its subsequent contracture rather than as a result of the osseous rearrangement due to the subtraction of bone. Wright et al. [66] actually showed that patellar height was increased with closing wedge HTO as the removal of bone resulted in an effective lowering of the joint line, whereas the reverse is true of opening wedge HTO. The high rate of patella baja occurred when the use of cast immobilisation was routine [67]. The recent trend towards rigid internal fixation and early mobilisation has greatly decreased this occurrence [68–70]. Problems associated with patella baja secondary to HTO and subsequent TKA relate to difficulties with patella eversion and thus exposure, an increased number of lateral releases and also a higher risk of patella tendon avulsion [61, 62]. Scarring around the proximal tibia also adds to the difficulties associated with exposure [62]. Altered patellofemoral biomechanics of both the native knee and after arthroplasty due to patella baja may potentially affect outcome [65].

Anatomical deformity of the proximal tibia occurs after HTO. This usually results in a decrease in the sagittal slope and a loss of lateral bone stock. Both these deformities must be taken into account when performing a TKA. In particular, the slope should be restored and lateral bone stock preserved. But further difficulties may be encountered when attempting to do so. Windsor et al. [65] showed asymmetry in the flexion and extension gaps when the tibial slope was corrected. Similarly, Bthis et al. [71] found similar gap balancing issues when performing TKA following HTO, as did Madan et al. [60]. Primary components usually suffice. But on occasion the use of revision components and in particular stems is required, especially when faced with poor bone stock issues. In this instance the requirement for a large angular correction of the proximal tibia may result in stem impingement on the lateral cortex and the use of modified or offset stems may be necessary [65]. All these issues with regard to the proximal tibia must be considered when planning a conversion to a TKA from an HTO.

Wound issues must also be considered. Some surgeons perform the HTO through a lateral J or hockey type incision and this may have implications with regard to the TKA incision. Particular attention should be paid to the possibility of skin necrosis at sites of scar intersections or as a result of thin skin bridges between previous scars and the TKA incision [72].

Consideration should also be made as to whether the implants used for the HTO should be removed and whether to perform TKA in a single sitting or whether it should be staged given the concern regarding infection, although there is little evidence of this in the literature either way. The use of Coventry type staples, however, usually does not necessitate removal as they rarely interfere with the subsequent insertion of the tibial component [72].

Conclusion

Closing wedge HTO remains an effective and successful treatment for single compartment arthrosis. It is, however, a technically demanding procedure and can result in significant complications. They include fracture, neurovascular injury, delayed and nonunion, thromboembolic disease, infection and under correction or recurrence of deformity. Most of these complications can be minimised or eliminated through careful preoperative planning and meticulous surgical technique. Finally, controversy still remains as to the outcome of TKA after HTO. Even so, there is general agreement that TKA following HTO is a much more technically challenging procedure than primary TKA and requires thorough planning and foresight to anticipate the potential difficulties associated with the procedure. It also requires a thorough understanding of the technical issues related to performing a TKA in a knee with a previous HTO in order to maximise outcome.

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