Osteotomy Complications: Prevention and Cure

Ravi T Rudraraju[1], Jobe Shatrov[1], Brett A Fritsch[1]

Abstract

Osteotomies around the knee are done to treat unicompartmental knee osteoarthritis, address instability and to correct the deformity. Careful selection of patient and preoperatively planning the target alignment are the key to achieve optimal results. There are multiple types of osteotomies with varying complication rates for each procedure. Opening wedge high tibial osteotomy (HTO) is the commonly performed osteotomy with an incidence of complications ranging from 1.9% to 55%. Closed wedge HTO has complication rate of around 10 to 34% and higher complication rates (19 to 70%) are reported with distal femoral osteotomy. Complications are broadly classified into general and osteotomy specific complications, and osteotomy specific complications can be further subdivided into failure of effect, complications of the osteotomy itself, and complications of the implant.

This paper presents an overview of the complications of common osteotomies around the knee, predominantly high tibial and distal femoral osteotomy, and the approaches and techniques the surgeon can use to minimise their frequency and severity.

Keywords: High Tibial Osteotomy, Medial Closed Wedge HTO, Lateral Closed Wedge HTO, Distal Femoral Osteotomy, Complications after Osteotomy

Introduction

The definition of osteotomy is "the cutting of bone, especially to allow realignment", and is used in knee surgery to create changes in the alignment of the limb to improve function. Knee osteotomies can be classified as closing wedge, opening wedge, dome, rotational, translation or a combination of each, depending upon the way the osteotomy is created and the realignment performed [1]. Each has specific indications, technical challenges and differing types and rates of complication. The scope of this paper is to give an overview of the complications of osteotomy and it is mostly focused on the three most commonly performed ; Medial opening wedge (MOW), lateral closing wedge (LCW) high tibial osteotomies (HTO) and lateral opening distal femoral osteotomy (DFO) [1].

Overall incidence of complications following osteotomies around the knee vary based on the case series, type and location of osteotomy and the definition of complication being employed in the study. Incidence following OWHTO ranges from 1.9 % to 55% [2], and from 10% to 34% [3-5] after lateral CWHTO. Higher complication rates (19-70%) have been reported for DFO [6-10]. Overall, osteotomy around the knee has a low serious complication rate, but a relatively high minor complication rate. Complications can be classified in many ways, though in simple terms they can be divided into general complications of surgery and osteotomy specific complications (Table 1). Osteotomy specific complications can be further subdivided into failure of effect, complications of the osteotomy, and complication of the implant.

The aim of this review was to summarize the current literature on complications of osteotomy around the knee. Additionally, this review makes recommendations for prevention and treatment options when encountering these problems. For the purpose of focus and brevity, this paper primarily describes the specifics of complications related to HTO and DFO.

General Complications of the Surgery

General complications include anaesthetic complications, regional pain syndrome, deep vein thrombosis (DVT), pulmonary embolism (PE), infections and compartment syndrome. Risk of adverse events following osteotomies around the knee appear to be related to the patient profile as much as the specific type of osteotomy. Diabetes, COPD, age > 45 and dependent functional status each have all been shown to independently double the risk of adverse outcomes following osteotomy, independent of the location (femoral or tibial) [11]. Incidence for infection, hematoma, thrombosis and complex regional pain syndrome may vary slightly between types of osteotomy [12, 13].

Deep Vein Thrombosis and Pulmonary Embolus

Deep vein thrombosis and PE occur due to combination of surgery, immobilisation of the limb and additional patient factors that have previously been well described. The incidence of DVT ranges from 2–5% in most series [2, 5]. Institution of postoperative thromboprophylaxis regime along similar lines to that used in knee

[1]Department of Orthopaedics, Sydney Orthopaedic Research Institute, Chatswood NSW, Australia.

Address of Correspondence:
Dr. Brett Fritsch,
Orthopaedic Surgeon, Sydney Orthopaedic Research Institute, Chatswood NSW, Australia.
E-mail: brett@brettfritsch.com.au


Dr. Ravi T Rudraraju


Dr. Jobe Shatrov


Dr. Brett A Fritsch

Submitted: 1/7/2021 , Review: 12/8/2021, Accepted: 26/9/2021 & Published: 10/12/2021

Asian Journal of Arthroscopy | ISSN 2456-1169 | Available on www.asianarthroscopy.com | DOI:10.13107/aja.2021.v06i02.034 |

General Surgical Complications	Specific Complications
1- Anaesthetic Complication	1- Hinge Fracture
2- Deep Vein Thrombosis/Pulmonary Embolism	2- Correction Failure
3- Infection	3- Non Union
4- Regional Pain Syndrom	4- Secondary Alignment Issue *Tibial Slope Change/Patella Baja
5- Compartment Syndrom	5- Neurovascular Injury
	6- Complications Related to Implant
	7- TKR Technical Challenges

Table 1: General complications and specific complications osteotomy surgery

arthroplasty is advisable.

Compartment Syndrome

Compartment syndrome is a rare (<1%) but devastating complication of osteotomy. Gibson et al. and Bauer et al. have shown that there is an increase in compartment pressures with HTO, leading to the possibility of an anterior compartment syndrome, however the precise aetiology is not known and can likely occur through a variety of pathways [14]. The incidence following lateral CW-HTO has been observed to be higher when compared to medial OW-HTO [15]. Consideration of approach, meticulous haemostasis and attention to fluid extravasation in combined arthroscopic procedures may help reduce the incidence of compartment syndrome following osteotomy. Furthermore, particular vigilance should be made in the early post-operative period to monitoring for the signs of compartment syndrome.

Infections

Rates of infection with osteotomies around the knee range from 0.8–10.4% with smokers and diabetes posing increased risk [2]. Higher rate of infections are seen with external fixation, usually due to pin-site infection [16]. Most are superficial infections and can be treated successfully with oral antibiotics. Deep infections are more problematic and may require irrigation and debridement with the use of intravenous antibiotics. A meta-analysis done by smith et al found no statistically significant difference in infection rate between closing and opening wedge HTO [17].

Failure of Effect

The effect of an osteotomy can be suboptimal for multiple reasons. Poor patient selection, incorrect planning of the osteotomy or failure of execution can all result in a failure to achieve the desired effect.

Patient Selection

The critical first step in performing an osteotomy is appropriate patient selection. This is dependent upon the condition being treated. For the management of knee osteoarthritis, the ideal candidate is young (<60 years), physically active, with a preserved range of motion, a stable joint, minimal contracture, correctable deformity and some joint space remaining on the side of arthritis. Patients affected by bicompartmental osteoarthritis, rheumatoid arthritis, fixed flexion contracture >25 degrees and patients with BMI ≥30 are not suitable candidates according to current ISAKOS guidelines [18]. Applications of osteotomy to instability alter the selection criteria to encompass the pattern being managed (for example posterolateral corner instability can be addressed via a valgising osteotomy, and the cruciate deficiencies addressed via changes in tibial slope).

Planning

Preoperative planning for coronal/sagittal osteotomy around the knee requires accurate assessment of starting alignment. This can be performed using 3 foot standing films [19], novel radiographic instruments like EOS machines, (Figure 1a) (Figure 1b) or reconstructive techniques such as CT or MRI [20-21] (Figure 1c). Each has their benefits and drawbacks; however one of the most significant differences is seen between non-weight bearing, double-leg stance and single-leg stance images [21-23]. Double leg weight bearing radiography is gold standard for assessing knee alignment but studies have shown single leg weight-bearing images more accurately represent dynamic joint load and have higher mean hip knee ankle angle (HKAA) (range 0.8 to 1.5 degrees higher) compared to double leg stance images [23]. Supine CT scans are taken in patients with flexion deformity and severe OA as obtaining standing full length radiography can be difficult. Surgeons should be aware that supine CT can underestimate the alignment angle (HKAA 1.3 degrees ± 0.4) when compared to double leg standing radiographs and therefore consider the difference when planning for an osteotomy [21, 24].

The second part of accurate planning is the target alignment. For many surgeons the work of Fujisawa et al have defined their target in medial osteoarthritis. Fujisawa's point is defined as a point in the lateral compartment, 62.5% the width of the tibial plateau with medial side starting point of 0% and the lateral edge of the lateral plateau being 100% [25]. Multiple studies have reported good results using this target alignment [26, 27].

Figure 1a: Preoperative planning: full-length weight-bearing radiographs of the lower extremities (hips to ankles) are essential to avoid complications

Figure 1b: EOS imaging is a low-dose, weight-bearing X-ray technology using significantly less radiation than traditional X-rays or CT scans

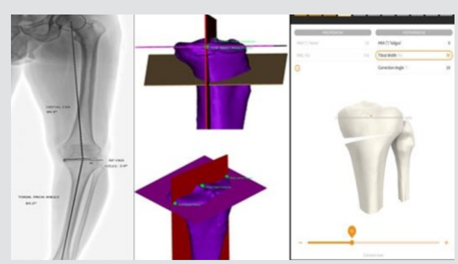

Figure 1c: Pre-operative planning using 3D computer software

Recently it has been suggested that the crossing point of the Weight Bearing Axis (WBA) in the tibial plateau (as expressed in percentage like Fujisawa's point) should be altered by the stage of osteoarthritic (OA). For mild OA (ICRS grade I–II) the target alignment should be set at 55–60%, and for more advanced OA (ICRS grade III or IV) the goal should be should be set to 58–63% whilst maintaining the postoperative medial proximal tibial angle (MTPA) below 95 degrees [21]. A WBA which crosses at a point of 54% of the width of the tibia plateau results in an overall hip-knee angle (HKA) range of 0-3 degrees of valgus [28, 29]. Under correction (<40%) or over-correction (80%) either does not achieve the goal of the surgery or results in non-physiological kinematics, abnormal ligament tension and should be avoided [30].

Coronal Alignment - Posterior Tibial Slope

Surgeons should understand how each specific osteotomy technique can effect tibial slope, and the consequences of such changes, if they are to avoid a complication related to inadvertent changes in slope. Because of the shape of the tibia and resulting axis of rotation being off centre, changes in coronal alignment will alter sagittal alignment unless this geometry is well understood by the surgeon. Medial OWHTO tends to increase PTS and restrict extension causing overload on the ACL. Lateral CWHTO results in a decrease in PTS causing hyperextension and overload on the PCL contributing to reduction in anterior instability. Noyes et al described this well and prescribed how the anterior osteotomy gap at the tibial tubercle should be one half of the posteromedial gap in order to maintain the starting sagittal tibial slope. Every millimeter of gap error at the tibial tubercle resulted in approximately 2° of change in the slope [31] (Figure 2). Yoon et al similarly shown that the anterior opening gap should be 67% of the posterior gap in order to maintain PTS [32].

Complications of Execution

With the osteotomy accurately planned, perfect delivery, and intra-operative confirmation of alignment, is required. Conventional methods using fluoroscopy with either a cable or straight rod, grid technique and anatomic referencing, or simple gap measurement can result in error in measurement and alignment outliers. Navigation has been shown to reduce the incidence of alignment outliers following osteotomy, though adds complex equipment and cost [33]. Patient specific cutting guides (PSCG) offer a solution to these problems and aid in accuracy and precision of correction angles during osteotomy [32]. Studies have shown PSCGs helps in achieving an optimal correction in a safe and reliable manner with good functional outcomes. They reduce the use of fluoroscopy, operating time and complications [34, 35].

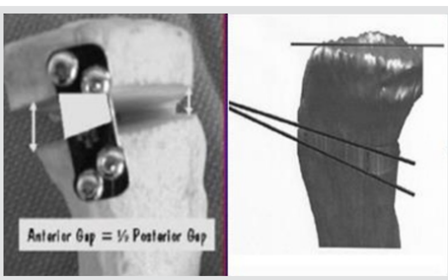

Figure 2: Frank R. Noyes et al observed that anterior osteotomy gap at the tibial tubercle was generally one half of the posteromedial gap to maintain the normal sagittal tibial slope.

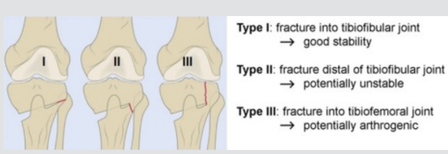

Figure 3: Cortical hinge fractures are classified into 3 groups as described by Takeuchi et al

Hinge Fracture / Intra articular Fracture

All osteotomies require some plastic deformation or microfracture in order to open or close the wedge, but this complication refers to an unintended macroscopic fracture which results in a loss of stability. It is a more significant issue around opening wedge osteotomies as they are inherently less stable than closing wedge. It is this loss of stability that makes these fractures the "mother of complications" as the resultant destabilisation of the proximal fragment can allow alteration of angular correction to occur, along with progression to malunion, delayed union or non-union.

Most literature regarding hinge fractures relate to HTO, and incidence for has been reported to be as high as 25% [2]. For medial OWHTO, incidence has been reported to be 13.8% in CT scans and range between 9 and 25% on plain radiographs [36, 37]. In CWHTO incidence of fracture is slightly lower ranging from 10% to 20% [20]. Very few data are currently available to draw accurate occurrence rate of this complication during DFO procedures.

Not all hinge fractures are equal. Takeuchi et al has described a classification for OW-HTO hinge fractures (Figure 3) [37]. Type I are relatively benign and tend to heal without consequence unless significantly displaced, Type II and III are more significant with both types having increased rates of non-union (38) and Type III being potentially arthrogenic. Both Type II and III are much more likely to benefit from secondary stabilisation while undisplaced type I fractures can generally be observed.

These fractures occur when forces through the hinge point are released by macrofracture rather than plastic deformation. It occurs when the lateral hinge is malpositioned, the osteotomy is incompletely performed, the MCL insufficiently released (Figure 4a) or poor technique is used to open the osteotomy. In simple terms the hinge point should be closer to the lateral cortex than the tibial plateau (approximately 10mm from the lateral cortex) [39]. Nakamura et al very well described the relationship between hinge position and fracture types. They divided hinge positions into five zones by their relationship to the proximal tibiofibular joint (PTFJ) and identified zone 'WL' (low and lateral) as the safest position for the placement of the osteotomy hinge to avoid fracture [40] (Figure 5). This corresponds to a similar point described by Ogawa et al who reported no lateral hinge fracture with an osteotomy whose endpoint was at the level of the fibular head [41]. Supplementary techniques for minimising the risk of hinge fracture include addition of a 5 mm diameter anteroposterior stress relieving drill hole 10 mm from the opposite cortex and 20 mm from the plateau (at the apex of the osteotomy) [42] (Figure 4b), or the passage of a 2.5 mm K-wire stress-shielding wire that

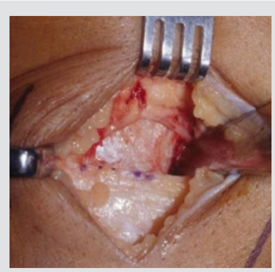

Figure 4a: Sufficient MCL release

Figure 4b: Anteroposterior stress relieving drill hole

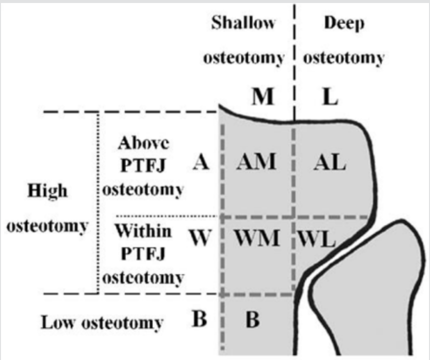

Figure 5: Nakamura et al described the relationship between hinge position and fracture types and identified zone 'WL' as the safest position for the placement of the osteotomy hinge to avoid fracture

Figure 6: Hinge pin to minimise the risk of fracture

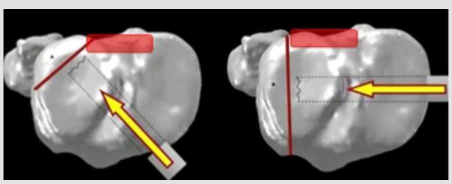

Figure 7: Incomplete osteotomy at the posterolateral cortex (in an OWHTO) will result in fracture

Figure 8: Wedge distraction using spreader

passes from distal/medial to proximal/lateral obliquely across the hinge point. Both techniques allow for significant increase in correction without hinge fracture (Figure 6) [43].

To allow easy opening or closing and minimise the risk of fracture the osteotomy needs to be complete. The most common region for incomplete osteotomy is the posterolateral cortex (in an OWHTO), and extra care needs to be taken to ensure the osteotomy is complete at this region (Figure 7). Forced opening without completion of the osteotomy will result in fracture. Similarly, if the MCL is incompletely released excessive force will also be applied on opening, increasing the likelihood of fracture. Finally the method used for opening the osteotomy is important. Opening via a laminar spreader placed on the medial edge of the osteotomy applies a lever to the hinge point allowing it to gradually open, whereas a impacting a wedge as some techniques describe, applies a combination of spreading with splitting, like a blockbuster through wood, with a result of increased risk of fracture (Figure 8). Whichever technique the surgeon prefers, a gradual, careful opening of the osteotomy keeping constant vigilance of the feel of pressure at the hinge and its response to further increases in pressure, are key in minimising the risk of fracturing the lateral hinge.

Delayed Union and Non Union

Rates of non-union and delayed union are slightly higher for opening wedge versus closing wedge osteotomies in both the femur and the tibia due to the inherent stability and immediate metaphyseal bone to bone compression that occurs with closing wedge osteotomies. For HTO, the incidence of delayed union ranges from 4 to 8.5% and 0 to 5.4% for non-union [44, 45]. For DFO, nonunion rates range from 2-5% . Average time to union for an opening wedge (OW) DFO is 3-6 months and 4 months following a closing wedge (DFO). Delayed union occurs in approximately 10% of cases [6, 8].

The risk of delayed union and nonunion is increased with hinge fracture, implant failure and smoking [46]. Furthermore, slower union has been demonstrated when the osteotomy is distal to the tibial tubercle in the tibia thought to be owed to the lower healing potential of the bone below the metaphysis [47]. Risk of non-union can be minimized through avoidance of intra-operative fracture, ensuring the osteotomy does not cross into diaphyseal bone, obtaining adequate rigid internal fixation and optimizing the patient biology if possible through smoking cessation.

Correction Failure

Correction failure is defined by not achieving or maintaining the intended limb-alignment. It is usually referred to in terms of coronal alignment, however should also consider the sagittal alignment as defined by the PTS. It can either be immediate (correct alignment never achieved) or delayed (correction was obtained but deformity gradually recurred). It can lead to recurrent varus or valgus deformity, the progression of joint arthritis and patient dissatisfaction. Correction failure occurs approximately 15% of the time following osteotomy about the knee [44].

Immediate correction failure is likely related to the intraoperative correction not being achieved. Most corrections are based on preoperative planning data and the faithful reproduction of the preoperative plan intraoperatively, and many of the challenges relating to this have been discussed in previous paragraphs [48]. The use of computer navigation in osteotomy surgery about the knee may solve some of these issues by affording real time data regarding mechanical axis and angular correction, allowing more precise control of the correction [49]. Another possible cause of early correction failure may be due to inappropriate wedge size in the case of DFO or OW-HTO typically from under sizing, or due to the use of wedge materials that are easily compressed and may lead to loss of correction at the time of surgery.

Delayed correction failure is more complex and likely multifactorial. MCL release has been shown to be important factor for reducing medial compartment pressures following OW-HTO, and inadequate release may leave the medial compartment compressed despite alignment being adjusted [50]. Fixation with rigid locking plates is also required to reduce movement of the osteotomy site, and inadequate fixation may lead to correction loss. Use of rigid locking plates, release of the MCL and wedges that are non-compressible such as bone autograft or allograft containing cortical and cancellous bone may help reduce the risk of delayed correction failure. Simple disease progression over time is very frequently the key factor resulting in loss of correction in the long term.

Patellar Height

HTO can result in changes in patellar height whenever the osteotomy is performed proximal to the tibial tubercle. Medial OWHTO can cause a decrease in patellar height because the tibial tuberosity is distalised relative to the joint line by opening of the proximal tibia during the procedure. Lateral CWHTO elevates the tibial tuberosity, bringing it closer to the joint line thus relatively increasing patellar height when measured against the joint line [51]. It should be remembered though that the tibial tubercle is close to the middle of the tibia medial-lateral, and thus the effect seen at this point is significantly less than the maximal size of the tibial wedge opened or closed. In cases of very large corrections, where the surgeon may be concerned about this effect, it can be completely overcome by creating an apex distal bi-planar step cut and keeping the tubercle attached to the proximal fragment [52]. Even where it does occur, short term studies have shown patella baja induced by the MOWHTO surgery does not lead to a reduction in functional results and the clinical consequences of patella baja post HTO remain unclear [53].

Neurovascular Complications

Both the popliteal structures (vascular and tibial nerve), and the common peroneal nerve, are at risk during osteotomies around the knee. Neural complications of osteotomies around the knee are from 0 to 20 %, though are generally reported at a much lower rate (<2%), and are most likely to involve the peroneal nerve [2, 54]. The proximity of the nerve to the fibular head and neck is thought be the causative factor and significantly higher in lateral CW-HTO compared to medial OW-HTO [55]. Wotton et al divided the fibula in 4 zones and noted majority of complications occurred in zone III between 8 and 15 cm below the fibular head.

Injuries to the popliteal and anterior tibial arteries have been reported with HTO but are rare ranging from 0.7%-1.7%. The anterior tibial artery is more commonly injured than popliteal artery [56]. Proper placement of retractors posterior to the tibia that is strictly on bone and completion of the posterior portion of the osteotomy with an osteotome adds a layer of protection against damage to the popliteal artery and nerve [47]. For DFO, the main structures at risk are the vastus medialis, femoral and saphenous nerves and distal geniculate artery [57]. Flexion of the knee whilst performing a DFO may aid in displacing the posterior neurovascular bundle further away from the osteotomy site.

Complications Related to Implant

A variety of propriety plating systems have been designed for osteotomies around the knee. Failure of implants is rare, but leads to loss of correction, fracture of the tibial plateau/lateral cortical bone and malunion. Soft tissue irritation and hardware related pain is the most common complication after osteotomy varying from 30-80% [8]. TomoFix rigid locking plate is the most commonly used plate followed by Puddu plate with an overall complication rate of 29 to 40% and 30 to 55% respectively [2, 14, 34, 51, 57]. TomoFix plate being a longer plate leads to local irritation and is reported as a major complaint and on contrary Puddu plate being a short plate result in a low incidence of local irritation, but has higher non-union and implant failure rates [58]. To address these limitations newer plates such as all-polyetheretherketone (PEEK) plate which are low profile, bioinert and exhibits biomechanical strength properties similar to existing plates are being used. Recent studies have shown promising results compared to traditional plating methods, however, further long term studies are required [59, 60]. Implant failure can also occur, either early or late, and relates to accumulated stresses on the plate exceeding its ability to resist fatigue. It is most commonly associated with delayed or non-union, and inconsequential if union has occurred. To minimise the risk, appropriate strength fixation for the size and scope of osteotomy should be used, and all the techniques described above to avoid delayed union (don't break the hinge).

TKR Challenges After HTO

TKA with previous HTO poses additional challenges compared to primary TKA. Altered limb axis and difficult exposure may lead to suboptimal component positioning, extensor mechanism complications, soft-tissue imbalance and limb alignment, resulting in poorer outcomes [61]. The presence of previous internal fixation can pose challenges. Contradictory results have been reported on TKA with previous HTO compared to primary TKA. In a registry-based New Zealand study that compared survival rates and functional outcomes between two methods, TKA with previous HTO had a revision rate almost three times higher than that of primary TKA [62]. In contrast, another study investigating the risk of revision between TKA with and without previous HTO using 32,476 TKAs in the Norwegian Arthroplasty Register found that previous HTO did not appear to increase the risk of revision after a secondary procedure with TKA at 15-year follow-up [63].

Surgeons need to assess and plan for the potential difficulties that are described during conversion of HTO to TKA. These include surgical approach, anatomical deformities, ligament imbalance, and selection of prosthesis types. Computer navigation or robotic assistance may aid ligament balancing as well as achieving target alignment, and is particularly useful in quantifying the changes between alignment and joint line that have been deliberately induced by the previous osteotomy and can make the replacement challenging. Constrained implants should be considered if there is concern around handling the collateral ligaments, though the majority of cases can be very successfully performed with standard implants.

Conclusion

Osteotomy about the knee is an important tool to manage deformity, instability and arthritis in young patients. We present an up-to-date summary of the literature detailing the incidence and causality for the general and specific complications related to this topic. Furthermore, techniques based on published outcomes and person experience to potentially avoid these complications is described.

Abbreviations Used: High Tibial Osteotomy- HTO, Medial Closed Wedge HTO– MC-WHTO, Lateral Closed Wedge HTO– LC-WHTO, Distal Femoral Osteotomy – DFO, Posterior Tibial Slope - PTS, Joint Line Congruency Angle - JLCA

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

Conflict of Interest: NIL; **Source of Support:** NIL

References

1. King A, Wall O. Osteotomies around the knee. Orthop Trauma. 2014 Dec 1;28(6):388–95.
2. Vena G, D'Adamio S, Amendola A. Complications of osteotomies about the knee. Vol. 21, Sports Medicine and Arthroscopy Review. 2013. p. 113–20.
3. Naudie D, Bourne RB, Rorabeck CH, Bourne TJ. The Install Award. Survivorship of the high tibial valgus osteotomy. A 10- to -22-year followup study. Clin Orthop Relat Res. 1999 Oct;(367):18–27.
4. Aglietti P, Buzzi R, Vena LM, Baldini A, Mondaini A. High tibial valgus osteotomy for medial gonarthrosis: a 10- to 21-year study. J Knee Surg. 2003 Jan;16(1):21–6.
5. Sun H, Zhou L, Li F, Duan J. Comparison between Closing-Wedge and Opening-Wedge High Tibial Osteotomy in Patients with Medial Knee Osteoarthritis: A Systematic Review and Meta-analysis. J Knee Surg. 2017 Feb 1;30(2):158–65.
6. Edgerton BC, Mariani EM, Morrey BF. Distal femoral varus osteotomy for painful genu valgum. A five-to-11-year follow-up study. Clin Orthop Relat Res. 1993 Mar;(288):263–9.
7. Magyar G, Toksvig-Larsen S, Alkstedt J, Lindstrand A, Nilsson LT, Andersen R, et al. Frequent complications in distal femoral osteotomy: a retrospective 8 year multicenter follow-up. Chir Organi Mov. 1999;84(1):19–26.
8. Ramanathan D, Keudell A Von, Minas T, Gomoll AH. Survivorship and Complications of the Distal Femoral Osteotomy. Vol. 2, Orthopaedic Journal of Sports Medicine. 2014.
9. Luceri F, Tamini J, Ferrua P, Ricci D, Batailler C, Lustig S, et al. Total knee arthroplasty after distal femoral osteotomy: a systematic review and current concepts. SICOT-J. 2020;6:35.
10. Kim YC, Yang J-H, Kim HJ, Tawonsawatruk T, Chang YS, Lee JS, et al. Distal Femoral Varus Osteotomy for Valgus Arthritis of the Knees: Systematic Review of Open versus Closed Wedge Osteotomy. Knee Surg Relat Res. 2018 Mar;30(1):3–16.
11. Cotter EJ, Gowd AK, Bohl DD, Getgood A, Cole BJ, Frank RM. Medical Comorbidities and Functional Dependent Living Are Independent Risk Factors for Short-Term Complications Following Osteotomy Procedures about the Knee. Cartilage. 2020 Oct;11(4):423–30.
12. Martin R, Birmingham TB, Willits K, Litchfield R, Lebel ME, Giffin JR. Adverse event rates and classifications in medial opening wedge high tibial osteotomy. Am J Sports Med. 2014;42(5):1118–26.
13. Spahn G. Complications in high tibial (medial opening wedge) osteotomy. Arch Orthop Trauma Surg. 2004;124(10):649–53.
14. Bauer T, Hardy P, Lemoine J, Finlayson DF, Tranier S, Lortat-Jacob A. Drop foot after high tibial osteotomy: A prospective study of aetiological factors. Vol. 13, Knee Surgery, Sports Traumatology, Arthroscopy. 2005. p. 23–33.
15. Song EK, Seon JK, Park SJ, Jeong MS, K Seon PJ, Surgeon J Park OS, et al. The complications of high tibial osteotomy CLOSING-VERSUS OPENING-WEDGE METHODS. J Bone Jt Surg [Br]. 2010;92(9):92–1245.
16. Anagnostakos K, Mosser P, Kohn D. Infections after high tibial osteotomy. Vol. 21, Knee Surgery, Sports Traumatology, Arthroscopy. 2013. p. 161–9.
17. Smith TO, Sexton D, Mitchell P, Hing CB. Opening- or closing-wedged high tibial osteotomy: A meta-analysis of clinical and radiological outcomes. Vol. 18, Knee. 2011. p. 361–8.
18. Gao L, Madry H, Chugaev D V., Denti M, Frolov A, Burtsev M, et al. Advances in modern osteotomies around the knee: Report on the Association of Sports Traumatology, Arthroscopy, Orthopaedic surgery, Rehabilitation (ASTAOR) Moscow International Osteotomy Congress 2017. Vol. 6, Journal of Experimental Orthopaedics. Springer Berlin Heidelberg; 2019.
19. Parihar M, Singh T, Shah L. How to obtain a non-digital Full-length lower limb Radiographs using regular X-ray plates. Vol. 1, Journal of Orthopaedic Case Reports. 2011. p. 36–8.
20. Vasconcellos David A.and Giffin JR and AA. Avoiding and Managing Complications in Osteotomies of the Knee. In: Meislin Robert J.and Halbrecht J, editor. Complications in Knee and Shoulder Surgery: Management and Treatment Options for the Sports Medicine Orthopedist [Internet]. London: Springer London; 2009. p. 115–32. Available from: https://doi.org/10.1007/978-1-84882-203-0_7
21. Matsushita T, Watanabe S, Araki D, Nagai K, Hoshino Y, Kanzaki N, et al. Differences in preoperative planning for high-tibial osteotomy between the standing and supine positions. Knee Surg Relat Res. 2021 Dec 1;33(1).
22. Marx RG, Grimm P, Lillemoe KA, Robertson CM, Ayeni OR, Lyman S, et al. Reliability of lower extremity alignment measurement using radiographs and PACS. Knee Surgery, Sport Traumatol Arthrosc. 2011 Oct;19(10):1693–8.
23. Yazdanpanah O, Mobarakeh MK, Nakhaei M, Baneshi MR. Comparison of Double and Single Leg Weight-Bearing. 2017;174:174–80.
24. Specogna A V, Birmingham TB, Hunt MA, Jones IC, Jenkyn TR, Fowler PJ, et al. Radiographic measures of knee alignment in patients with varus gonarthrosis: effect of weightbearing status and associations with dynamic joint load. Am J Sports Med. 2007 Jan;35(1):65–70.
25. Fujisawa Y, Masuhara K, Shiomi S. The effect of high tibial osteotomy on osteoarthritis of the knee. An arthroscopic study of 54 knee joints. Orthop Clin North Am. 1979 Jul;10(3):585–608.

26. Schallberger A, Jacobi M, Wahl P, Maestretti G, Jakob RP. High tibial valgus osteotomy in unicompartmental medial osteoarthritis of the knee: a retrospective follow-up study over 13-21 years. Knee Surg Sports Traumatol Arthrosc. 2011 Jan;19(1):122–7.

27. Bode G, von Heyden J, Pestka J, Schmal H, Salzmann G, Südkamp N, et al. Prospective 5-year survival rate data following open-wedge valgus high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc. 2015 Jul;23(7):1949–55.

28. Laprade RF, Spiridonov SI, Nystrom LM, Jansson KS. Prospective outcomes of young and middle-aged adults with medial compartment osteoarthritis treated with a proximal tibial opening wedge osteotomy. Arthrosc J Arthrosc Relat Surg Off Publ Arthrosc Assoc North Am Int Arthrosc Assoc. 2012 Mar;28(3):354–64.

29. De Neve F, Braems B, Holvoet M, De Scheerder M-A, Arnout N, Victor J. Return to sport and work after medial open wedge high tibial osteotomy : a case series. Acta Orthop Belg. 2021 Mar;87(1):117–24.

30. Kuriyama S, Watanabe M, Nakamura S, Nishitani K, Sekiguchi K, Tanaka Y, et al. Classical target coronal alignment in high tibial osteotomy demonstrates validity in terms of knee kinematics and kinetics in a computer model. Knee Surg Sports Traumatol Arthrosc. 2020 May;28(5):1568–78.

31. Noyes FR, Goebel SX, West J. Opening wedge tibial osteotomy: The 3-triangle method to correct axial alignment and tibial slope. Am J Sports Med. 2005 Mar;33(3):378–87.

32. Song SJ, Bae DK. Computer-assisted navigation in high tibial osteotomy. Vol. 8, CiOS Clinics in Orthopedic Surgery. Korean Orthopaedic Association; 2016. p. 349–57.

33. Akamatsu Y, Mitsugi N, Mochida Y, Taki N, Kobayashi H, Takeuchi R, et al. Navigated opening wedge high tibial osteotomy improves intraoperative correction angle compared with conventional method. Knee Surg Sports Traumatol Arthrosc. 2012 Mar;20(3):586–93.

34. Jacquet C, Sharma A, Fabre M, Ehlinger M, Argenson J-N, Parratte S, et al. Patient-specific high-tibial osteotomy's "cutting-guides" decrease operating time and the number of fluoroscopic images taken after a Brief Learning Curve. Knee Surg Sports Traumatol Arthrosc. 2020 Sep;28(9):2854–62.

35. Munier M, Donnez M, Ollivier M, Flecher X, Chabrand P, Argenson J-N, et al. Can three-dimensional patient-specific cutting guides be used to achieve optimal correction for high tibial osteotomy? Pilot study. Orthop Traumatol Surg Res. 2017 Apr;103(2):245–50.

36. Han SB, Choi JH, Mahajan A, Shin YS. Incidence and Predictors of Lateral Hinge Fractures Following Medial Opening-Wedge High Tibial Osteotomy Using Locking Plate System: Better Performance of Computed Tomography Scans. J Arthroplasty. 2019 May 1;34(5):846–51.

37. Takeuchi R, Ishikawa H, Kumagai K, Yamaguchi Y, Chiba N, Akamatsu Y, et al. Fractures around the lateral cortical hinge after a medial opening-wedge high tibial osteotomy: A new classification of lateral hinge fracture. Arthrosc - J Arthrosc Relat Surg. 2012 Jan;28(1):85–94.

38. Kang K-T, Koh Y-G, Lee J-A, Lee JJ, Kwon SK. Biomechanical effect of a lateral hinge fracture for a medial opening wedge high tibial osteotomy: finite element study. J Orthop Surg Res. 2020 Feb;15(1):63.

39. Jung G-H, Lee K-H, Wang L. Three-dimensional analysis of lateral cortical hinge in medial open-wedge high tibial osteotomy: A computational simulation study of adult cadavers. J Orthop Surg (Hong Kong). 2020;28(3):2309499020959172.

40. Nakamura R, Komatsu N, Fujita K, Kuroda K, Takahashi M, Omi R, et al. Appropriate hinge position for prevention of unstable lateral hinge fracture in open wedge high tibial osteotomy. Bone Jt J. 2017;99(10):1313–31.

41. Ogawa H, Matsumoto K, Akiyama H. The prevention of a lateral hinge fracture as a complication of a medial opening wedge high tibial osteotomy: a case control study. Bone Joint J. 2017 Jul;99-B(7):887–93.

42. Boström A, Amin AK, Macpherson GJ, Pankaj P, Scott CEH. Hinge location and apical drill holes in opening wedge high tibial osteotomy: A finite element analysis. J Orthop Res. 2021 Mar 1;39(3):628–36.

43. Dessyn E, Sharma A, Donnez M, Chabrand P, Ehlinger M, Argenson J-N, et al. Adding a protective K-wire during opening high tibial osteotomy increases lateral hinge resistance to fracture. Knee Surg Sports Traumatol Arthrosc. 2020 Mar;28(3):751–8.

44. Miller BS, Downie B, McDonough EB, Wojtys EM. Complications After Medial Opening Wedge High Tibial Osteotomy. Arthrosc - J Arthrosc Relat Surg. 2009 Jun;25(6):639–46.

45. de Mello Junior WA, Arruda LRP, Coluccini AM, da Silva Nunes RP, Pedro M do AC, de Souza MR, et al. COMPLICATIONS FOLLOWING MEDIAL OPENING WEDGE OSTEOTOMY OF THE KNEE: RETROSPECTIVE STUDY. Rev Bras Ortop. 2011 Jan;46(1):64–8.

46. Pearson RG, Clement RGE, Edwards KL, Scammell BE. Do smokers have greater risk of delayed and non-union after fracture, osteotomy and arthrodesis? A systematic review with meta-analysis. BMJ Open. 2016 Nov;6(11):e010303.

47. Tunggal JAW, Higgins GA, Waddell JP. Complications of closing wedge high tibial osteotomy. Vol. 34, International Orthopaedics. 2010. p. 255–61.

48. Gaasbeek RDA, Welsing RTC, Verdonschot N, Rijnberg WJ, Van Loon CJM, Van Kampen A. Accuracy and initial stability of open- and closed-wedge high tibial osteotomy: A cadaveric RSA study. Knee Surgery, Sport Traumatol Arthrosc. 2005 Nov;13(8):689–94.

49. Hankemeier S, Hufner T, Wang G, Kendoff D, Zeichen J, Zheng G, et al. Navigated open-wedge high tibial osteotomy: Advantages and disadvantages compared to the conventional technique in a cadaver study. Knee Surgery, Sport Traumatol Arthrosc. 2006 Oct;14(10):917–21.

50. Suero EM, Sabbagh Y, Westphal R, Hawi N, Citak M, Wahl FM, et al. Effect of Medial Opening Wedge High Tibial Osteotomy on Intraarticular Knee and Ankle Contact Pressures. 2015;(April):598–604.

51. El-Azab H, Glabgly P, Paul J, Imhoff AB, Hinterwimmer S. Patellar height and posterior tibial slope after open- and closed-wedge high tibial osteotomy: A radiological study on 100 patients. Am J Sports Med. 2010 Feb;38(2):323–9.

52. Erquicia J, Gelber PE, Perelli S, Ibañez F, Ibañez M, Pelfort X, et al. Biplane opening wedge high tibial osteotomy with a distal tuberosity osteotomy, radiological and clinical analysis with minimum follow-up of 2 years. J Exp Orthop. 2019 Feb;6(1):10.

53. Goshima K, Sawaguchi T, Shigemoto K, Iwai S, Nakanishi A, Ueoka K. Patellofemoral Osteoarthritis Progression and Alignment Changes after Open-Wedge High Tibial Osteotomy Do Not Affect Clinical

Outcomes at Mid-term Follow-up. Arthrosc - J Arthrosc Relat Surg. 2017 Oct 1;33(10):1832–9.

54. Kley K, Bin Abd Razak HR, Khakha RS, Wilson AJ, van Heerwaarden R, Ollivier M. Soft-Tissue Management and Neurovascular Protection During Opening-Wedge High Tibial Osteotomy. Arthrosc Tech. 2021 Feb;10(2):e419–22.

55. Wootton JR, Ashworth MJ, MacLaren CA. Neurological complications of high tibial osteotomy--the fibular osteotomy as a causative factor: a clinical and anatomical study. Ann R Coll Surg Engl. 1995 Jan;77(1):31–4.

56. Woodacre T, Ricketts M, Evans JT, Pavlou G, Schranz P, Hockings M, et al. Complications associated with opening wedge high tibial osteotomy - A review of the literature and of 15 years of experience. Knee. 2016 Mar 1;23(2):276–82.

57. Visser J, Brinkman J-M, Bleys RLAW, Castelein RM, van Heerwaarden RJ. The safety and feasibility of a less invasive distal femur closing wedge osteotomy technique: a cadaveric dissection study of the medial aspect of the distal femur. Knee Surg Sports Traumatol Arthrosc. 2013 Jan;21(1):220–7.

58. van den Bekerom MPJ, Patt TW, Kleinhout MY, van der Vis HM, Albers GHR. Early complications after high tibial osteotomy: a comparison of two techniques. J Knee Surg. 2008 Jan;21(1):68–74.

59. Hartz C, Wischatta R, Klostermeier E, Paetzold M, Gerlach K, Pries F. Plate-related results of opening wedge high tibial osteotomy with a carbon fiber reinforced poly-ether-ether-ketone (CF-PEEK) plate fixation: A retrospective case series of 346 knees. J Orthop Surg Res. 2019 Dec 27;14(1).

60. Roberson TA, Momaya AM, Adams K, Long CD, Tokish JM, Wyland DJ. High Tibial Osteotomy Performed With All-PEEK Implants Demonstrates Similar Outcomes but Less Hardware Removal at Minimum 2-Year Follow-up Compared With Metal Plates. Orthop J Sport Med. 2018 Jan 2;6(3).

61. Lim JBT, Chong HC, Pang HN, Tay KJD, Chia SL, Lo NN, et al. Revision total knee arthroplasty for failed high tibial osteotomy and unicompartmental knee arthroplasty have similar patient-reported outcome measures in a two-year follow-up study. 2017;99(10).

62. Pearse AJ, Hooper GJ, Rothwell AG, Frampton C. Osteotomy and unicompartmental knee arthroplasty converted to total knee arthroplasty: data from the New Zealand Joint Registry. J Arthroplasty. 2012 Dec;27(10):1827–31.

63. Badawy M, Fenstad AM, Indrekvam K, Havelin LI, Furnes O. The risk of revision in total knee arthroplasty is not affected by previous high tibial osteotomy. Acta Orthop. 2015;86(6):734–9.

How to Cite this Article

Rudraraju RT, Shatrov J, Fritsch BA | Osteotomy Complications: Prevention and Cure | Asian Journal of Arthroscopy | July-December 2021; 6(2): 46-53.