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Technical Notes

Prevention of lateral plateau fractures during open-wedge high tibial osteotomy: A technical tip and a review of the literature

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ABSTRACT

Open-wedge high tibial osteotomy is a joint-preserving procedure associated with a number of complications including intra-articular fractures. The primary purpose is to change the varus malalignment into a neutral or valgus alignment according to the extent of cartilage damage. Thus, injury to the lateral tibial plateau would result in serious consequences. This report proposes a simple technical tip to intraoperatively mitigate such a troublesome complication. We also conducted a literature review to investigate the incidence and effects of intra-articular fractures highlighting the techniques recommended by previous authors to avoid intra-articular fractures during tibial valgization osteotomy.

Keywords: Fracture, High tibial osteotomy, Knee, Osteoarthritis, Tibia

INTRODUCTION

High tibial osteotomy (HTO) is a well-known joint-preserving surgery for treating medial compartmental knee osteoarthritis (OA) with varus malalignment. It has gained popularity due to the advantage of joint preservation compared to arthroplasty. The HTO aims to shift the mechanical axis to the relatively healthy lateral knee compartment. It can postpone knee arthroplasty by slowing down the degeneration process.

Debeyre and Artigou were the first to introduce open-wedge HTO (OWHTO) in 1951,[1] and it became widespread in 1987 by Hernigou *et al.*[2] Several amendments in the surgical techniques have been described, and special implants have been developed.[3] The OWHTO allows maintenance of the bone stock and restoration of normal alignment and does not require fibular osteotomy with an early and active rehabilitation protocol. On the other hand, OWHTO is not free of complications. The previous authors reported a 37–55% complication rate.[4-6] The reported complications included lateral hinge fracture (LHF), delayed wound healing, surgical site infections, vascular injury, venous thromboembolism, alterations in the posterior tibial slope (PTS), overcorrection, undercorrection, delayed union, non-union, implant failure, temporary peroneal nerve paresis, and leg length change.[2,3,7-9]

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Intra-articular or lateral tibial plateau (LTP) fractures are the most important complication of OWHTO. It has been reported as early as 1985.[10] Mabrey and McCollum identified 14 complications in 72 knees undergoing OWHTO where the intra-articular fracture was the only complication causing a persistent problem.[11] It is considered a serious adverse event since the lateral compartment of the articular surface is injured. Together with the change of varus malalignment into valgus, a transfer of the weightbearing load from the medial tibial plateau to the injured LTP occurs resulting in poor functional and radiographic outcomes.

The current technical report aimed to describe a simple technical tip that we adopted in our institution to prevent intra-articular fractures during OWHTO and minimize their impact on patients' outcomes if they occur.

SURGICAL TECHNIQUE

Anteroposterior full-length lower limb weightbearing radiographs are performed preoperatively for deformity analysis. To estimate the desired correction angle, we use the Miniaci *et al*. planning method considering the associated laxity of the lateral soft tissues measured by the joint line convergence angle to avoid overcorrection.[12]

A 5–8 cm longitudinal skin incision is made extending from the posterior border of the tibial plateau just distal to the joint line to the medial aspect of the tibial tubercle. Then, the superficial part of the medial collateral ligament and pes anserinus is released subperiosteally from the proximal tibia. After that, to expose the osteotomy site and protect the neurovascular bundle, a Hohmann retractor with a blunt tip is positioned beneath the posterior aspect of the upper tibia. Another Hohmann retractor is positioned beneath the patellar tendon.

Under fluoroscopic guidance, one or two Kirschner wires (K-wires) are introduced just below and parallel to the articular surface extending from medial to lateral [Figure 1]. The main objective of these subchondral K-wires is to avoid intra-articular extension of the osteotomy during gap distraction. If intra-articular fractures are inevitable, these subchondral wires should maintain the fracture in place until definite osteosynthesis is accomplished.

Then, two additional parallel K-wires are introduced anteriorly and posteriorly as a guide for the osteotomy plane at a point 40 mm distal to the medial joint line. The guide wires are directed superolaterally, reaching a point 15 mm distal to the lateral joint line [Figure 1]. We utilized the safe zone described by Nakamura *et al.* located within and lateral to the medial margin of the proximal tibiofibular junction (PTFJ) for the hinge point.[13]

An oscillating saw is used to perform the horizontal osteotomy distal to the guidewires extending to 10 mm medial to the lateral cortex. A second complete vertical osteotomy is performed with a thinner blade starting from the proximal to the insertion of the patellar tendon and directed at an angle of 120° to the horizontal osteotomy plane.

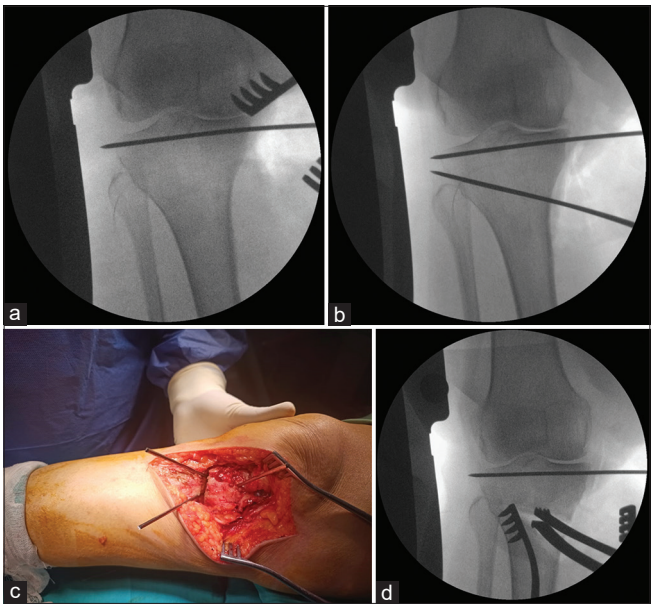

Figure 1: (a) Insertion of protective subchondral Kirschner wires (K-wire). (b) Insertion of guide wires along the osteotomy line. (c) Intraoperative image of K-wires inserted during open-wedge high tibial osteotomy. (d) Gradual distraction of the osteotomy gap using a laminar spreader.

Then, we hammer step-by-step chisels of increasing widths into the osteotomy gap. Subsequently, a gradual distraction of the osteotomy is carried out using a bone spreader. After achieving the desired degree of correction, the leg is extended with the patella facing forward. A laminar spreader is inserted in the posterior part of the osteotomy gap to maintain the achieved opening distance while preserving the PTS [Figure 1]. After a desired angular correction is achieved, internal fixation is carried out.

Isometric exercises and straight leg raises are initiated in the early postoperative period. Partial weightbearing should be allowed at three weeks if there is radiographic evidence of gap healing. Full weightbearing should be started at six weeks postoperatively.

A 42-year-old female patient presented with symptomatic knee varus deformity and OA of the medial compartment treated with OWHTO and fixed by the TomoFix locking plate (OrthoMed, Egypt) [Figure 2]. Intraoperatively, a fracture line was noted extending from the osteotomy plane into the articular surface of the tibial head during the gap opening. The preliminary subchondral K-wire maintained the plateau fracture in place until definite fixation using the same plate was done. At six weeks postoperatively, the union

Table 1: Reports on intra-articular fractures during OWHTO over the past two decades.

First author	Year	No. knees	Implant	No. LTP fractures (%)	Follow-up	Comment
Spahn[22]	2003	55 30	Puddu C-plate	8 (14.6) 2 (6.6)	-	Need a higher correction of 11° Additional osteosynthesis
Amendola[26]	2004	74	Puddu	7 (19)	16–26 m	-
Esenkaya and Elmali[27]	2006	58	2- or 4-hole wedge plate	5 (8.6)	21 m	Limited ROM to 70° on discharge
Asik[28]	2006	65	Puddu	1 (1.5)	34 m	Additional osteosynthesis
Niemeyer[29]	2007	43	TomoFix	1 (2.3)	Min 2 year	Revision surgery using screws on 3rd post-operative day
Niemeyer[30]	2010	69	TomoFix	1 (1.4)	Min 36 m	Additional osteosynthesis
Nelissen[5]	2010	49	Puddu	3 (6.1)	-	-
Song[21]	2010	90	Aescula	6 (6.7)	26.7 m	Additional osteosynthesis or casting Healed at 3 m
Takeuchi[15]	2010	27	TomoFix	1 (3.7)	61 m	Insignificant effect
Takeuchi[15]	2011	104	TomoFix	2 (2)	41 m	Insignificant effect
de Mello Junior[31]	2011	67	Puddu	2 (4.4)	Min 12 m	-
Chae[32]	2011	138	Locking T-plate	3 (2.2)	36.8 m	Additional osteosynthesis (plate)
Schröter[33]	2011	35	Position HTO plate	1 (3)	Min 12 m	Additional osteosynthesis (screws)
Saragaglia[34]	2011	124	AO T-plate	9 (7.25)	10.39 year	Insignificant effect
Tabrizi[35]	2013	21	L-plate T-plate	2 (12.5)	6 m	Insignificant effect
Jung[18]	2013	92 94	TomoFix Aescula	3 (3) 2 (2)	2 year	-
Martin[36]	2014	323	TomoFix Puddu	9 (2.8)	39.5 m	Delayed weight-bearing
Giuseffi[37]	2015	89	Arthrex wedge plate	6 (6.7)	4 year	Insignificant effect
Nakamura[16]	2015	47	TomoFix	6 (12.8)	Min 1 year	Additional osteosynthesis Low intensity ultrasound pulse Delayed union Overcorrection and loss of correction
Nakamura[13]	2017	111	TomoFix	8 (7.2)	-	Additional osteosynthesis (screws) Revision for undercorrection Overcorrection and loss of correction
Ogawa[20]	2017	82	TomoFix	4 (4.9)	20.2 m	-
Han[38]	2019	209	TomoFix	2 (1)	Min 2 year	Insignificant effect
Tuhanioglu[39]	2019	18	Locked wedge HTO plates	1 (5.6)	31.61 m	-
Hartz[40]	2019	346	PEEK power HTO plate	7 (2)	Min 1 year	Insignificant effect
Schwartz[41]	2019	19	4-hole plate	1 (5.3)	Min 1 year	Partial loss of correction Delayed union
Yabuuchi[42]	2020	85	TomoFix	4 (4.7)	4.5 year	Loss of correction>5° Change rehabilitation protocol
Sidhu[43]	2020	200	TomoFix	6 (3)	Min 2 year	Delayed union Delayed weight-bearing
Jin[19]	2020	339	Aescula	12 (3.5)	9.6 year	Insignificant effect

OWHTO: Open-wedge high tibial osteotomy, HTO: High tibial osteotomy, LTP: Lateral tibial plateau, PEEK: Polyetheretherketone, ROM: Range of motion

was achieved. Full weightbearing was permitted after eight weeks with no subsequent complications.

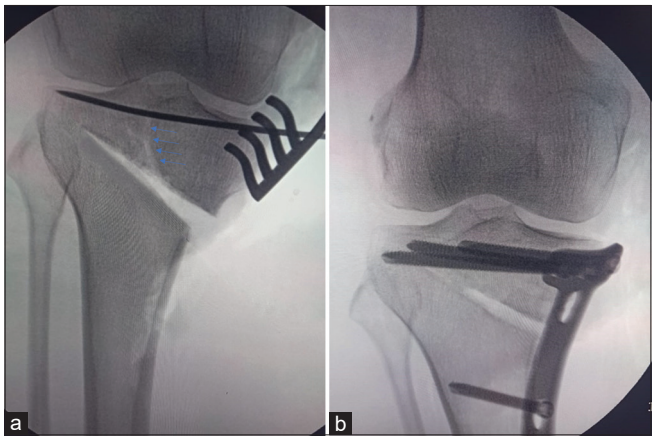

Figure 2: (a) Intra-articular fracture (blue arrows) during gap opening where displacement was prevented by the subchondral Kirschner wires. (b) Definite fixation of intra-articular fracture during high tibial osteotomy using the TomoFix plate.

DISCUSSION

The HTO is a technically challenging procedure that might be complicated by intra- and extra-articular fractures. Extra-articular fractures (classified as LHFs type I and II) have no significant impact on radiologic or functional outcomes.[14] On the contrary, intra-articular or LTP fractures (sometimes classified as LHF type III) are unstable. They may result in union problems and correction loss or alter the PTS.[15] From a biomechanical point of view, type I LHFs represent the propagation of the osteotomy line within the PTFJ, which is surrounded by dense connective tissue. Its stability is due to the compressive forces exerted by weightbearing while the fibula supports the LTP.

On the other hand, type II LHFs involve the distal part of the PTFJ where the weightbearing axis is transferred to the fibula. In type III LHFs, the proximal segment seems to be only supported by the implant.[16]

Although most intra-articular fractures occur intraoperatively, they may not be easily detectable on conventional radiographs.

Table 2: Technical notes to avoid intra-articular fractures in OWHTO.

Surgical step	First author, year	Recommendation
Direction of osteotomy	Amendola, 2004[26]	The osteotomy should be more horizontal, away from the joint line>1.5 cm.
	Chae, 2011[32]	The osteotomy should be directed toward a "safe zone" around 1.6 cm (range, 1.2–1.8) and extending from 0.8 cm distal to the lateral tibial joint line to the fibular circumference line.
	Vanadurongwan, 2013[44]	The osteotomy should be directed toward the "anatomical safe zone" between articular cartilage of posterolateral proximal tibia and PTFJ.
	Nakamura, 2017[13]	The osteotomy should be directed toward zone WL (within the PTFJ, lateral to the medial margin of the PTFJ). The bone density at the level of the PTFJ is higher than that above or below it and the PTFJ has many soft-tissue insertions which can confer stability even if the osteotomy direction or force is suboptimal.
Depth of osteotomy	Jacobi, 2010[45] and Schwartz, 2018[41]	The saw must cut until it is going through the external cortex to achieve an almost complete osteotomy with temporary external fixation of the lateral hinge.
Creation of osteotomy	Amendola, 2004[26]	Thin AO osteotomes are preferred.
	Jacobi, 2010[45]	Osteotomy is done below a K-wire which guides the saw blade and osteotomy chisels.
Opening of osteotomy	Esenkaya and Elmali, 2006[27] and Lee, 2013[18]	Enlargement of the osteotomy must be performed very slowly and cautiously below the guide wires.
		After sawing, chisels of increasing widths must be hammered step by step into the osteotomy space, followed by a gradual controlled opening through the plastic deformation zone (a spreader-chisel or osteotomy jack could be used).
		A lever force must be strictly avoided.

OWHTO: Open-wedge high tibial osteotomy, PTFJ: Proximal tibiofibular junction, K-wires: Kirschner wires, AO: Arbeitsgemeinschaft für Osteosynthesefragen,

Therefore, computed tomography may be necessary for early detection.[17] Tibial head infraction starts in the cancellous bone, which can be discovered by continuous radiographic control. To minimize the amount of radiation exposure intraoperatively, Lee *et al.* described the unequal separation of proximal and distal segments during the gap-opening process as an early sign of LTP fractures. The sign is attributed to the medial shift of the pivoting center from the lateral hinge to the lateral plateau.[18]

Several studies reporting different rates of intra-articular fractures during OWHTO over the past two decades [Table 1]. The overall rate of intraoperative LTP fractures ranged from 1% to 19%. A recent study by Jin *et al.* of 339 knees reported intra-articular fractures as the most common complication in their series.[19] Some authors described intra-articular fractures as a minor complication with no significant effect on surgical outcomes or rehabilitation programs. Others reported the need for additional fixation by screws or plates, revision surgery, delayed union, alignment overcorrection, undercorrection, loss of correction, limited range of motion, and delayed weightbearing.

Intraoperative LTP fractures usually arise secondary to technical problems and inadequate surgical experience. The previous studies demonstrated several factors contributing to the propagation of the osteotomy to the articular surface such as incomplete anterior or posterior corticotomy, high-level osteotomy above the fibular head closer to the LTP joint line, and application of excessive valgus force during the gap opening. Furthermore, using thick osteotomes, large correction angles (>−12°), and the creation of inappropriate osteotomies not parallel to the PTS make intra-articular fractures more likely to occur.[20-22]

In Table 2, we summarized several technical notes recommended by previous authors in terms of direction, depth, creation, and opening of the osteotomy so that knee surgeons would avoid such troublesome complications. Recently, novel devices have been developed to decrease the rate of intraoperative complications such as LTP fractures. Akamatsu *et al.* showed that navigation systems provided more satisfactory radiographic outcomes in the context of LTP fractures compared to conventional techniques.[23] Based on the fact that intra-articular fracture is attributed to the misplacement of the osteotomy bone cut and using a spacer for osteotomy gap opening, Ribeiro *et al.* performed OWHTO on eight cadaveric knees using a realignment high control system.[24] The system consisted of an implant linked to a dynamic instrument so that the plate could be fixed before opening the osteotomy gap. This allowed accurate mechanical correction and appropriate control of the PTS. Furthermore, Ghinelli *et al.* examined the iBalance HTO system, which consists of a non-absorbable polyetheretherketone implant and anchors inserted into the opening wedge osteotomy site.[25] Although no intra-articular fractures were reported in either technique, the cost and unavailability of such complex devices hinder their routine application.

CONCLUSION

In the current technical report, we described a quite simple and applicable technique using readily available tools to mitigate intra-articular fractures during HTO. Insertion of subchondral K-wires before implementation of the desired osteotomy will not only decrease the risk of intraoperative LTP fractures but also keep the intra-articular fracture, if it occurs, undisplaced until definite fixation is achieved. Nevertheless, a large-scale case series is necessary to support our conclusion.

AUTHORS' CONTRIBUTIONS

ES and AA carried out the conception and technique idea and performed the surgery. AMA and HT carried out data acquisition and performed the literature search. All authors drafted the manuscript and critically reviewed and approved the final draft, and responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

The Institutional Review Board approval is not required.

DECLARATION OF PATIENT CONSENT

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

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY FOR MANUSCRIPT PREPARATION

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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