



Satisfactory functional and radiological outcomes can be expected in young patients under 45 years old after open wedge high tibial osteotomy in a long-term follow-up

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Abstract

Purpose To report the long-term outcomes of medial open wedge high tibial osteotomy (MOWHTO) for the treatment of medial compartment knee osteoarthritis in patients younger than 45 years old. It was hypothesized that the correction of knee alignment would result in preservation of knee function in a long-term follow-up.

Methods Patients under 45 years old, who underwent MOWHTO for symptomatic medial compartment knee osteoarthritis between 2001 and 2005 were retrospectively reviewed after a minimum of 10 years. The osteotomy was performed utilizing a locking plate without the use of bone graft. Patients were evaluated pre- and postoperatively using the International Knee Documentation Committee Score, the Oxford Knee Score, the Knee injury Osteoarthritis Outcome Score and the Short Form-12 Score. Standardized standing whole-limb radiographs were also obtained to assess mechanical tibiofemoral angle (mTFA) and the grade of osteoarthritis.

Results A total of 20 patients (18 males, 2 females, mean age 35.4 years) with a mean follow-up of 12.3 years were included in the study. During the follow-up period, one patient required conversion to total knee replacement (95% survival rate). All clinical outcome scores (IKDC, KOOS, OKS, and SF-12) significantly improved postoperatively ($p < 0.05$), with no significant deterioration over time. Preoperative varus alignment with an mTFA of $-5.8 \pm 2.4^\circ$ was corrected to $2.5 \pm 1.9^\circ$ immediately after surgery ($p < 0.05$), and remained $2.2 \pm 1.7^\circ$ at the last follow-up. Furthermore, no significant radiographic progression of osteoarthritis was observed.

Conclusions MOWHTO with a locking plate is an effective joint preservation method to treat medial compartment OA in active patients less than 45 years. Clinical and radiological results are satisfactory and the survival rate is 95%, 12 years after the procedure.

Level of evidence Level IV therapeutic, retrospective, cohort study.

Keywords High tibial osteotomy · Open wedge · Osteoarthritis · Long term · Young patients · Knee alignment · TomoFix

Abbreviations

OA	Osteoarthritis	IKDC	International knee documentation committee
HTO	High tibial osteotomy	OKS	Oxford Knee Score
MOWHTO	Medial open wedge high tibial osteotomy	KOOS	Knee Injury Osteoarthritis Outcome Score
mTFA	Mechanical tibiofemoral angle	SF-12	Short Form-12
		TKA	Total knee arthroplasty
		LCWHTO	Lateral closing wedge high tibial osteotomy

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Introduction

Symptomatic knee osteoarthritis (OA) in young population is challenging. The disability can be significant due to their relatively higher activity levels. The real challenge for these young and active patients with symptomatic knee OA

is lack of definitive solution, whereas older patients typically have the option of arthroplasty. While there is still no absolute cure, patients with medial compartment knee OA present typical mechanical abnormalities, which may be a reasonable target to tackle. In knees with varus alignment, increased medial tibiofemoral compressive loads and higher knee adduction moments during walking are reported [3, 19, 34]. In the absence of ligamentous instability, unloading osteotomy can be considered for mild-to-moderate knee OA with malalignment [14]. Osteotomy may be performed above or below the knee to redirect the load through the joint into the relatively unaffected compartment. High tibial osteotomy (HTO) has been a common procedure in particular to treat symptomatic knee OA with varus alignment in young patients when conservative treatment fails. This is achieved by overcorrecting the varus alignment to 2°–6° of valgus [6, 36]. Historically, despite its theoretical benefits, HTO had not been widely accepted, presumably because it was predominated by uni-compartmental and total knee arthroplasty. In addition, older devices for MOWHTO had high rate of mechanical failure [29, 35]. More recently, the technique of medial open wedge high tibial osteotomy (MOWHTO) has been popularized with the use of advanced internal fixation devices (e.g., Tomofix™ plate, DePuySynthes, West Chester, PA, USA) [7]. The procedure is less complicated compared to closed wedge osteotomy, allowing early weight bearing due to the use of strong internal fixation. The procedure offers short-term pain relief, and due to realignment, prevention of osteoarthritis progression in the long term. Excellent short- to mid-term outcomes have been reported [6, 7, 13]. However, to our knowledge, no studies have reported long-term outcomes (mean follow-up more than 10 years) of young patients (45 years old or younger) who underwent MOWHTO.

The purpose of the study, therefore, was to investigate clinical and radiological long-term outcomes following MOWHTO using TomoFix plate for medial compartment knee OA in patients aged younger than 45 years. It was hypothesized that patients would demonstrate preservation of radiological alignment with minimal arthritic progression, along with reasonable clinical, functional and quality of life outcomes.

Materials and methods

This was a retrospective, with prospectively collected data, study of patients who underwent MOWHTO with the use of TomoFix™ plate system (DePuySynthes, West Chester, PA, USA) between 2001 and 2005. Informed consent was obtained from all the participants.

Patients younger than 45 years old with symptomatic medial compartment knee OA, were examined by the senior author (M.H.) in the outpatient clinic, scheduled for MOWHTO and enrolled in the study. Knee alignment and the grade of OA were assessed on plain radiographs. MOWHTO was indicated if conservative treatment failed in a symptomatic patient with medial compartment knee OA, if mechanical axis deviation was more than 4° in varus, and if medial compartment OA was grade 3 or milder according to Ahlbäck classification [1]. Patients were excluded if there was (1) symptomatic OA in lateral compartment or patellofemoral joint (excluded by MRI), (2) inflammatory arthritis, (3) significant loss of knee joint range in flexion (less than 100°) or in extension (less than –10°), (4) ligamentous instability, (5) obesity with a body mass index greater than 30, (6) significant psychological disorder, or (7) inability to communicate in Greek or English language. During the enrollment period, a total of 20 patients (18 males and 2 females) with a mean age of 35.4 years (28–44) at the time of surgery were included and followed for a minimum of 10 years. Five of these patients underwent an anterior cruciate ligament reconstruction and six of them a medial meniscectomy before HTO.

Preoperative planning and surgical procedure

Preoperative planning was routinely performed on anteroposterior standing full lower limb radiographs by measuring mechanical tibiofemoral angle (mTFA), which determined the correction angles. Our aim was to correct the mTFA to 2°–3° of valgus. The mechanical axis was designed to pass across the knee at the Fujisawa point (a point at 62% of the cross-sectional diameter of the tibial plateau) [14], providing slight overcorrection. Typical correction angles ranged between 8° and 12°.

All surgeries were performed by one experienced surgeon (M.H.). After sufficient exposure of the proximal tibia, a biplane osteotomy was utilized with an angle of 110°–120° between them in the coronal plane to increase primary stability [23]. The osteotomy was internally fixed with a TomoFix™ plate without use of any type of bone graft or synthetic bone substitutes. Patients were allowed partial weight bearing with 20 kg for 6 weeks and then progressed to full weight bearing.

Routine follow-up was scheduled at 6 weeks, 3 months, 6 months, 1 year and each year thereafter.

Clinical outcome and radiological assessment

Clinical, functional scores and scores measuring quality of life completed preoperatively, at 1 year and at final follow-up. These included International Knee Documentation Committee Score (IKDC), Oxford Knee Score (OKS),

Knee injury Osteoarthritis Outcome Score (KOOS) and Short Form-12 (SF-12). IKDC is a subjective Evaluation Form, studying the function of the knee joint in terms of pain (range 0–10), function, quality of life and level of activity. Oxford Knee Score contains 12 questions regarding the functionality and pain of osteoarthritic knees. KOOS is an extensive patient reported score consisting of five domains: pain, other symptoms, function in daily life, in sport and leisure, quality of life [8]. SF-12 assesses general health-related quality of life and has a mental and physical component [21].

Standardized full length radiographs were evaluated at the same time including immediate postoperatively. Mechanical tibiofemoral angle (mTFA) was measured on anteroposterior standing full lower limb radiographs by drawing lines from the center of femoral head to center of the knee and from the center of the knee to the center of the ankle joint. Ahlbäck classification [1] modified by Koshino [22] was utilized for grading knee OA on standing anteroposterior knee radiographs.

Intraoperative complications such as fracture of the lateral cortex or the proximal tibial fragment were recorded. Postoperative complications that monitored included compartment syndrome, peroneal nerve palsy, deep venous thrombosis, infection (superficial or deep), complex regional pain syndrome, delayed union, malunion or nonunion.

IRB approval

The study was approved by the local medical ethical committee (University Hospital of Larissa, 15–13/11/2016).

Statistical analysis

Descriptive statistics were applied. Paired t test was utilized to compare preoperatively and postoperatively scores, and radiographic measurements. Statistical significance was set to $p < 0.05$. Data analysis was performed using SPSS statistical software version 21.0, SPSS Inc., Chicago, Illinois. No sample size was calculated because of the retrospective nature of the study. There was no control group in the study.

Results

Clinical findings

A total of 20 patients (18 males, 2 females) were included in the study. Mean age at surgery was 35.4 years (range 28–44) and patients had a mean follow-up of 12.3 years (range: 10–15 years). No patient dropped off the study. Of the 20 patients who underwent this surgery between 2001 and 2005, only one patient had to be converted to total knee replacement. Therefore, the survival rate of the

procedure was 95% in this long-term follow-up. All clinical scores (IKDC, KOOS, Oxford Knee Score and SF-12) showed a statistically significant improvement from pre- to final postoperative evaluation (Table 1).

Radiological findings

Healing of the osteotomy site, with evidence of porosis in at least 3 out of 4 cortices, was observed after a mean of 5.5 months (4–7.5 months). No cases developed narrowing of the lateral joint space during the follow-up period. Preoperative varus deformity was satisfactorily corrected in all knees. The mTFA was corrected to slight valgus, from $-5.8^{\circ} \pm 2.4^{\circ}$ preoperatively to $2.5^{\circ} \pm 1.9^{\circ}$ postoperatively $p < 0.05$. This correction remained almost unchanged (only minor deterioration) at 1 year (mTFA = $2.3^{\circ} \pm 1.8^{\circ}$), and at the final follow-up after a mean of 12 years (mTFA = $2.2^{\circ} \pm 1.7^{\circ}$) (Fig. 1). No deterioration of the radiographic degree of the arthritis was observed in any patient, except one that progressed from grade 2 to grade 4 according to Ahlbäck classification. This patient had previous anterior cruciate ligament reconstruction and partial medial meniscectomy. Although the mechanical axis was fully corrected, the patient underwent total knee arthroplasty 9 years after MOWHTO.

Complications

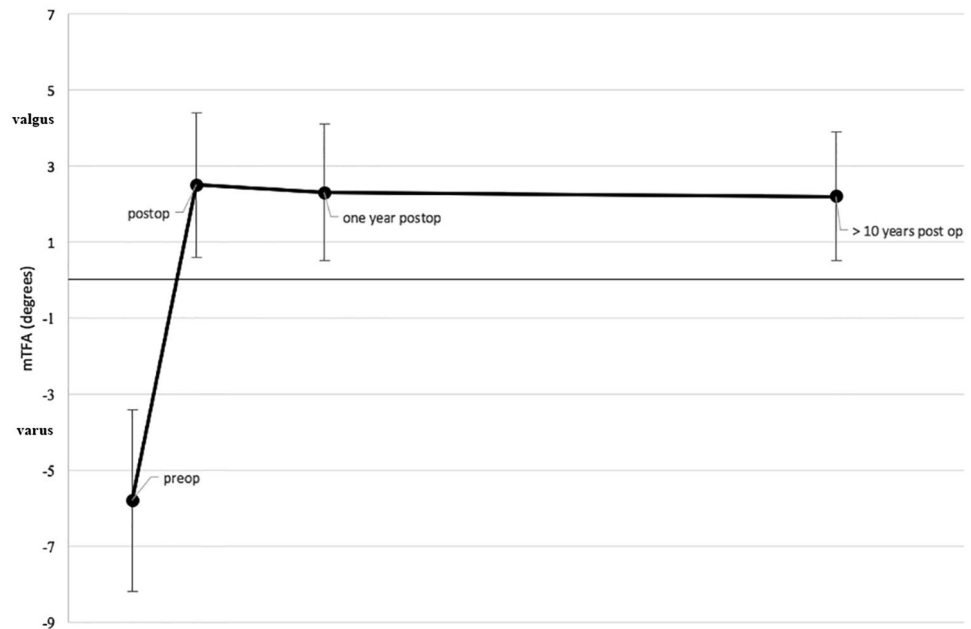
No complications directly associated to the procedure occurred in this series of patients. We did not observe any intraoperative complication such as fracture of the lateral cortex or of the proximal fragment of the tibia. No postoperative complication occurred compartment syndrome, peroneal nerve palsy, delayed union of the opening gap, deep venous thrombosis, superficial or deep infection, complex pain regional syndrome.

Table 1 Clinical outcome scores

	Preoperatively	One year postoperatively	Final follow-up (> 10 years postoperatively)	<i>p</i> value
IKDC	42.5 (± 14)	71.2 (± 11)	68.2 (± 13)	$p < 0.05$
KOOS	40.8 (± 16)	72.6 (± 12)	69.4 (± 14)	$p < 0.05$
OKS	20.4 (± 6)	34.2 (± 4)	33.9 (± 4)	$p < 0.05$
SF-12 PCS	31.7 (± 5)	42.7 (± 5)	42.5 (± 4)	$p < 0.05$
MCS	36.6 (± 6)	50.6 (± 5)	53.9 (± 6)	$p < 0.05$

Mean values (standard deviation)

Fig. 1 The mechanical axis was corrected from varus to slight valgus. No deterioration was observed throughout the follow-up period



Discussion

The most important finding of the present study was that satisfactory clinical and radiological outcomes were found in young patients undergoing MOWHTO with the use of a locking plate. This concurs with the hypothesis that the correction of mechanical axis would have favorable long-term survival of the native knee in patients less than 45 years old with early medial compartment OA of the knee. According to the present study, the clinical and the radiological outcomes remain stable and satisfactory even after 12 years. The correction of the mechanical axis (mTFA) was kept almost constant after 12 years, preventing the progression of arthritis on the medial or the development of arthritis on the lateral compartment of the knee joint.

Osteoarthritis of the knee is generally considered to be a mechanical phenomenon. In the young adult, meniscal injury or meniscectomy, osteochondral injury, and ligamentous insufficiency can predispose to the development of arthritis [2]. Total knee arthroplasty (TKA) have been shown to improve functional outcome scores in the older and less active patient. However, the younger, more active patient with knee arthritis presents a difficult problem due to increased demands and expectations [24]. Instability, which often is combined with knee arthritis in young patients, adds another dimension to this difficult to treat problem. Performing a TKA in this population of patients ensures that they will undergo one or even two revisions during their lifetime, even with the best performing arthroplasty implants [4]. Registry data show that young patients have higher revision rate [4, 27]. MOWHTO is a joint preserving treatment, compatible with the young age of the patients. Many studies

have shown the improvement of symptoms of medial compartment arthritis with MOWHTO [9, 13]. This is important, especially to young and active patients who want to avoid the total knee arthroplasty in young age. The appropriate correction or slight overcorrection of femorotibial alignment is the key for the long-term success of the procedure.

MOWHTO with TomoFix plate or other devices have shown satisfactory results in the short-, mid- and long-term follow-up (Table 2). Survival ranges from 80 to 98% at 5 years, to 74–86.6% after 10 years. Complications varied between 0 and 31%. These studies included not only young but also older patients. Hui et al. [17] and Flecher et al. [12] have shown that older age is a risk factor for failure of the osteotomy. We believe that the good results in our study with survivorship of 95% after 12.3 years are related to the young age of the patients. No study with long-term follow-up of young patients under 45 with MOWHTO has been reported in the literature according to the author's knowledge.

In the study of Duivenvoorden et al. [10], complications developed in seventeen patients (38%) in the opening-wedge group and in four (9%) in the closing-wedge group. Most of the complications in the opening-wedge group were related to the donor site of the bone graft (iliac crest). To avoid this complication, we did not use any bone graft in our study. One of the most dreadful intraoperative complications is the fracture of the opposite cortex. This fracture occurs more often in LCWHTO [41] and may result in recurrent varus deformity [25] and adverse outcomes [18]. The development of newer anatomical angular stable (locking) plates fueled, however, the interest for MOWHTO. The TomoFix plate is one such anatomical locking plate with favorable biomechanical characteristics [15, 37]. TomoFix plate provides

Table 2 Studies of medial open wedge high tibial osteotomy

References	Follow-up	Number of osteotomies	Method of assessment	Results	Complications
Chun [7]	2 years	92	Knee Society Knee Score and Knee Society Function Score	95.5 ± 5.4 95.0 ± 7.6	26%
Floerkemeier [13]	3.6	553	Oxford Knee Score	43 (range 8–48)	6%
Niemeyer [26]	3 years	69	International Knee Documentation Committee Score, Lysholm Score	72.72 ± 17.15 79.14 ± 16.63	8.6%
Woodacre [42]	8.4 years	115	Survival of implants	80% at 5 years	31%
Ihle [20]	1.5 years	120	SF-36 (MCS and PCS)	PCS = 45.9 ± 13.5 MCS = 49.5 ± 12.4	8%
Staubli [37]	9 months	92	VAS Score	0.5–1.5	4%, 3/92 conversion to TKA
Takeuchi [39]	1.6 years	57	American Knee Society Score and Function Score	91.7 ± 6.9	5%
Zaki [44]	5	50	Oxford Knee Score Knee Society Score Survival (TKA)	22 (range 17–31) 82 (range 45–92) 98% at 5 years	6%
Ruangsomboon [31]	6	50	Survival (TKA)	95.5% at 4 years	6%
van Egmond [40]	7.9	25	Knee Society Score VAS pain WOMAC Survival (TKA)	155 (± 34.9) 4.1 (± 2.6) 36.2 (± 26.8) 81.3% at 7.9 years	–
Polat [28]	11.7	88	Knee Society Score Survival (TKA)	70.4 ± 10.7 86.6% at 11.7 years	–
Yoo [43]	8.8	32	Lysholm Knee Score American Knee Score	88.7 ± 6.4 86.6 ± 5.9	0%
Herignou [16]	11.5	93	Recurrent pain Reoperation	45% at 10 years 18% at 10 years	–
Saragaglia [32]	10.4	124	Lysholm KOOS Survival (TKA)	88 ± 12.7 86 ± 14.6 74% at 10 years	24%

satisfactory stability of the osteosynthesis even in cases of delayed union of the osteotomy site [37]. There is no need for bone grafting. Additionally, the plate permits early weight bearing and accelerated rehabilitation. Loss of correction may lead to suboptimal results [5, 36]. It must be noticed that premature removal of the implant, i.e., before 12 months, can lead to loss of correction, especially when the mechanical axis is under corrected [30]. Better clinical outcomes and lower implant-related complications have been reported with TomoFix plate [7]. It is reported that the plate is stable enough even after fracture of the lateral cortex [38]. In the present study, no mechanical failures of implants or loss of correction occurred in this study of high demand young patients.

Cartilage damage has been linked with knee osteoarthritis. Varus malalignment has been shown to increase the rate of medial meniscus pathology, increasing the loading in the medial compartment due to a failed meniscus and leading to cartilage damage and OA [11]. In the MOST study, it was reported that varus alignment was correlated with cartilage

damage on MRI in the medial compartment with a dose effect [33]. This study concurs with the above epidemiological observations in the sense that the correction of alignment protects the knee from further cartilage damage for many years. Only one patient had to be converted to TKA in the present study.

The strength of the present study is that it adds some useful insights in a difficult problem (young patients with symptomatic medial knee arthritis). This case series included only young active patients (specific population) that treated with the same technique and the same implant, evaluated in a long-term follow-up. The satisfactory clinical and radiological results without major complications, after a mean of 12 years reassures that MOWHTO is a safe and effective treatment, for a bothersome problem. Surgeons can add the procedure to their armamentarium of treating young adults with medial knee osteoarthritis and patients can be informed about the good prognosis of the procedure.

Limitations of the study include the small number of patients, its retrospective nature and the lack of a control

group. The small number of patients precluded the statistical analysis for finding risk factors that predicted failure of the treatment.

Conclusion

MWOHTO with TomoFix plate is an effective joint preservation method to treat medial compartment OA in active patients less than 45 years. Clinical and radiological results are satisfactory and the survival rate is 95%, 12 years after the procedure.

Author contributions MH conceived, designed and co-ordinated the study, and critically reviewed the manuscript. PN collected data and analysed the data, and drafted the manuscript. AK drafted the manuscript and analysed the data. YO collected data and drafted the manuscript. ND collected data and drafted the manuscript. KN participated in the design of the study, and critically reviewed the manuscript. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interests Michael E. Hantes, Prodromos Natsaridis, Koutalos A. Antonios, Yohei Ono, Nikos Doxariotis, and Konstantinos N. Malizos declare that they have no conflicts of interest.

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Ethical approval Ethical approval was obtained for this study by the local ethical committee.

Informed consent Informed consent was obtained by all patients.

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