RESEARCH ARTICLE

Clinical and Functional Outcomes Following MOWHTO for Combined Tibial and Femoral Deformities in Varus Knees: A Retrospective Cohort Study

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Abstract

Objectives: Varus knee deformities involving both the tibia and femur can be addressed using proximal tibial osteotomy alone or in combination with femoral osteotomy; however, the outcomes have been inconsistent. Medial opening wedge high tibial osteotomy (MOWHTO) presents a viable alternative for correction. This study aims to evaluate the clinical and functional outcomes of MOWHTO in patients with combined tibial and femoral deformities.

Methods: We retrospectively analyzed 30 patients who underwent MOWHTO at Shafa Yahyaiyan Hospital, Iran University of Medical Sciences, between 2015 and 2021. In all cases, the procedure aimed to overcorrect the medial proximal tibial angle (MPTA) to 90 degrees, without addressing the femoral varus deformity. Preoperative and postoperative standing radiographs were used to measure the joint line obliquity angle (JLOA), joint line convergence angle (JLCA), hip-knee-ankle angle (HKA), MPTA, and mechanical lateral distal femoral angle (mLDFA). Functional outcomes were assessed using the Knee Society Score (KSS), Knee Injury and Osteoarthritis Outcome Score (KOOS), and Visual Analog Scale (VAS).

Results: The mean age of patients was 32.19 ± 11.63 years, with a mean follow-up duration of 39.38 months. MPTA increased significantly (90.53 ± 1.80 vs. 82.47 ± 3.66; p = 0.001), while the HKA and JLCA decreased significantly ($p < 0.05$). Functional outcomes, assessed by the KSS, KOOS, and VAS, showed significant improvement ($p < 0.05$). Although the JLOA increased by approximately 3 degrees postoperatively, this change was not clinically significant.

Conclusion: MOWHTO, with overcorrection of the MPTA to 90 degrees, demonstrated excellent short- to mid-term clinical and radiological outcomes. Although the follow-up duration was limited, the findings support the efficacy of MOWHTO in managing combined tibial and femoral deformities in patients with varus knee alignment

Level of evidence: III

Keywords: Biomechanics, Gait analysis, Malalignment correction, Mechanical axis deviation, Osteoarthritis, Patient-reported outcome measures, Radiographic evaluation

Introduction

Lower limb mechanical alignment plays a key role in preventing osteoarthritis and reducing knee joint degeneration.[1,2] Despite growing enthusiasm for knee arthroplasty and the widespread use of implants, which have led to a decline in osteotomy procedures,[3,4] there has been a renewed interest in osteotomy as a means to delay or prevent arthroplasty—particularly in younger patients with unicompartmental chondral damage and mechanical malalignment.[5]

Varus deformity, a common form of knee malalignment, is frequently associated with osteoarthritis.[6] Its etiology involves increased loading of the medial tibiofemoral compartment, which accelerates cartilage degeneration.[7-9] Varus alignment may result from deformities in the distal

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femur, proximal tibia, or both, and is often accompanied by lateral ligament dysfunction.[7,10,11] Previous studies have identified the medial proximal tibial angle (MPTA) and the mechanical lateral distal femoral angle (mLDFA) as key contributors to varus knee deformity.[12-14]

Current evidence suggests that medial opening wedge high tibial osteotomy (MOWHTO) is among the most effective treatments for addressing these deformities.[15-17] According to Dror Paley,[18] precise correction of varus deformity at its anatomical origin is essential; any deviation from this principle may result in joint line obliquity (JLO)—defined as the angle between a line parallel to the ground and a tangent to the tibial plateau,[19] which can contribute to progressive joint degeneration.[10,20]

Previous studies based on a medial proximal tibial angle (MPTA) of ≤95° have shown that only approximately 60% of patients achieve adequate alignment correction following high tibial osteotomy, to prevent joint line obliquity (JLO). Moreover, more than one-third of patients require a concomitant distal femoral osteotomy (DFO) to attain proper JLO.[10] Indications for combined tibial and femoral deformity correction include: (1) an estimated modified MPTA (mMPTA) >94° after proximal tibial osteotomy alone; and (2) mMPTA <87°, mechanical lateral distal femoral angle (mLDFA) >90°, and a required tibial correction wedge size >15 mm.[21] Conflicting results have been reported regarding the use of distal femoral osteotomy alone or in combination with high tibial osteotomy for varus knee correction.[22] Several studies have also suggested that combined procedures may be associated with a higher risk of complications.[23] In addition to the postoperative MPTA, compensatory changes in the hip and ankle joints may also influence JLO.[24]

Given the current evidence and the potential risks associated with double-level osteotomy, we adopted a treatment strategy using medial opening wedge high tibial osteotomy (MOWHTO) alone to correct combined tibial and femoral varus deformities. Our technique involved correcting the medial proximal tibial angle (MPTA) to 90°, thereby preserving joint line obliquity and minimizing complications. To avoid excessive correction and its potential impact on joint mechanics, we did not exceed an MPTA of 90°, thereby preventing joint line obliquity greater than 4°. We also avoided inducing secondary varus alignment that could necessitate more complex osteotomies. To the best of our knowledge, no previous studies have evaluated the outcomes of this approach in patients with concurrent distal femoral and proximal tibial deformities. Therefore, this study aims to assess the radiological, functional, and clinical outcomes of MOWHTO in the correction of combined varus knee deformities.

Materials and Methods

Patients, design and setting

This retrospective cohort study was approved by the Research Ethics Committee of Iran University of Medical Sciences (Approval No. IR.IUMS.REC.1402.238). It was conducted under the Declaration of Helsinki and the national regulations and ethical standards for medical research in Iran.

The study evaluated the medical records of patients who underwent medial opening wedge high tibial osteotomy (MOWHTO) for correction of combined tibial and femoral varus deformities at Shafa Yahyaiyan Hospital, affiliated with Iran University of Medical Sciences, between 2015 and 2021.

Inclusion and exclusion criteria

Eligible patients presented with varus knee deformity involving both the tibia and femur, defined by a medial proximal tibial angle (MPTA) < 87° and a mechanical lateral distal femoral angle (mLDFA) > 90°, accompanied by medial knee pain. Radiographic classification was limited to Kellgren–Lawrence grades 0 to 2. Inclusion criteria were age between 18 and 60 years and a minimum postoperative follow-up duration of 12 months. Exclusion criteria included a history of knee fractures, ligamentous injuries, or any neurological or rheumatological disorders.

Patients classified as Kellgren–Lawrence grade 3 or 4, as well as those falling under any grade of the Ahlbäck classification, were excluded.[25–27] Additional exclusion criteria included incomplete medical records or insufficient postoperative follow-up data. Among 209 patients who underwent medial opening wedge high tibial osteotomy (MOWHTO), 35 met the inclusion and exclusion criteria. Five patients were excluded due to loss to follow-up, resulting in a final cohort of 30 patients. Four patients underwent bilateral procedures, yielding a total of 34 knees included in the analysis. All patients were treated with MOWHTO using the same type of fixation plate, and the osteotomy gap was filled with allograft in each case. The medial proximal tibial angle (MPTA) was corrected to 90° based on preoperative standing full-length alignment radiographs. The degree of correction was determined by the principle of 1 mm of wedge opening per 1° of angular deformity.

Data collection

Of the 209 patients treated with medial opening wedge high tibial osteotomy (MOWHTO), only those with complete follow-up data and who strictly met the inclusion and exclusion criteria were selected, resulting in a final cohort of 30 patients (34 knees). Patient data were collected using a structured checklist and divided into two categories. The first set of data was obtained from hospital medical records and the radiology department archive. The second set was gathered through postoperative patient follow-up, including clinical assessments and radiographic evaluations.

Demographic data, including age, sex, and body mass index (BMI), were extracted from patients' medical records. Radiographic and clinical parameters—such as joint line obliquity angle (JLOA), joint line convergence angle (JLCA), hip-knee-ankle angle (HKAA), mechanical lateral distal femoral angle (mLDFA), and medial proximal tibial angle (MPTA)—were measured preoperatively, one year postoperatively, and at the final follow-up using standing full-length radiographs.

Finally, the outcomes of MOWHTO were evaluated based on the degree of correction and the achievement of appropriate joint line obliquity (JLO). The mechanical femorotibial angle was defined as the hip-knee-ankle angle (HKAA).[28] The medial proximal tibial angle (MPTA) was defined as the angle between the tibial plateau and the

mechanical axis of the tibia on the medial side.[28] The joint line convergence angle (JLCA) was defined as the angle formed by the divergent lines of the distal femur and proximal tibia.[28] The mechanical lateral distal femoral angle (mLDFA) was defined as the angle between the line drawn from the center of the femoral head to the midpoint of the knee and the tangent to the distal femoral articular surface on the lateral side.[19] Joint line obliquity angle (JLOA) was defined as the angle between a line parallel to the ground and the surface of the tibial plateau.[19] Since JLOA may vary with hip adduction or abduction, it was measured using the Mikulicz joint line angle, defined as the medial angle between the bisector of the JLCA and the lower limb mechanical axis (Mikulicz line), which accurately represents true JLOA.[29] All angular measurements were performed on standing full-length radiographs using digital imaging software. Each angle was measured three times, and the average value was recorded for analysis.

All angular measurements were performed independently by two orthopedic surgeons. In cases of discrepancy, a third expert reviewer was consulted to reach a consensus. To assess interobserver reliability for these quantitative measurements, the intraclass correlation coefficient (ICC) was calculated. The ICC value was 0.93, indicating excellent agreement between observers.

Functional endpoint

Postoperative knee function was assessed using the Knee Society Score (KSS) and the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaires. The KSS assigns a total score ranging from 0 to 200, with higher scores indicating better knee function. The first 100 points reflect the clinical knee score, comprising 50 points for pain, 25 points for range of motion, and 25 points for stability. The remaining 100 points assess patient function, including 50 points for stair climbing and 50 points for walking distance. The KOOS questionnaire provides a score ranging from 0 to 100 for each subscale, with higher scores indicating better knee function. Both the KSS and KOOS have been validated and shown to be reliable for use in the Iranian population.[30,31] In addition, the Visual Analog Scale (VAS) was used to evaluate knee pain, with scores ranging from 0 (no pain) to 10 (maximum pain). The validity of the VAS has also been confirmed for the Iranian population.[32]

Statistical analysis

"Statistical analysis was performed using SPSS software (version 22.0, IBM Corp., Armonk, NY, USA). Quantitative variables were reported as mean ± standard deviation (SD), while qualitative variables were presented as frequencies and percentages. Paired t-tests or their non-parametric equivalent, the Wilcoxon signed-rank test, were used to compare preoperative and postoperative values of functional scores and radiographic angles. The chi-square test was applied for comparisons of categorical variables. Pearson's correlation coefficient was used to assess the relationship between age and body mass index (BMI) with changes in mean radiographic and functional outcomes following surgery. A p-value of less than 0.05 was considered statistically significant.

Results

Demographic characteristics

Among the 30 patients included in the study, 13 (43.3%) were female and 17 (56.7%) were male. The mean age at the time of surgery was 32.19 ± 11.63 years (range: 18–60 years). The mean body mass index (BMI) was 23.34 ± 3.17 kg/m^2. The mean follow-up duration was 39.38 ± 8.84 months. Of the 34 knees evaluated, 18 were right-sided and 16 were left-sided. Four patients underwent bilateral surgery.

Alignment correction

The mean medial proximal tibial angle (MPTA) increased significantly from 82.47 ± 3.66° preoperatively to 90.53 ± 1.80° postoperatively ($p < 0.001$). The mean hip-knee-ankle angle (HKAA) also showed a significant reduction of 10.47° following surgery ($p < 0.001$). The mean joint line convergence angle (JLCA) decreased significantly after surgery, reaching 1.06° ($p = 0.006$). In contrast, the mean joint line obliquity angle (JLOA) increased significantly postoperatively, with a mean difference of 2.92° ($p = 0.001$). However, there was no statistically significant difference in the mean mechanical lateral distal femoral angle (mLDFA) before and after surgery ($p = 0.133$). A comparison of all angular parameters, including MPTA, mLDFA, HKAA, JLCA, and JLOA, is summarized in [Table 1]. No significant correlation was observed between changes in angular parameters (MPTA, mLDFA, HKAA, JLCA, and JLOA) and patient age or BMI ($p > 0.05$).

Functional outcomes

The mean Knee Society Score (KSS) improved significantly following surgery, with a mean difference of 21.13 points ($p < 0.001$). The mean Knee Injury and Osteoarthritis Outcome Score (KOOS) increased from 138.65 ± 17.39 preoperatively to 175.62 ± 12.54 postoperatively, representing a statistically significant improvement. The mean Visual Analog Scale (VAS) score also improved significantly after surgery, with a mean decrease of 5.21 points ($p = 0.001$). A summary of functional outcome changes is presented in [Table 2]. No significant correlations were found between changes in KSS or KOOS and patient age or body mass index (BMI) ($p > 0.05$).

Table 1. Comparing radiographic findings between pre and post-operation

Variable	Time mean ± SD		Mean Difference	P-value
	Pre-Operation	Post-Operation		
MPTA°	82.47 ± 3.66	90.53 ± 1.80	8.06 ± 3.24	<0.001
MLDFA°	92.76 ± 1.38	93.00 ± 1.46	0.24 ± 0.28	0.133
HKA°	14.41 ± 6.40	3.94 ± 2.76	-10.47 ± 6.46	<0.001
JLCA°	2.79 ± 2.47	1.74 ± 1.36	-1.06 ± 2.10	0.006
JLOA°	88.18 ± 3.96	91.1 ± 1.42	2.92 ± 3.94	<0.001

Table 2. Comparing functional outcomes between pre and post-operation

Variable	Time mean ± SD		Mean Difference	P-value
	Pre-Operation	Post-Operation		
KSS	63.47 ± 8.30	84.60 ± 6.20	21.13 ± 6.81	<0.001
KOOS	138.65 ± 17.39	175.62 ± 12.54	36.97 ± 15.78	<0.001
VAS	7.29 ± 0.94	2.09 ± 1.19	-5.21 ± 1.01	<0.001

Discussion

We hypothesized that medial opening wedge high tibial osteotomy (MOWHTO) provides appropriate clinical alignment for the correction of combined tibial and femoral deformities. Additionally, by avoiding the need for a second osteotomy, this approach may reduce the risk of complications associated with double-level procedures. This study aimed to evaluate the functional outcomes of MOWHTO with overcorrection of the medial proximal tibial angle (MPTA) to 90°, applied as a single-stage intervention for the first time in this specific patient population.

Our findings demonstrated a mean follow-up duration of approximately 40 months. Following MOWHTO, the mean hip-knee-ankle angle (HKAA) decreased significantly, while the mean medial proximal tibial angle (MPTA) increased by approximately 8°, indicating successful angular correction. Additionally, the mean joint line convergence angle (JLCA) decreased by 1.06°, reflecting improved alignment. Although the mean joint line obliquity angle (JLOA) increased by nearly 3° postoperatively, this change was not considered clinically significant, as it remained within the normal physiological range. Despite the statistical significance observed in the JLOA difference before and after surgery, this may be attributed to random variation or low statistical power, likely due to the limited sample size of the study cohort.

This study demonstrated that the mean medial proximal tibial angle (MPTA) after surgery was 90.53°, indicating an overcorrection of approximately 3° using the MOWHTO approach in patients with combined varus deformities of the distal femur and proximal tibia. This degree of correction was associated with favorable functional outcomes. Additionally, both the Knee Injury and Osteoarthritis Outcome Score (KOOS) and the Knee Society Score (KSS) improved significantly following surgery. The mean Visual Analog Scale (VAS) score also showed a significant postoperative decrease, reflecting reduced pain. In summary, although a slight increase in the joint line obliquity angle (JLOA) was observed, the MOWHTO technique yielded positive short- to mid-term clinical and functional outcomes in this patient population. A critical review of the current literature on osteotomy procedures suggests that several traditionally accepted 'principles' lack robust scientific evidence to support their long-term efficacy in joint preservation.[33-35]

Song et al.[36] One hundred nine patients who underwent MOWHTO were evaluated with a mean follow-up of 55 months. The findings indicated that patients with a joint line obliquity (JLO) angle of less than 5° had better functional outcomes, suggesting that limited overcorrection within the normal physiological range does not adversely affect postoperative function.

Feucht et al.[37] analyzed 303 standing digital radiographs and found that fewer than one-third of patients with varus knee deformity had isolated tibial involvement. When applying a joint line obliquity (JLO) threshold of ≤5°, 57% of cases could be successfully managed with proximal tibial osteotomy alone. However, for patients with a varus angle greater than 10° or an estimated medial proximal tibial angle (MPTA) exceeding 95°, double-level osteotomy (DLO) involving both the distal femur and proximal tibia was recommended. Despite the biomechanical benefits, adding a second osteotomy to avoid JLO may increase the risk of complications and lead to lower patient satisfaction.[38] Saito et al.[21] reported a mean postoperative MPTA of 89° in patients with severe varus osteoarthritis who underwent correction with a two-level osteotomy using the condylar valgus tibial osteotomy technique. Their findings suggested that overcorrection of the MPTA may negatively impact clinical outcomes.

Nakayama et al.[39] evaluated radiological and clinical outcomes in 20 patients with osteoarthritis and severe varus deformity treated using double-level minimally invasive osteotomy (DLO). At 12 months postoperatively, the mean medial proximal tibial angle (MPTA) was 90.6°, which was associated with excellent short-term radiological and clinical outcomes. They also reported that a joint line obliquity (JLO) angle greater than 5° increases shear stress on the cartilage, potentially leading to degeneration. Saragaglia et al.[40] observed that while overcorrection may be required to achieve favorable long-term clinical outcomes, it may also lead to adverse effects and greater mechanical deviation. They emphasized the importance of carefully defining the correction target and surgical protocol to optimize results. In our study, the mean postoperative MPTA was 90.5°, which, consistent with Nakayama et al., was associated with good functional outcomes. The mean postoperative JLO angle was 91°, with a mean change of less than 3° compared to preoperative values. Since this deviation remained within the normal physiological range, it did not appear to negatively affect clinical or functional outcomes.

In 2023, Caubère et al.[41] reported that joint line obliquity (JLO) had no adverse effects on clinical or functional outcomes when limited to ≤3°. In contrast, negative effects were observed in patients with JLO >3°. These findings are consistent with the results of our study. Similarly, Rosso et al.[29] in a 10-year follow-up study, found no significant correlation between increased lateral JLO or joint line obliquity angle (JLOA) and clinical outcomes following high tibial osteotomy (HTO) with wedge opening, further supporting our observations.. In a review, Xie et al.[42] concluded that, based on current evidence, the proper relationship between postoperative JLO and clinical outcomes after HTO remains unclear. However, they suggested that mild deviations in JLO within a certain threshold may not significantly affect clinical results.

Limitations

This study has several limitations. The relatively small sample size and limited follow-up duration reduce the strength and generalizability of the findings. These limitations underscore the need for future studies with larger cohorts and longer-term follow-up to validate and expand upon our results. Furthermore, as the study was conducted within a specific patient population, caution should be exercised when generalizing the findings to broader populations.

Conclusion

This study demonstrated that correcting the medial proximal tibial angle (MPTA) to 90° using the medial opening wedge high tibial osteotomy (MOWHTO) technique in patients with combined tibial and femoral varus deformities yields favorable short- and mid-term functional outcomes. Although the mean joint line obliquity angle (JLOA) increased slightly postoperatively (approximately 3°), this change remained within normal physiological limits and was not clinically significant. The MOWHTO approach appears to be an effective method for managing varus knee deformities, offering significant improvements in clinical outcomes and pain relief. Despite the study's limited follow-up duration and sample size, the results support the efficacy of MOWHTO as a single-level corrective procedure. Future studies with larger cohorts and long-term follow-up are needed to confirm these findings and assess the durability of outcomes over time.

Abbreviation list:

BMI: Body Mass Index
DLO: Double Level Osteotomy
HKAA: Hip-Knee-Ankle Angle
ICC: Intraclass Correlation Coefficient
JLO: Joint Line Obliquity
JLOA: Joint Line Obliquity Angle
JLCA: Joint Line Convergence Angle
KOOS: Knee Injury and Osteoarthritis Outcome Score
KSS: Knee Society Score
mLDFA: Mechanical Lateral Distal Femoral Angle
MOWHTO: Medial Opening Wedge High Tibial Osteotomy
MPTA: Medial Proximal Tibial Angle
VAS: Visual Analogue Scale

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Declaration of Informed Consent: *Written informed consent was obtained from all participants.*

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