

Acute Correction of Varus Knee by Biplanar Medial Opening-Wedge High Tibial Osteotomy and Fixation with TomoFix Plate

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Abstract

Background: Biplanar medial opening wedge high tibial osteotomy (MOWHTO) is a treatment method that allows adequate correction of symptomatic varus knee deformity. However, MOWHTO tends to decrease patellar height and increase the posterior tibial slope, which can affect the knee joint stability. **Objective:** The aim of this study was to describe the technique of biplanar MOWHTO and fixation by TomoFix plate, as well as to evaluate the accuracy of the planned correction and the postoperative tibial slope. **Patients and Methods:** This prospective cohort study was conducted on patients who presented with varus knee deformity and underwent biplanar MOWHTO and fixation by TomoFix plate during the period from March 2016 to March 2017. Assessment of patients included pre- and postoperative Knee and function scores, mechanical femorotibial angle (mFTA), posterior tibial slope angle (pTSA), range of motion (ROM) and radiological evaluation of the healing of the osteotomy site. **Results:** The recruited patients were 13 (8 men and 5 women), with average age 31.7 years old. The knee and functional scores improved from the preoperative mean of 45 and 41 to the postoperative mean of 85 and 72 points, respectively. The average knee flexion was 115 degrees, which at the final follow-up remained unchanged except for one case. The mean preoperative mFTA was 13.5° varus and decreased postoperatively to a mean of 3° valgus. The average postoperative follow-up period was 12 months (10 - 18 M). **Conclusion:** The biplanar MOWHTO allows preservation of posterior tibial slope while correcting the varus knee adequately.

Keywords

Varus Knee, Biplanar, Medial Opening-Wedge, High Tibial Osteotomy,

1. Introduction

High tibial valgus osteotomy (HTO) is becoming an increasingly popular method to correct varus malalignment in patients with or without medial-compartment osteoarthritis (OA) of the knee. This procedure is considered to be joint preserving, as when performed precisely it can delay or eliminate the need for joint replacement [1] [2]. The goal of biplanar HTO is to decrease the load in the medial compartment of the knee by transferring the mechanical axis slightly lateral to the midline of the joint, thereby delaying the development and progression of OA [3] [4] [5]. HTO surgery includes the lateral closed-wedge high tibial valgus osteotomy (CWHTO) [6] and medial open-wedge high tibial valgus osteotomy (OWHTO) [7].

The CWHTO procedure used to be the most commonly used technique of HTO [8]. However, many drawbacks have been reported for CWHTO, including lateral-offset increases (due to horizontal osteotomy), decreased bone block distal to the lateral tibial plateau and shortening of the operated side after the surgery (with subsequent discrepancies in leg lengths) [9] [10]. The CWHTO procedure may also be complicated by delayed union at the osteotomy site due to loss of opposition between the area on the proximal and distal fragments; therefore, the alignment should be maintained for a long time until bone healing is achieved.

Recently, the MOWHTO procedure has gained more popularity [11] due to its advantages. Compared to CWHTO, the MOWHTO is easier, maintains more bone block, and it avoids injury to the peroneal nerve, proximal tibiofibular joint and the anterior leg compartment [12].

The AO principles recommend stable fixation of osteotomy to allow early and safe mobilization. The TomoFix knee osteotomy system is a plating system that allows stable fixation of osteotomies at the knee joint by supporting fixed angle stability between the screw and plate [13].

The purpose of this study was to describe the technique of biplanar MOWHTO and fixation by TomoFix plate, as well as to evaluate the accuracy of the planned correction and the postoperative tibial slope.

2. Patients and Methods

This prospective study was conducted in the Andalusia hospitals during the period from the 1st of March 2016 to the 1st of March 2017. Patients suffering from varus knee deformity were included in this study and were treated with biplanar MOWHTO and internal fixation by TomoFix plate. Informed consent was obtained from the patients or their parents prior to the procedure. Confidentiality of patients' data was maintained by assigning a code number to each patient

known only to the researchers.

Inclusion criteria: All patients who presented with symptomatic varus knee deformity, with or without medial gonarthrosis (idiopathic or posttraumatic varus deformity of the proximal tibia) were included in the study.

Exclusion criteria: Patients were excluded from the study if they had inflammatory arthritis, previous osteotomy of the same knee, bi-compartmental (medial and lateral) OA, fixed flexion contracture $> 25^\circ$, restricted range of motion/fixed deformities (knee flexion < 90 degrees), ligamentous instability, lateral tibial subluxation of more than 1 cm or medial compartment tibial bone loss of more than 2 or 3 mm.

2.1. Preoperative Planning

Patients' characteristics, including age, gender, body mass index (BMI) and side, were recorded. The measurement of mechanical femorotibial angles (mFTAs) were obtained using plain anteroposterior radiographs with full-leg length, weight bearing view. The radiographs were taken with the patients standing on both legs and the knee joints fully extended.

The amount of required correction (target correction angle) was determined by drawing a line from Fugisawa point to the center of femoral head and another line to the center of knee joint [14] The Fugisawa point is located at 62.5% of the tibial plateau from the medial tibial articular margin [15].

2.2. Surgical Technique

The same surgical procedure was applied in all cases and biplanar osteotomy was carried out according to the technique recommended by the AO principles [9]. (Figure 1) In all cases, an ascending and transverse biplanar medial open wedge osteotomies were performed with the use of insertion bone grafts. Fixation by locked plates was done to stabilize osteotomy using TomoFix® system (Synthes, Solothurn, Switzerland) (Figure 2).

2.3. Technical Details of the Biplanar MOWHTO Procedure

Patient's position and incision: The patient was placed in supine position on a radiolucent operating table. The anatomic landmarks (medial joint line, upper border of pes anserinus, course of the medial collateral ligament and tibial tuberosity) were marked on the skin. A longitudinal incision, 6 to 7 cm in length, was performed midway between the tibial tuberosity (TT) and the posteromedial border of the tibia. The incision started half an inch distal to the joint line and was extended to the tendons of pes anserinus. A Hohmann retractor was inserted between the superficial medial collateral ligament and the posterior cortex of the tibia (Figure 3). The distal end of the patellar tendon was clearly visualized to allow planning of the ascending and transverse cuts of the biplanar osteotomy [16].

Biplanar medial opening wedge osteotomy: The starting point of osteotomy was the upper border of the pes anserinus. Under the c-arm image, two parallel

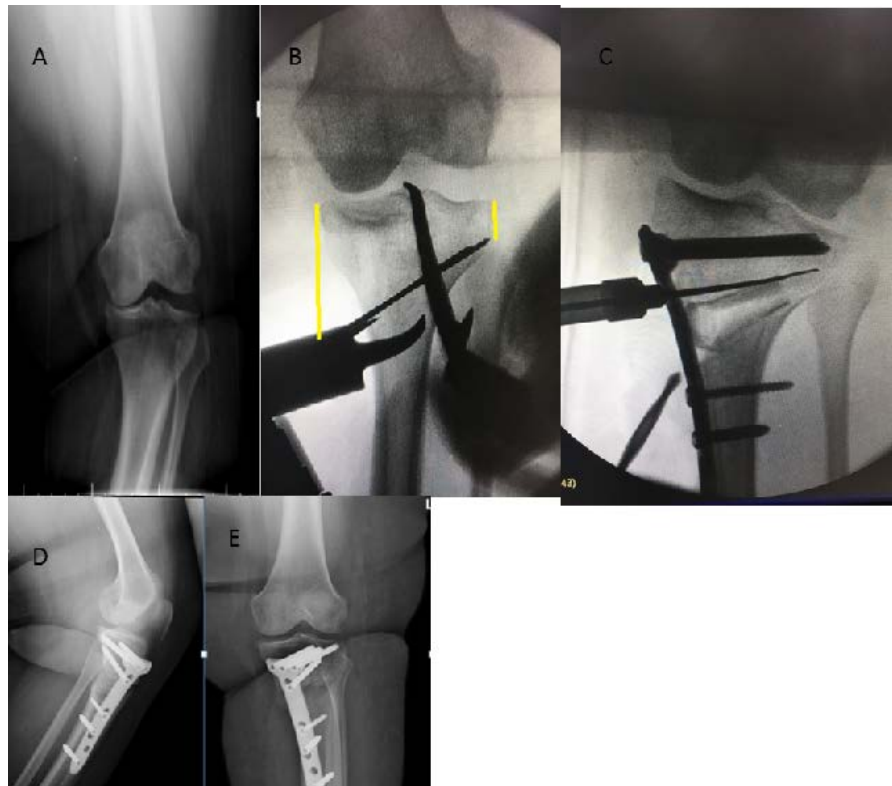


Figure 1. (A) AP standing view of knee with severe varus deformity; (B) Oblique k wire directed to head of the fibular without penetration to lateral cortex, arrow line 1 cm on lateral cortex from joint line; (C) Left knee, medial view Locking Tomfix HTO plate. Osteotomy gap filled with tricortical synthetic allograft; (D) Postoperative radiographic AP and lateral with correction of varus deformity Note that Measurement of posterior tibial slope has been made.



Figure 2. (A) (B) Photo view showing pre and postoperative biplanar osteotomy fixed by Tomofix plate both knee, right knee more than 1 y; (C) Postoperative X-ray right knee AP and LAT with overcorrection about 3° with bone healing at osteotomy side and rigid plate.



Figure 3. (A) Photo standing position showing Rt more varus knee; (B) Full-weight-bearing long-leg standing (Scanograms) anteroposterior (AP) radiographs showing severe varus knee on right sid; (C) Intraoperative photoshow win: Right knee, medial view. A 2.4-mm K. guidewire is placed in the medial cortex of the tibia, aimed toward the tip of the fibular head in a proximal and posterolateral direction, both wires must run in parallel and aim towards the hinge point; (D) Osteotomy gap filled with tricortical iliac bone crest allograft (E) Postoperative X ray AP and LAT knee with corrected osteotomy and Tomofix plate, with slight increase of posterior tibial slope.

Kirschner wires were inserted obliquely directed from medial to the lateral hinge. The lateral hinged point was the upper end of fibular head. Care was taken to avoid penetration of the lateral cortex to preserve the hinged point [17]. The ascending osteotomy cut was made parallel to the anterior cortex of the tibial shaft about one inch behind the tibial tuberosity. The transverse cut was made parallel to tibial plateau to ensure good bony contact in the area of the ascending cut after opening the osteotomy 110° to the transverse osteotomy [17] (Figure 3).

After achieving biplanar the osteotomies, the gap was spread gradually using chisels and a specially calibrated spreading device. When the measurement of the gap was acceptable and equal to the preoperative planned angle, the laminar spreader was inserted to save the realignment position until the cable line as-

sessed the mechanical axis by connecting the hip center to the ankle center, passing through the knee center laterally [15] (Figure 3).

Filling of the osteotomy gap was achieved using allograft or autograft tricortical strut mixed with autologous bone marrow or bone chips. Under fluoroscopy, the prepared plate was inserted medially and the shaft portion was aligned with the tibial diaphysis, in order to prevent the occurrence of anterior or posterior cortical overhang. Eight locked holes were used in the TomoFix device (four proximal and four distal), with three of them being unicortical. Conventional plate was inserted firstly to contour the plate. In addition, another lag screw was inserted through the first distal hole below the osteotomy after proximal fixation in order to functionally compress the lateral hinged cortex of the osteotomy and to eliminate any potential instability in this area [17] (Figure 3).

2.4. Post-Operative Care and Follow-Up Protocol

Ice bag and intermittent venous compression were applied to relieve the swelling. Continuous passive motion (CPM) and muscle-strengthening exercises were started on the second day after surgery. Before six weeks, partial weight bearing with walker was allowed based on the amount of pain. After six weeks, full weight-bearing was allowed.

The final evaluations of the patients were performed by measuring the American Knee Society (AKS) knee and function scores, as well as assessing the mFTAs and changes in pTSA. The pTSA was measured between the medial tibial plateau and the posterior tibial cortex [17].

2.5. Statistical Analysis

Statistical analysis was carried out using SPSS for Windows (version 17.0; SPSS, Chicago, IL). Categorical data (gender, site, complications, graft used) were summarized as number and frequency. Numerical data were all normally distributed (as assessed by Shapiro Wilk test); they were summarized as mean \pm standard deviation ($M \pm SD$). Comparison between pre- and postoperative measurements was done using paired T test. Statistical significance was considered at p value < 0.05 .

3. Results

Thirteen patients underwent biplanar MOWHTO during the study period, 8 men and 5 women. Their age ranged between 17 and 45 years old, with average age of 31.7 ± 9.5 years old. Their BMI ranged between 20.5 and 35, with average of 29 ± 3.7 Kg/m². Varus deformity affected the right knee in 6 patients (46.2%), left knee in 4 patients (30.8%) and both knees in 3 patients (23.1%) (Table 1).

The knee score improved from the preoperative mean of 45 (range 32 - 60) to postoperative mean of 85 points (range 49 - 92). The mean preoperative functional score was 41 (range 32 - 58) and mean postoperative functional score was 72 points (range 52 - 93). The mean preoperative TFA was 13.5° varus (range 7 -

Table 1. Patients' characteristics. Age and BMI are summarized as mean \pm SD (range). Gender and side are expressed as number (%).

Patient	Age	Gender	BMI	Side
1	34	M	35	Bilat
2	19	M	34	RT
3	30	F	28	RT
4	25	F	26.5	RT
5	18	F	26.5	Bilat
6	45	M	27	Bilat
7	39	M	28.5	LT
8	42	F	30	RT
9	17	M	29.5	LT
10	38	M	31.5	RT
11	40	M	20.5	LT
12	29	F	31	LT
13	36	M	29	RT
Summary statistics	31.7 \pm 9.5 (17.0 - 45.0)	Male 8 (61.5%) Female 5(38.5%)	29.0 \pm 3.7 (20.5 - 35.0)	Bilat 3 (23.1%) Rt 6 (46.2%) Lt 4 (30.8%)

M: male; F: female; BMI: body mass index; Bilat: bilateral; Rt: right; Lt: left.

20) and decreased significantly after the surgery to a mean of 3.2° valgus (range -2 - 8; $p < 0.001$). The preoperative average knee flexion was 121 (ranged from 100 to 140), which at the final follow-up remained unchanged except for one case that was complicated by limited full extension about 5°. Overcorrection was observed in one patient only. The mean pTSA changed significantly from 4° preoperatively, to 6.5° postoperatively ($p = 0.015$). The mean time of bone union was at 4.7 months, with a range between 3 and 6 months after osteotomy. Correction was maintained for all patients postoperatively, except for one patient who presented by delayed union at 5 months and improved by knee brace and follow up until bone healing. Skin irritation occurred in one case only. The mean time to full weight-bearing was 5.6 weeks (range 4 - 8 weeks). Superficial wound infection occurred in one case and was treated successfully with appropriate antibiotics (**Table 2**).

4. Discussion

The current study demonstrates that acceptable correction of the mFTA was achieved by biplanar MOWHTO and fixation by TomoFix plate. Furthermore, the knee function improved significantly (improved knee and function scores) at the final follow-up. Previous studies have reported similar results.

The mean corrected angle of mFTA was 3.3 in our study, with a range between -2 to 8 degrees. The reported corrected angle of mFTA ranged from 6 to

Table 2. Comparison of mean TFA and pTSA pre- and post-operatively, ROM, FW bearing, time of union, bone graft, and complications.

Patient	TFA		pTSA		ROM	FW bearing	Time of union	Bone graft	Complications
	Pre	Post	Pre	Post					
1	7	1	5	7.2	100	8	4	Auto	
2	12.5	3	2.5	8	110	4	5	Synth	skin irritation
3	13	4	3	12	105	6	6	Synth	
4	15.5	6	5.4	9.7	120	5	3	Auto	
5	15	5	3.5	4	130	6	4	Synth	
6	20	7	4	5.5	120	7	5	Synth	
7	13.5	0	6	6.5	135	4	4	Auto	limited extension
8	10	-2	4	3	120	4	5	Synth	
9	10	1	5	3.5	115	5.5	6	Synth	
10	9.5	6	4.5	4	125	6.5	4.5	Synth	superficial infection
11	16	8	3	10	140	6.5	3.5	Synth	overcorrection
12	17	2	2.8	9	125	5.5	6	Synth	
13	16	1	5.7	6.7	130	4.5	5	Synth	
Summary statistics	13.5 ± 3.6 (7.0 - 20.0)	3.2 ± 3.0 (-2.0 - 8.0)	4.2 ± 1.2 (2.5 - 6.0)	6.9 ± 2.8 (3.0 - 12.0)	121 ± 12 (100 - 140)	5.6 ± 1.3 (4.0 - 8.0)	4.7 ± 1.0 (3.0 - 6.0)	Auto 3 (23.1%) Synth 10 (76.9%)	
	P < 0.001* #		p = 0.015* #		p = 0.039*	p = 0.039*	p = 0.042*		

TFA: tibio-femoral angle; pTSA: posterior tibial slope angle; Pre: preoperative; Post: postoperative; ROM: range of motion; FW: full weight; Synth: synthetic; #: paired T test; * significant at $p < 0.05$.

14 degrees with good clinical outcomes. Overcorrection occurred in one patient only in the present study. Over and undercorrection were reported by previous studies, with contradictory clinical results. Hernigou *et al.* [18] reported that an overcorrection of more than 6° was associated with progressive articular degeneration; an undercorrection was associated with poor patient satisfaction and increased the symptoms of the medial compartment OA. On the contrary, overcorrection of the mFTA was recommended by Ivarsson *et al.* [19]. Rudan and Simurda [20] found that overcorrection (with the mFTA above 15°) seemed to achieve excellent clinical results, but the patient was not satisfied cosmetically; undercorrection was associated with more failure of the procedure.

The average knee flexion in our patients remained unchanged till the final follow-up period, except for one case that had limited full extension that may be attributed to increased tibial slope in this case by about 10 degrees.

In the current study, bone graft was used in all patients, either tricortical synthetic (10 cases) or autologous (3 cases) grafts. Gaasbeek *et al.* [21] have observed that the TCP filler that was used with MOWHTO was absorbed, with the new bone being completely remodeled and incorporated into the native bone. In patients who are at increased risk of non-union, such as smokers and obese pa-

tients, autologous graft from iliac bone are recommended to be used [21]. However, Staubli and Jacob [22] and Zaki and Rae [23] reported the achievement of good bone healing without bone graft or substitute in a TomoFix plate group.

The common drawbacks of MOWHTO were evaluated in this study and their incidence was low, including skin irritation, limited extension, superficial infection and overcorrection, which occurred in one case each. Changes in tibial slope are the most common drawbacks reported by previous studies. Tibial slope is crucial for maintaining the knee joint stability and biomechanics [24]. Generally, tibial slope tends to increase after OWHTO and to decrease after CWHTO [25]. The increase in tibial slope is due to the anatomical characteristics of the proximal tibia. It was found that an opening wedge with equal heights of the anterior and posterior gaps could increase the sagittal tibial slope [26] [27]. Increased pTSA may disturb the corrected coronal plane [28] and could result in more tension on cruciate ligament and destabilization of the knee joint [29] [30]. Tibial slope changes might also progress to early OA. In order to reduce the increase in tibial slope, the anterior opening gap is recommended to be 1/2 to 2/3 of the posterior gap [26] [27].

The undercorrection in the frontal plane in cases of severe varus deformity was shown by Asada *et al.* [28] to increase pTSA. We found that pTSA was maintained postoperatively. Other previous studies have also reported an increase of pTSA after OWHTO that ranged from 2 to 4 degrees [28] [31] [32] [33]. TomoFix plate fixation allowed for maintenance of pTSA in the sagittal plane. Proximal screws were fixed first, followed by a single screw in the distal plate. Thereafter, the pTSA was adjusted guided by fluoroscopy, with the knee joint in the extended position. Lastly, a screw was inserted in the remaining distal hole to complete the fixation.

Another reported drawback of MOWHTO is the decrease in patellar length which was suggested by Goutallier *et al.* [16]. This change results from destabilization and lateralization of the tibial tuberosity. Moreover, Amzallag *et al.* [34] showed that patellar height decreased more than 20% in one third of patients after OWHTO. Therefore, standard OWHTO is contraindicated in patients with patella baja or infera [34]. The patellar height was not affected in the present study.

There was no screw loosening or implant failure in this study as we used the TomoFix locking system. The use of TomoFix plate provided many advantages as it enabled rigid fixation, early range of motion, weight-bearing [28] and maintenance of pTSA [35] [36]. However, there are some disadvantage of TomoFix system that includes extensive skin irritation, prominent implant and soft tissue incision. Skin irritation was observed in one case in this study and was attributed to prominent implant and subcutaneous inflammation.

This study was subject to some limitations. The number of cases was small and follow-up period was short. Future studies should be conducted on larger sample size and with patient follow-up for longer duration.

5. Conclusion

Biplanar MOWHTO accompanied with stable fixation using a TomoFix plate produced good clinical outcomes with low incidence of complications, without affecting patellar height or the posterior tibial slope. In order to minimize the rate of complications, surgeons must perform accurate planning before the surgery, follow the surgical technique meticulously and provide ample fixation using rigid stable implants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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