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Can Long-Term Survival of Medial Opening-Wedge High Tibial Osteotomy Be Reliably Predicted?

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ABSTRACT

Objective: High tibial osteotomy (HTO) is an established joint-preserving procedure for medial compartment osteoarthritis with varus deformity. While it can delay the need for total knee arthroplasty (TKA), the long-term survival of HTO varies, and predictive factors remain under investigation.

Materials and Methods: This retrospective cohort study evaluated patients who underwent medial opening-wedge HTO between 2005 and 2017. Inclusion criteria were isolated medial osteoarthritis with varus alignment and a minimum 5-year follow-up. Patients were grouped based on whether they later required TKA. Pre-operative, post-operative, and final radiographic parameters – including mechanical tibiofemoral angle (mTFA) and medial proximal tibial angle – were measured by two blinded observers. Statistical analyses were performed to compare groups and identify potential predictors of failure.

Results: A total of 327 patients (295 females, 32 males) were reviewed; 34 (10.4%) underwent subsequent TKA at an average of 7.6 years post-HTO. Pre-operative mean mTFA was 12.48±4.25°, corrected post-operatively to –0.76±3.82° ($p<0.001$). Patients requiring TKA showed less optimal post-operative alignment and greater progression of lateral or patellofemoral joint degeneration. Higher pre-operative deformity and undercorrection after HTO were associated with increased risk of conversion to TKA.

Conclusion: Medial opening-wedge HTO can offer substantial joint preservation benefits, but a subset of patients progresses to TKA within a decade. Achieving appropriate mechanical alignment correction and careful patient selection are crucial for improving long-term survival. Understanding radiographic and demographic risk factors may help guide surgical planning and enhance native knee preservation in active populations.

Keywords: Ankle joint, Genu varum, High tibial osteotomy, Lateral distal tibial-ground surface angle, Total knee arthroplasty

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INTRODUCTION

High tibial osteotomy (HTO) is a well-established surgical technique aimed at treating unicompartmental medial knee osteoarthritis associated with varus deformity by realigning the mechanical axis to unload the degenerated medial compartment and transfer load toward the healthier lateral compartment.[1,2]

As life expectancy increases, the maintenance of functional mobility in the aging population becomes paramount, and preserving the native knee joint rather than proceeding directly to total knee arthroplasty (TKA) has gained importance, especially in younger and active patients.[3,4] Varus malalignment is a recognized mechanical risk factor for the progression of medial compartment osteoarthritis due to increased medial load transmission, cartilage wear, and eventual joint space narrowing.[5,6] In appropriately selected patients, HTO can provide substantial symptomatic relief, delay disease progression, and postpone the need for joint replacement.[2,4,7] However, despite advances in surgical techniques – such as the adoption of medial opening-wedge osteotomies supported by locking plates – long-term survival rates after HTO vary considerably, and some patients ultimately require conversion to TKA.[8,9]

Several factors have been associated with HTO outcomes, including patient age, body mass index, pre-operative severity of osteoarthritis, the magnitude of deformity correction, and post-operative rehabilitation protocols.[4,6,9] It has been demonstrated that optimal post-operative mechanical axis alignment, particularly achieving slight valgus positioning, correlates with better survival rates of the osteotomy and improved functional outcomes.[2,9] Conversely, undercorrection, overcorrection, residual varus, or disease progression in the lateral or patellofemoral compartments can result in clinical failure and necessitate TKA conversion.[5,7,10] In addition, surgical complications, such as non-union, infection, hardware irritation, and neurovascular injuries, although less frequent with modern techniques, remain concerns that can impact long-term success.[8,11]

As interest in joint-preserving strategies persists, it is crucial to further elucidate the predictors of failure and the longevity of HTO, especially with an increasing demand for high functional outcomes and longer prosthesis-free survival periods in active populations.[3,7,12] The present study aims to retrospectively evaluate the long-term results of medial opening-wedge HTO performed for medial compartment osteoarthritis with varus deformity, using conversion to TKA as the principal failure endpoint. By analyzing a homogenous cohort of patients, we seek to determine the survival rate of HTO and identify potential predictive factors associated with failure, including patient demographics, pre-operative deformity severity, achieved correction angles, and follow-up duration. A clearer understanding of these parameters may aid in refining patient selection criteria, optimizing surgical planning, and improving the long-term preservation of the native knee joint.[2,4,9] Furthermore, the study endeavors to contribute to the existing body of evidence by offering insights into the realistic expectations patients and surgeons can have regarding the durability and effectiveness of HTO in the context of contemporary orthopedic practice.

MATERIALS AND METHODS

Study Design and Ethical Approval

This study was designed as a retrospective, observational, and comparative cohort analysis. Institutional Review Board approval was obtained from the Ethics Committee of Baltalimani Bone Diseases Training and Research Hospital, University of Health Sciences (Approval No: 18/124, dated 28 February 2024). All procedures were conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent had been obtained from all patients at the time of their initial surgical treatment regarding the use of their anonymized medical data for research purposes.

Patient Selection

The institutional surgical database was retrospectively reviewed to identify patients who underwent medial opening-wedge HTO for medial unicompartmental knee osteoarthritis between January 2005 and December 2017. Inclusion criteria for the study were: diagnosis of isolated medial compartment knee osteoarthritis with varus malalignment; treatment with medial opening-wedge HTO; available complete pre-operative, post-operative (after HTO), and final post-operative (after subsequent TKA, if performed) radiographic imaging; and a minimum follow-up of 5 years after HTO.

Patients were divided into two groups:

- Group 1 consisted of individuals who underwent HTO and were later converted to TKA due to persistent symptoms or disease progression
- Group 2 included those who underwent HTO but did not require TKA during the follow-up period. Exclusion criteria were: incomplete medical records; inadequate radiographic follow-up; history of previous trauma, fracture, or surgery involving the ipsilateral lower extremity; inflammatory arthritis or neuromuscular disorders affecting gait.

Study Population

A total of 327 patients (295 females, 32 males) who underwent medial opening-wedge HTO were initially screened. Among these, 34 patients (33 females, 1 male) who subsequently required ipsilateral TKA were identified and included in the TKA group. The mean age at the time of HTO was 57 years (range: 49–62 years), and the mean age at the time of TKA conversion was 64 years (range: 55–72 years). The time interval between HTO and TKA was on average 7.6 years (range: 5–11 years). In the TKA group, 20 patients (59%) had surgery on the left side and 14 (41%) on the right side. No specific age limitation was set for inclusion; however, all patients exhibited varus alignment of the lower extremity pre-operatively.

All HTO procedures were performed using the medial opening-wedge technique with fixation by locking plates. Subsequent total knee arthroplasties were performed with mechanical axis correction using standard instrumentation without navigation. Only patients with a minimum 5-year interval between HTO and TKA were included to ensure sufficient remodeling and adaptation periods for evaluating compensatory changes.

Radiographic Evaluation

Radiographic assessments included weight-bearing, full-length, standing anteroposterior (AP) orthoroentgenograms obtained at three timepoints: Pre-operative (before HTO), early post-operative (within the 1st year after HTO), and final post-operative (following TKA for those who underwent it). Radiographs were independently evaluated by two blinded orthopedic surgeons (H.B., S.G.), and the mean of the two measurements was used for statistical analysis to reduce interobserver variability.

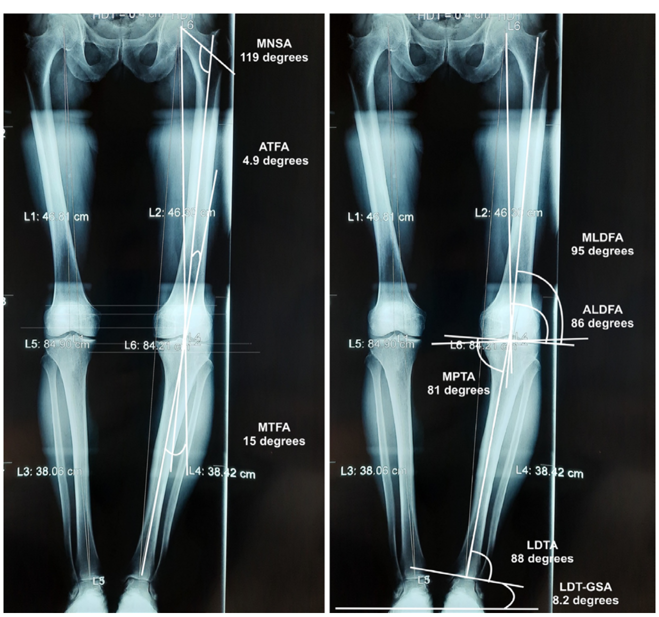

Figure 1. Angle measurements on standing orthoroentgenogram of the lower extremity taken before surgery.

The following parameters were measured (Figs 1-3):

- Mechanical tibiofemoral angle (mTFA)
- Anatomical tibiofemoral angle (aTFA)
- Mechanical lateral distal femoral angle (mLDFA)
- Anatomical lateral distal femoral angle (aLDFA)
- Medial proximal tibial angle (MPTA)
- Lateral distal tibial angle (LDTA)
- Lateral distal tibial-ground surface angle (LDT-GSA)

All measurements were performed using digital radiographic analysis software calibrated for limb-length images. On average, radiographic follow-up occurred at 4.6 years post-operatively (range: 3–5 years).

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means and standard deviations. Categorical variables were presented as frequencies and percentages. The normality of data distribution was assessed using the Shapiro–Wilk test. For variables demonstrating normal distribution, paired samples Student's t-test was employed to compare pre-operative, post-operative, and

Figure 2. Angle measurements on standing orthoroentgenogram of the lower extremity taken after high tibial osteotomy.

Eur Arch Med Res 2025;41(2):97–103

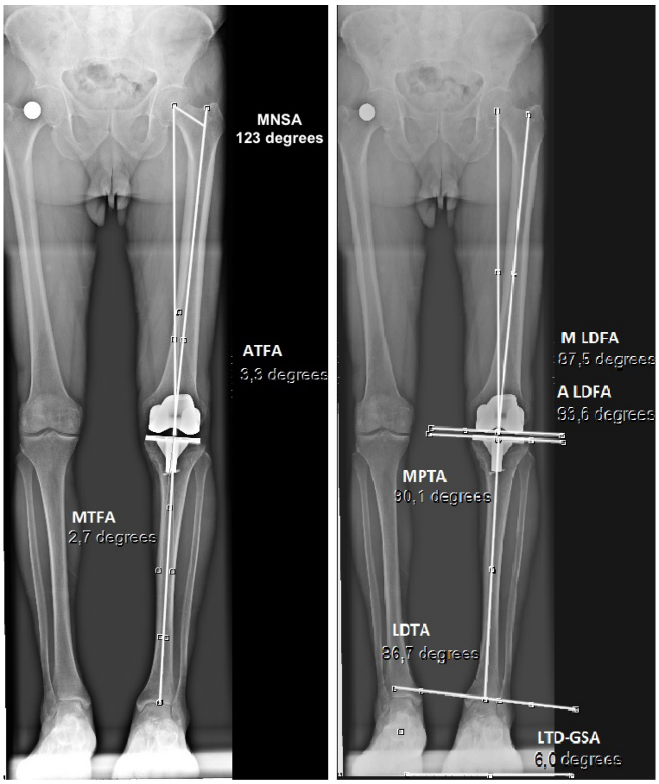

Figure 3. Angle measurements on standing orthoroentgenogram of the lower extremity taken after total knee arthroplasty.

final measurements. For non-normally distributed variables, the Wilcoxon signed-rank test was used. A two-tailed p<0.05 was considered statistically significant. Missing data points were handled by complete case analysis; no imputation methods were applied. Interobserver reliability for radiographic measurements was assessed by calculating the intraclass correlation coefficient (ICC), with an ICC value >0.80 considered indicative of excellent agreement.

RESULTS

Radiographic measurements were obtained from standing AP orthoroentgenograms at three distinct time points: Pre-operatively (before HTO), early post-operatively (after HTO), and at final follow-up (after TKA). The mean values, standard deviations, and statistical comparisons for each radiographic parameter are presented below.

mTFA

The mean pre-operative mTFA was 12.48±4.25°, indicating a varus alignment. Following medial opening-wedge HTO, the mean post-operative mTFA was corrected to –0.76±3.82°, demonstrating a statistically significant improvement (p<0.001). In patients who subsequently underwent TKA after HTO, the mean mTFA measured at the final post-operative evaluation was 7.35±14.91°. The difference between the post-HTO and post-TKA mTFA values was statistically significant (p<0.001).

aTFA

The mean pre-operative aTFA was measured at 5.83±4.50°. Post-operatively after HTO, the aTFA was corrected to –6.56±3.64°, and this change was statistically significant (p<0.001). After subsequent TKA, the mean aTFA was recorded as 3.66±3.04°. Comparison between the post-HTO and post-TKA aTFA values also revealed a significant difference (p<0.001).

MPTA

There was a significant increase in the MPTA following HTO compared to pre-operative values (p<0.001). In patients who later underwent TKA, the mean MPTA at final follow-up was 88.91±2.55°. The difference between post-HTO and post-TKA MPTA measurements remained statistically significant (p<0.001).

LDT-GSA

A statistically significant change was observed between the pre-operative and postoperative (post-HTO) LDT-GSA values (p=0.002). Following TKA, the mean LDT-GSA was measured as 4.63±2.46°. The difference between post-HTO and post-TKA LDT-GSA values was also statistically significant (p=0.041).

Other Radiographic Measurements

Although the main focus was on mTFA, aTFA, MPTA, and LDT-GSA, additional radiographic parameters, such as the mLDFA, aLDFA, and LDTA were also recorded. However, the differences in these parameters did not reach statistical significance across the evaluated time points. A comprehensive summary of all measurements, including statistically significant and non-significant data, is provided in Table 1.

DISCUSSION

In this study, we aimed to investigate whether correction of knee deformity via HTO and subsequent TKA would influence associated ankle alignment. Our principal finding was that although TKA following HTO significantly reduced varus alignment in the ankle, a residual varus deformity still persisted.

Knee deformities, particularly varus malalignment, are known to influence adjacent joints such as the ankle through compensatory mechanisms; however, this relationship has rarely been the primary focus of research.[6] Corrective procedures such as HTO address tibial metaphyseal deformities, but due to the nature of closed-chain biomechanics, abnormal force distribution across the ankle joint can lead to additional deformities.[7-9]

Table 1. Angular values and statistical analyses of patients with varus gonarthrosis before surgery, after high tibial osteotomy, and after total knee arthroplasty

	Pre-operative	Post-HTO	Post-TKA	Pre-operative versus Post-operative HTO p*	Post-HTO versus post-TKA p*
mTFA					
Mean	12.48	-0.76	7.35	<0.001	<0.001
SD	4.25	3.82	14.91		
aTFA					
Mean	5.83	-6.56	3.66	<0.001	<0.001
SD	4.50	3.64	3.04		
aLDFA					
Mean	85.21	85.21	85.26	n.s	0.764
SD	3.64	3.64	2.78		
mLDFA					
Mean	91.59	91.59	91.88	n.s	0.622
SD	3.32	3.32	2.99		
MPTA					
Mean	84.29	96.65	88.91	<0.001	<0.001
SD	2.90	3.01	2.55		
LDTA					
Mean	88.03	88.32	88.26	0.599	0.985
SD	3.86	2.92	3.29		
LDT-GSA					
Mean	7.63	5.21	4.63	<0.002	0.041
SD	4.98	2.28	2.46		

HTO: High tibial osteotomy; TKA: Total Knee Arthroplasty; mTFA: Mechanical Tibiofemoral Angle; aLDFA: Anatomical Lateral Distal Femoral Angle; mLDFA: Mechanical Lateral Distal Femoral Angle; MPTA: Medial Proximal Tibial Angle; LDTA: Lateral Distal Tibial Angle; LDT-GSA: Lateral Distal Tibial-Ground Surface Angle; SD: Standard deviation.

In our study, lower pre-operative LDT-GSA values were associated with greater knee varus, supporting the notion that patients with varus knees utilize compensatory mechanisms at the ankle joint.[10] Previous literature has reported compensatory valgus orientation of the ankle joint in varus knees.[11] In our cohort, the mean pre-operative LDT-GSA was in valgus; after HTO, it shifted significantly toward varus but remained in residual valgus.[6]

Our findings align with Kazemi et al.,[12] who demonstrated a significant correction in the LDT-GSA following HTO, despite no significant changes in distal tibial parameters such as the LTDA. Similarly, in our series, while foot pronation decreased, the residual ankle valgus persisted, reflecting incomplete reversal of compensatory changes. Following TKA, knee deformities were neutralized, and compensatory ankle malalignment also tended to improve, although not fully corrected.

Our results are consistent with Gao et al.,[1] who reported that ankle alignment improves after TKA when knee deformity is corrected. However, despite mechanical alignment being restored via TKA in our patients, the ankle joint did not completely revert to normal, suggesting partial but not total biomechanical recovery. The observed regression in MPTA after TKA, despite remaining within a functional range, highlights the interconnected biomechanical relationship between the knee and ankle.

We used mechanical alignment rather than kinematic alignment, which may partly explain the persistence of minor varus stresses post-operatively.[13] Importantly, although HTO successfully valgized the knee and TKA neutralized it, the sequence of interventions may influence the degree of residual deformities across both joints. Recent studies have increasingly highlighted outcomes that align with the findings of the present work.[12,14] Specifically, Karasavvidis et al.[13] reported high long-term success rates in similar patient populations, underscoring the durability of the intervention. Furthermore, both Jeong[14] and Matsumoto et al.[15] demonstrated that clinical improvements are consistently correlated with favorable radiographic and functional outcomes. In addition, in their work, Graef et al.[16] emphasized the critical role of minimizing complication rates in achieving sustained implant longevity. Consistent with these reports, our results indicate that early post-operative gains are largely maintained over time. Taken together, these findings suggest that our study provides meaningful reinforcement to the present body of evidence in this field.

There are limitations to this study. First, its retrospective design introduces potential selection bias. Second, radiological assessments were made at discrete time points and do not account for dynamic loading patterns during gait. Third, the sample size, although sufficient for statistical analysis, may limit the generalizability of the findings. Finally, the lack of a control group (e.g., isolated TKA without prior HTO) restricts direct comparative analysis.

CONCLUSION

While correction of knee varus deformity via HTO and TKA significantly improves associated ankle alignment, a residual varus deformity in the ankle persists. These findings underscore the importance of considering ankle biomechanics during surgical planning for knee deformity correction, particularly in staged procedures involving both HTO and TKA.

DECLARATIONS

Ethics Committee Approval: The study was approved by University of Health Sciences, Baltalimani Bone Diseases Training and Research Hospital Ethics Committee (No: 18/124, Date: 28/02/2024).

Informed Consent: Written informed consent had been obtained from all patients at the time of their initial surgical treatment regarding the use of their anonymized medical data for research purposes.

Conflict of Interest: The authors declare that there is no conflict of interest.

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