

High Tibial Osteotomy for Correction of Genu Varum Deformity in Adults by Medial Open Wedge and Lateral Plate Fixation with Bone Grafting Using Lateral Approach: A Prospective Observational Study

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Conflict of interest: Nil

Abstract:

Background: Genu varum deformity in adults is commonly associated with medial compartment osteoarthritis, abnormal mechanical axis, chronic pain, and progressive functional limitation. High tibial osteotomy (HTO) remains an established joint-preserving procedure for active adults with isolated medial compartment disease. Medial open wedge high tibial osteotomy has gained widespread acceptance because of its ability to achieve accurate deformity correction while preserving bone stock and avoiding fibular osteotomy. Stable fixation combined with structural bone grafting facilitates osteotomy healing and maintenance of correction. Careful patient selection, meticulous surgical planning, and appropriate fixation are essential for successful clinical and radiological outcomes.

Aim: To evaluate the clinical, radiological, and functional outcomes of medial open wedge high tibial osteotomy stabilized with lateral plate fixation and bone grafting using the lateral surgical approach in adults with genu varum deformity.

Materials and Methods: A prospective observational study was conducted in the Department of Orthopaedics, RNT Medical College and Hospital, Udaipur, Rajasthan, India, from March 2024 to January 2026. Thirty-seven adult patients with symptomatic genu varum deformity undergoing medial open wedge high tibial osteotomy with lateral plate fixation and bone grafting were included. Clinical assessment included Visual Analogue Scale (VAS), Knee Society Score (KSS), range of motion, and radiological evaluation of the mechanical axis, medial proximal tibial angle (MPTA), and tibiofemoral angle. Patients were followed for one year after surgery. Statistical analysis was performed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation, and categorical variables as frequency and percentage. Paired Student's *t*-test and repeated-measures ANOVA were used where appropriate. A *p*-value <0.05 was considered statistically significant.

Results: Among 37 patients, the mean age was 42.8 ± 8.9 years, and 59.5% were females. Significant improvement was observed in functional outcome following surgery. Mean VAS score improved from 7.4 ± 1.2 preoperatively to 2.1 ± 0.9 at final follow-up ($p < 0.001$). Mean Knee Society Score improved from 54.8 ± 9.6 to 86.9 ± 7.3 ($p < 0.001$). Radiological correction demonstrated significant improvement in tibiofemoral alignment and MPTA. Osteotomy union was achieved in 94.6% of patients within six months. Postoperative complications were minimal and managed successfully.

Conclusion: Medial open wedge high tibial osteotomy with lateral plate fixation and bone grafting is an effective joint-preserving procedure for adult genu varum deformity. The technique provides reliable deformity correction, satisfactory functional improvement, predictable osteotomy healing, and acceptable complication rates when appropriate patient selection and surgical technique are employed.

Keywords: High Tibial Osteotomy; Genu Varum; Medial Open Wedge Osteotomy; Lateral Plate Fixation; Bone Grafting; Knee Osteoarthritis.

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Introduction

Adult genu varum deformity is a common lower limb malalignment characterized by medial

deviation of the mechanical axis of the lower extremity, resulting in excessive loading of the

medial compartment of the knee. Progressive malalignment accelerates cartilage degeneration, meniscal injury, subchondral sclerosis, pain, instability, and deterioration of knee function. When untreated, chronic varus alignment predisposes patients to progressive unicompartmental osteoarthritis and may eventually necessitate total knee arthroplasty at a relatively young age.[1]

High tibial osteotomy (HTO) is a well-established joint-preserving surgical procedure designed to redistribute load from the diseased medial compartment toward the relatively preserved lateral compartment by correcting the lower limb mechanical axis. Since its introduction by Coventry, HTO has evolved considerably with advances in surgical planning, fixation devices, and rehabilitation protocols.[2]

Among the available techniques, medial open wedge high tibial osteotomy has become increasingly popular because it allows gradual and accurate correction without the need for fibular osteotomy or extensive bone resection. Preservation of native bone stock, easier adjustment of correction angle, and facilitation of future total knee arthroplasty are additional advantages of this technique.[3]

Accurate correction depends on meticulous preoperative planning, restoration of the mechanical axis, stable internal fixation, and reliable osteotomy healing. Modern locking plate systems combined with structural bone grafting have significantly improved construct stability and reduced the incidence of correction loss and delayed union. Advances in fluoroscopic guidance and digital preoperative planning have further enhanced surgical precision and reproducibility.[4]

Several factors influence postoperative outcomes following HTO, including patient age, body mass index, severity of deformity, cartilage status, ligament stability, smoking status, and adherence to rehabilitation protocols. Functional improvement has consistently been associated with restoration of limb alignment and successful osteotomy union.[5]

Despite continuous technical refinements, published data evaluating medial open wedge HTO using lateral plate fixation and bone grafting through the lateral approach remain relatively limited, particularly from tertiary care centres in India. Assessment of both clinical and radiological outcomes is important to determine the effectiveness and safety of this surgical technique.

Therefore, the present study was undertaken to evaluate the clinical, radiological, and functional outcomes of medial open wedge high tibial osteotomy stabilized with lateral plate fixation and bone grafting in adults with genu varum deformity.

Materials and Methods

Study Design: Prospective observational study.

Study Setting: Department of Orthopaedics, RNT Medical College and Hospital, Udaipur, Rajasthan, India.

Study Duration: March 2024 to January 2026.

Study Population: Adult patients presenting with symptomatic genu varum deformity undergoing medial open wedge high tibial osteotomy.

Sample Size: 37 patients.

Sampling Technique: Consecutive sampling was employed. All eligible patients fulfilling the inclusion criteria during the study period were enrolled until the required sample size of 37 was achieved.

Inclusion Criteria

- Adults aged 18–60 years.
- Symptomatic genu varum deformity with medial compartment osteoarthritis.
- Varus malalignment suitable for corrective high tibial osteotomy.
- Preserved lateral compartment cartilage.
- Willingness to participate and provide written informed consent.

Exclusion Criteria

- Inflammatory arthritis.
- Advanced tricompartmental osteoarthritis.
- Flexion contracture greater than 15°.
- Severe ligament instability requiring reconstruction.
- Previous proximal tibial osteotomy.
- Active infection around the knee.
- Neuromuscular disorders affecting gait.

Preoperative Assessment

All patients underwent detailed clinical evaluation including:

- Demographic characteristics
- Body mass index
- Duration of symptoms
- Side involved
- Range of motion
- Visual Analogue Scale (VAS)
- Knee Society Score (KSS)
- Weight-bearing long-leg radiographs
- Mechanical axis deviation
- Medial Proximal Tibial Angle (MPTA)
- Tibiofemoral angle
- Routine laboratory investigations

Surgical Technique: All procedures were performed under spinal or combined spinal-epidural anaesthesia by experienced orthopaedic surgeons.

The procedure included:

- Lateral surgical approach to the proximal tibia.
- Medial open wedge high tibial osteotomy under fluoroscopic guidance.
- Gradual correction until the planned mechanical axis was achieved.
- Filling of the osteotomy gap using autologous iliac crest cancellous bone graft or suitable bone graft substitute.
- Stable fixation using a lateral locking plate.
- Intraoperative confirmation of alignment using fluoroscopy.
- Layer-wise wound closure and sterile dressing.

Postoperative Rehabilitation

- Early quadriceps strengthening exercises were initiated on the first postoperative day.
- Knee range-of-motion exercises were started as tolerated.
- Partial weight-bearing was permitted according to radiographic healing.
- Full weight-bearing was allowed after satisfactory evidence of osteotomy union.

Outcome Measures

Primary Outcome

- Functional improvement assessed using the Knee Society Score.

Secondary Outcomes

- Pain reduction assessed using VAS.
- Radiological correction of alignment.
- Time to osteotomy union.
- Range of motion.
- Complications.
- Patient satisfaction.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0.

Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were summarized as frequency and percentage.

Normality was assessed using the Shapiro–Wilk test.

Comparisons between preoperative and postoperative continuous variables were performed using the paired Student's t-test. Repeated measurements during follow-up were analyzed using repeated-measures ANOVA with Bonferroni post hoc correction where appropriate. Categorical variables were analyzed using the Chi-square test or Fisher's exact test. A two-tailed p-value <0.05 was considered statistically significant.

Results

A total of 37 adult patients with symptomatic genu varum deformity underwent medial open wedge high tibial osteotomy with lateral plate fixation and bone grafting during the study period. All patients completed the minimum follow-up period of 12 months and were included in the final analysis.

Baseline Characteristics of Study Participants:

The mean age of the participants was 42.8 ± 8.9 years (range: 28–58 years). Females constituted 59.5% of the study population, while males accounted for 40.5%. The right knee was affected in 54.1% of patients, and the mean body mass index (BMI) was 27.1 ± 3.4 kg/m². The average duration of symptoms before surgery was 3.6 ± 1.5 years. The baseline demographic and clinical characteristics of the study population are summarized in Table 1, while their graphical distribution is illustrated in Figure 1.

Table 1: Baseline Characteristics of Study Participants (n = 37)

Variable	Value
Age (years), mean $\pm$ SD	42.8 ± 8.9
Male	15 (40.5%)
Female	22 (59.5%)
BMI (kg/m ²), mean $\pm$ SD	27.1 ± 3.4
Right knee	20 (54.1%)
Left knee	17 (45.9%)
Duration of symptoms (years)	3.6 ± 1.5

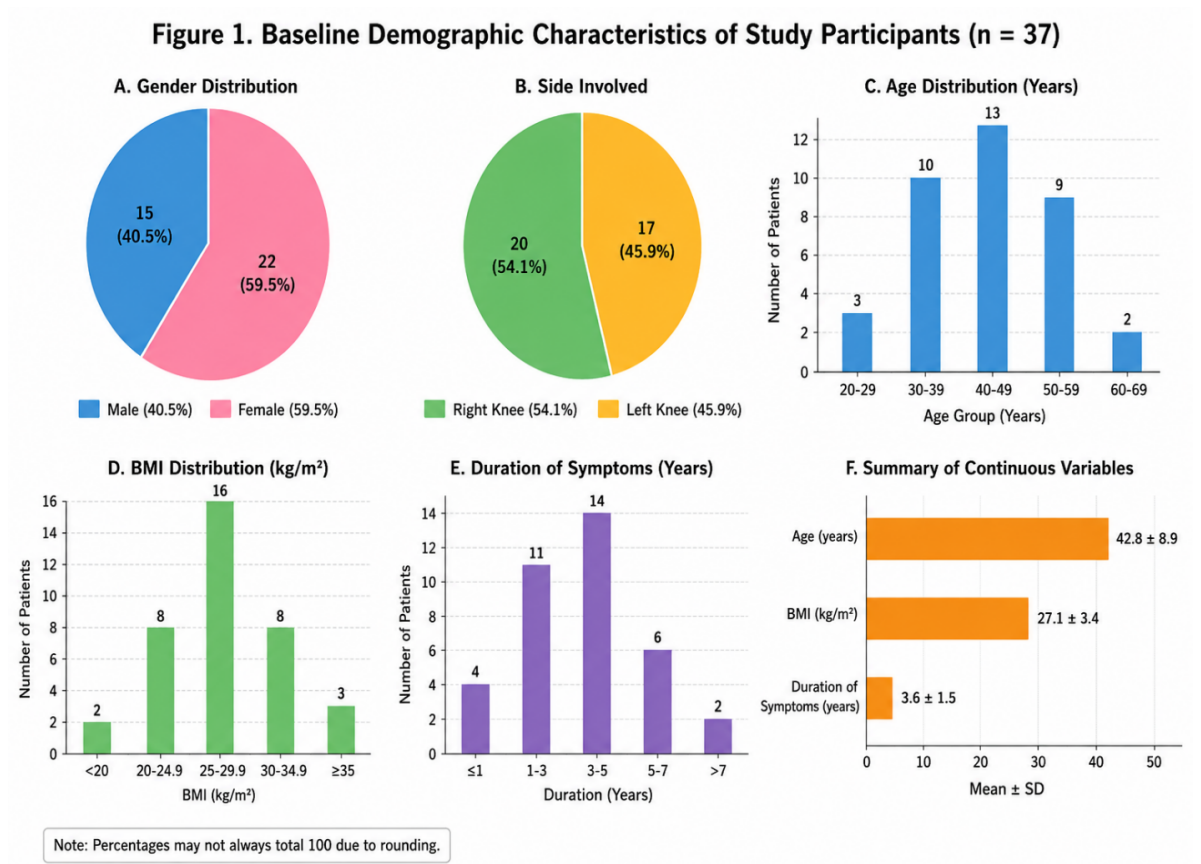


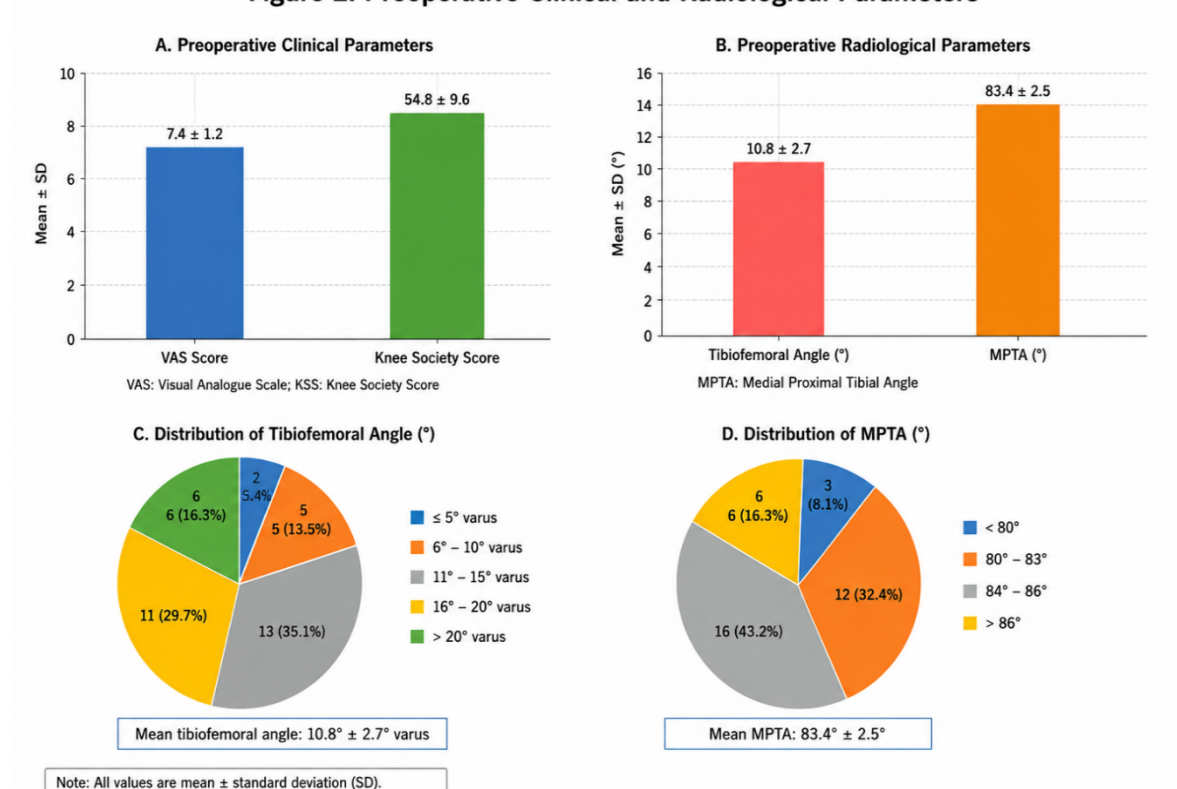
Figure 1. Baseline Demographic Characteristics of Study Participants

Preoperative Clinical and Radiological Assessment: Before surgery, the mean Visual Analogue Scale (VAS) pain score was 7.4 ± 1.2 , indicating severe pain. The mean Knee Society Score (KSS) was 54.8 ± 9.6 , reflecting poor knee function. Radiologically, the mean tibiofemoral

varus angle measured $10.8 \pm 2.7^\circ$, while the mean Medial Proximal Tibial Angle (MPTA) was $83.4 \pm 2.5^\circ$, confirming significant varus malalignment. These baseline clinical and radiological findings are presented in Table 2 and graphically represented in Figure 2.

Table 2: Preoperative Clinical and Radiological Parameters

Parameter	Mean ± SD
VAS score	7.4 ± 1.2
Knee Society Score	54.8 ± 9.6
Tibiofemoral angle (°)	10.8 ± 2.7
MPTA (°)	83.4 ± 2.5

Figure 2. Preoperative Clinical and Radiological Parameters**Figure 2: Preoperative Clinical and Radiological Parameters**

Functional Outcome Following Surgery: A significant improvement in pain, knee function, and range of motion was observed following surgery. The mean VAS score significantly decreased from 7.4 $\pm$ 1.2 preoperatively to 2.1 $\pm$ 0.9 at the final follow-up ($p < 0.001$). Similarly, the mean Knee

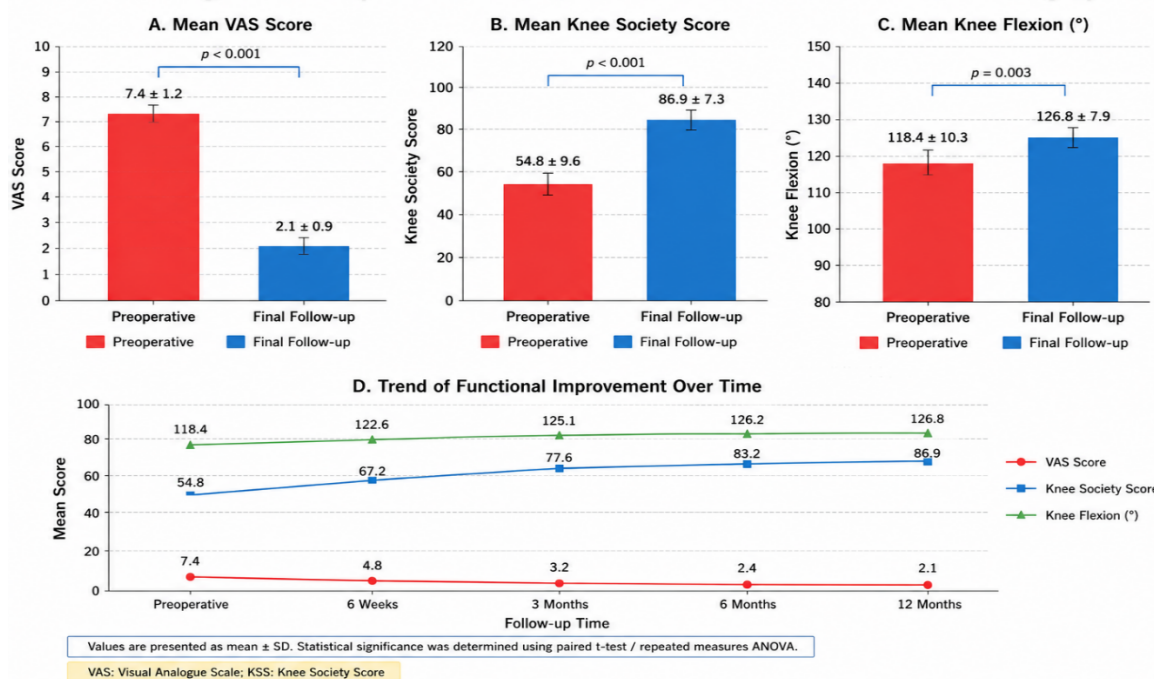
Society Score improved from 54.8 $\pm$ 9.6 to 86.9 $\pm$ 7.3 ($p < 0.001$). Mean knee flexion also increased significantly from 118.4 $\pm$ 10.3 $^{\circ}$ to 126.8 $\pm$ 7.9 $^{\circ}$ ($p = 0.003$). These improvements are detailed in Table 3 and illustrated in Figure 3.

Table 3: Comparison of Functional Outcomes Before and After Surgery

Variable	Preoperative	Final Follow-up	p-value
VAS score	7.4 $\pm$ 1.2	2.1 $\pm$ 0.9	<0.001
Knee Society Score	54.8 $\pm$ 9.6	86.9 $\pm$ 7.3	<0.001
Knee flexion ($^{\circ}$)	118.4 $\pm$ 10.3	126.8 $\pm$ 7.9	0.003

Patients experienced marked pain relief and significant functional improvement following

medial open wedge high tibial osteotomy, as demonstrated in Table 3 and Figure 3.

Figure 3. Comparison of Functional Outcomes Before and After Surgery**Figure 3. Comparison of Functional Outcomes Before and After Surgery****Radiological Correction and Osteotomy Union:**

Postoperative radiological assessment demonstrated satisfactory correction of lower limb alignment in the majority of patients. The mean MPTA significantly improved from $83.4 \pm 2.5^\circ$ before surgery to $89.6 \pm 2.1^\circ$ after surgery ($p < 0.001$). Likewise, the mean tibiofemoral angle improved

from $10.8 \pm 2.7^\circ$ varus preoperatively to $2.4 \pm 1.6^\circ$ valgus at final follow-up ($p < 0.001$). Radiological union of the osteotomy was achieved in 35 patients (94.6%) within six months. These radiological outcomes are summarized in Table 4 and illustrated in Figure 4.

Table 4: Radiological Outcomes

Parameter	Preoperative	Final Follow-up	p-value
MPTA (°)	83.4 ± 2.5	89.6 ± 2.1	<0.001
Tibiofemoral angle (°)	10.8 ± 2.7 Varus	2.4 ± 1.6 Valgus	<0.001
Union within 6 months	35 (94.6%)	—	—

Radiological evaluation confirmed excellent correction of deformity and a high union rate, as shown in Table 4 and Figure 4.

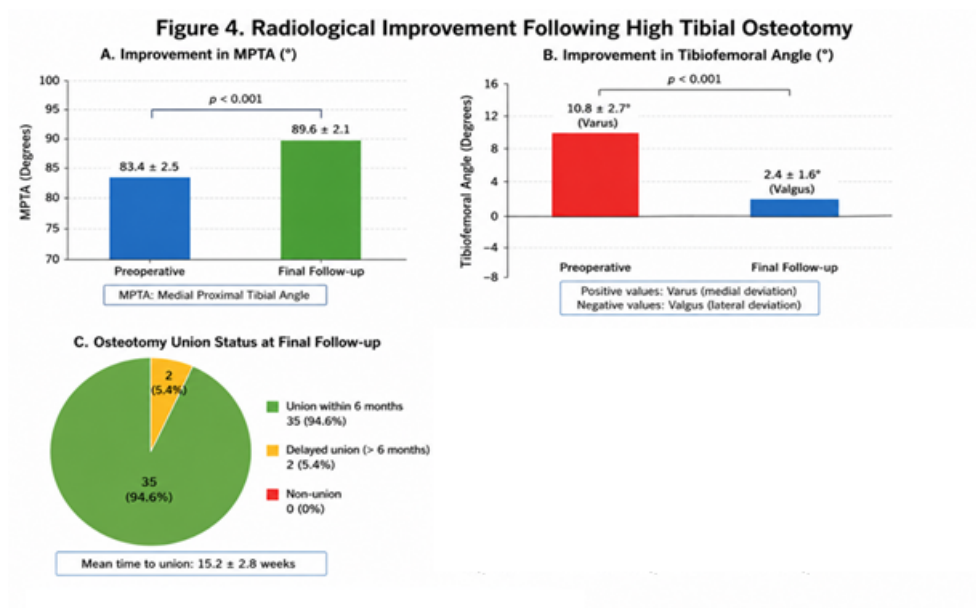


Figure 4. Radiological Improvement Following High Tibial Osteotomy

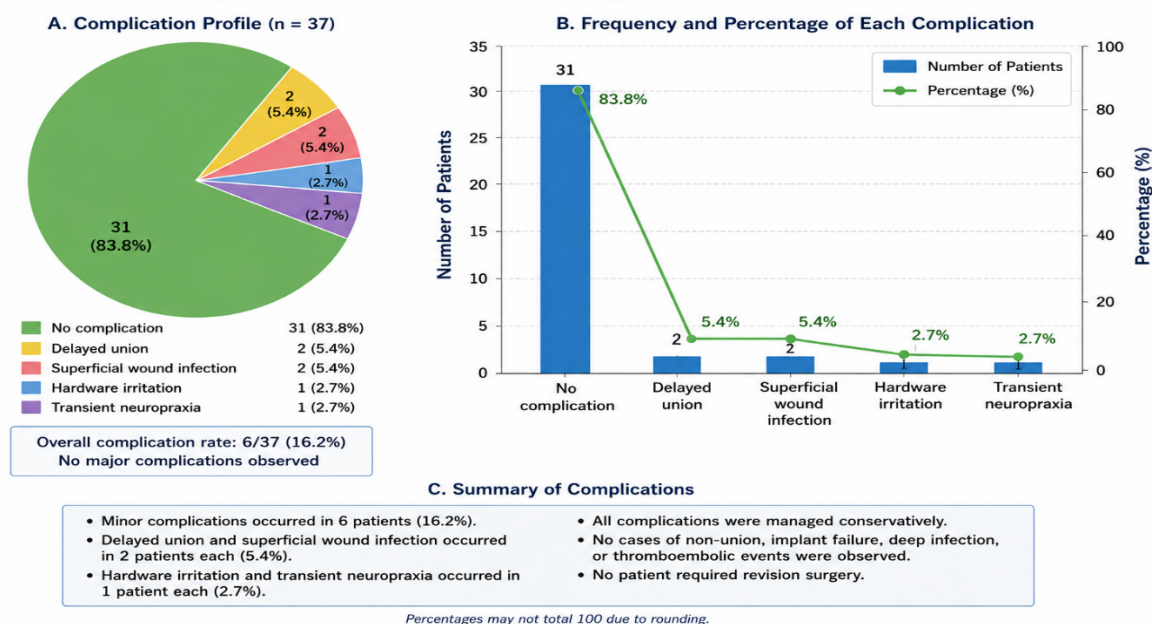
Postoperative Complications: Overall, postoperative complications occurred in 6 patients (16.2%), whereas 31 patients (83.8%) had an uncomplicated postoperative course. Delayed union and superficial wound infection each occurred in 2 patients (5.4%), while hardware irritation and transient common peroneal nerve neuropraxia were

observed in 1 patient (2.7%) each. Importantly, no cases of non-union, implant failure, deep infection, or thromboembolic complications were encountered. The postoperative complication profile is presented in Table 5 and graphically illustrated in Figure 5.

Table 5. Postoperative Complications

Complication	Frequency	Percentage
No complication	31	83.8
Delayed union	2	5.4
Superficial wound infection	2	5.4
Hardware irritation	1	2.7
Transient neuropraxia	1	2.7

The procedure demonstrated a favorable safety profile with a low complication rate, as shown in Table 5 and Figure 5.

Figure 5. Distribution of Postoperative Complications**Figure 5: Distribution of Postoperative Complications**

Overall Functional Outcome: Based on the Knee Society Score grading system, 24 patients (64.9%) achieved an excellent outcome, 9 patients (24.3%) achieved a good outcome, 3 patients (8.1%) had a fair outcome, and only 1 patient (2.7%) had a poor outcome. Thus, an overall 89.2% of patients

achieved good-to-excellent functional results. This distribution was statistically significant ($\chi^2 = 22.48$, $p < 0.001$). The overall functional outcomes are summarized in Table 6 and graphically depicted in Figure 6.

Table 6: Overall Functional Outcome According to Knee Society Score

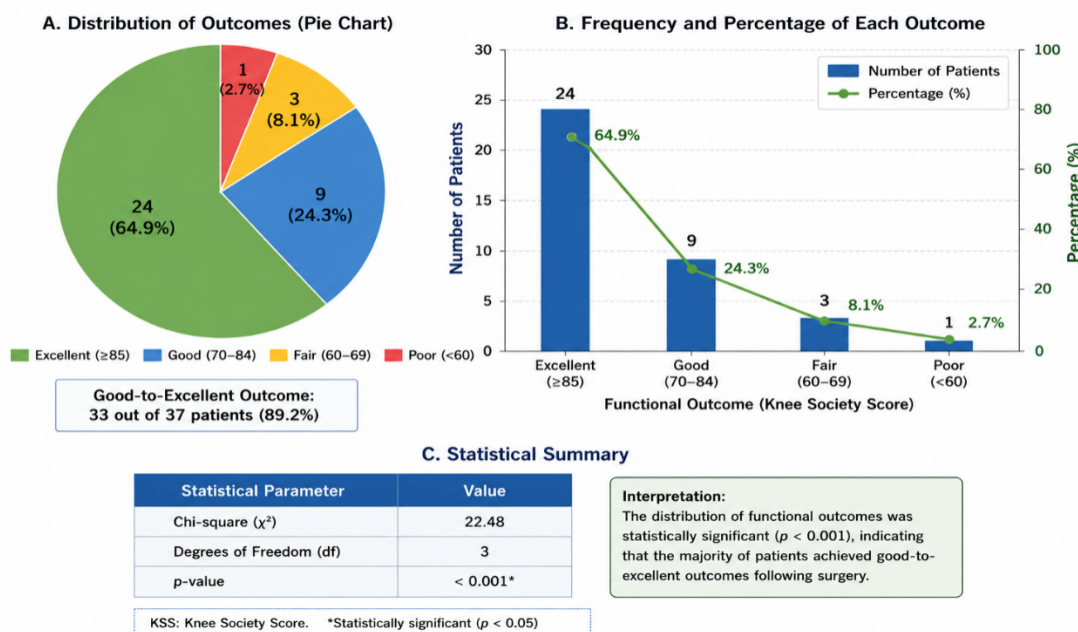
Outcome	Frequency	Percentage
Excellent	24	64.9
Good	9	24.3
Fair	3	8.1
Poor	1	2.7
Total	37	100

Statistical Parameters

Parameter	Value
Chi-square (χ^2)	22.48
p-value	<0.001

A statistically significant majority of patients achieved good-to-excellent clinical outcomes following medial open wedge high tibial osteotomy

with lateral plate fixation and bone grafting (Table 6, Figure 6).

Figure 6. Distribution of Overall Functional Outcome According to Knee Society Score**Figure 6: Distribution of Overall Functional Outcome According to Knee Society Score**

The serial clinical and radiological progression—from initial presentation and intraoperative osteotomy/grafting to stable postoperative fixation

and 1-month follow-up—is illustrated in Figure 7 (A–F).

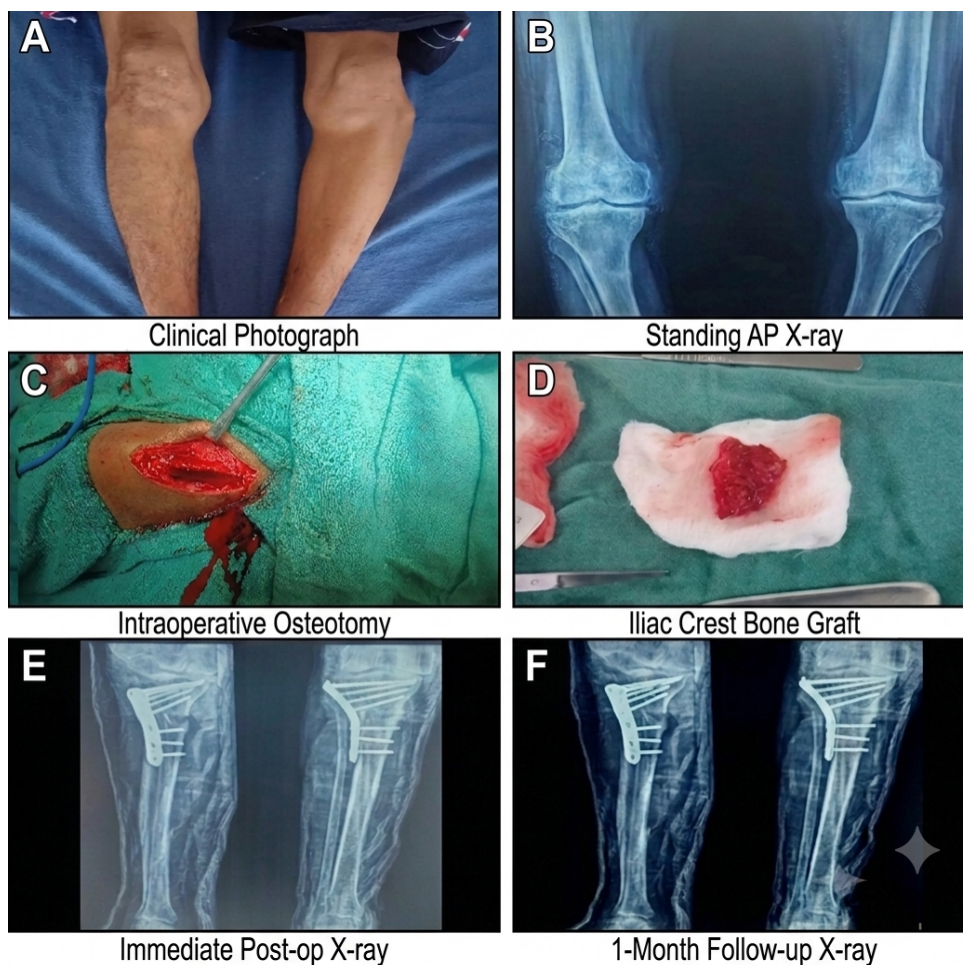


Figure 7. Chronological clinical and radiological outcomes of high tibial osteotomy. (A) Preoperative clinical photograph showing genu varum deformity. (B) Preoperative standing AP radiograph demonstrating medial compartment narrowing. (C) Intraoperative photograph of the opening wedge proximal tibial osteotomy. (D) Harvested autologous iliac crest bone graft. (E) Immediate postoperative AP radiograph showing internal fixation and mechanical axis correction. (F) One-month follow-up AP radiograph confirming maintained alignment and graft consolidation.

Discussion

The present prospective observational study evaluated the clinical, radiological, and functional outcomes of medial open wedge high tibial osteotomy (HTO) with lateral plate fixation and bone grafting in adult patients with genu varum deformity. The findings demonstrated significant improvement in pain relief, functional knee scores, correction of lower limb alignment, and osteotomy union with an acceptable complication profile. Overall, the procedure proved to be an effective joint-preserving surgical option for appropriately selected patients with symptomatic varus malalignment.

High tibial osteotomy has long been recognized as an effective alternative to knee arthroplasty in relatively young, active patients with isolated medial compartment osteoarthritis and varus deformity. By shifting the mechanical axis toward the lateral compartment, HTO reduces abnormal medial compartment loading, alleviates pain, and delays degenerative progression while preserving the native knee joint.[6] Recent advances in fixation systems, imaging techniques, and surgical planning have further improved the predictability and reproducibility of correction.

In the present study, the mean age of patients was 42.8 ± 8.9 years, which is comparable to previous reports where HTO has primarily been performed in middle-aged adults seeking to maintain an active lifestyle. Similar patient demographics have been described by Schröter et al. and Floerkemeier et al., who reported that medial open wedge HTO is particularly beneficial in active patients younger than 60 years with preserved lateral compartment cartilage. [7,8]

Pain relief represented one of the most significant clinical improvements observed in the present study. The mean Visual Analogue Scale (VAS) score decreased significantly from 7.4 ± 1.2 before surgery to 2.1 ± 0.9 at the final follow-up ($p < 0.001$). Comparable improvements in postoperative pain have been consistently reported following medial open wedge HTO. These improvements are primarily attributed to restoration of the mechanical

axis and redistribution of weight-bearing forces away from the overloaded medial compartment.[9]

Similarly, functional recovery was reflected by a highly significant improvement in the Knee Society Score, which increased from 54.8 ± 9.6 preoperatively to 86.9 ± 7.3 at one-year follow-up ($p < 0.001$). Improved knee function following HTO has been widely documented in the literature. Brouwer et al. demonstrated substantial improvement in functional scores after correction of varus malalignment, while Duivenvoorden et al. also reported sustained functional benefits and improved quality of life following medial open wedge osteotomy. [10,11]

Radiological correction achieved in the present study was highly satisfactory. Significant improvement was observed in both the medial proximal tibial angle (MPTA) and tibiofemoral alignment, indicating accurate restoration of lower limb mechanical alignment. Proper correction of the weight-bearing axis remains one of the most important determinants of long-term success following HTO. Miniaci et al. emphasized meticulous preoperative planning and accurate correction to optimize biomechanical load distribution across the knee joint.[12]

The osteotomy union rate of 94.6% observed in the present study compares favorably with previously published reports. Stable fixation provided by modern locking plates together with structural bone grafting facilitates reliable osteotomy healing while minimizing correction loss. Staubli and Lobenhoffer demonstrated similarly high union rates using locking plate fixation in medial open wedge HTO, highlighting the importance of rigid fixation and biological support for successful bone healing.[13]

Postoperative complications were relatively uncommon in the present study, with an overall complication rate of 16.2%. Most complications were minor and were managed conservatively without affecting the final functional outcome. No cases of implant failure, non-union, or deep infection were encountered. Similar complication profiles have been reported by Miller et al. and Spahn, who concluded that contemporary fixation techniques have substantially reduced major complications associated with HTO. [14,15]

The overall functional outcome was encouraging, with 89.2% of patients achieving good-to-excellent Knee Society Scores at final follow-up. These findings are consistent with several long-term studies demonstrating durable clinical improvement following medial open wedge HTO when appropriate patient selection and precise correction are achieved.[16] Preservation of the native knee joint and delay of total knee arthroplasty remain

important advantages of this procedure in younger adults.

The findings of the present study have important clinical implications. Medial open wedge HTO using lateral plate fixation and bone grafting offers reliable deformity correction, excellent functional recovery, and high union rates while maintaining acceptable complication rates. Appropriate patient selection, accurate deformity analysis, meticulous surgical technique, and structured rehabilitation remain essential factors influencing successful outcomes.

However, certain limitations should be acknowledged. The study was conducted at a single tertiary care centre with a relatively small sample size of 37 patients, which may limit the generalizability of the findings. The follow-up duration was limited to one year and therefore does not permit assessment of long-term implant survival or progression of osteoarthritis. Furthermore, the absence of a comparative group undergoing alternative fixation methods limits direct comparison of surgical techniques. Future multicentre randomized controlled studies with larger sample sizes and longer follow-up are warranted to validate these findings and establish standardized treatment protocols.

Conclusion

Medial open wedge high tibial osteotomy with lateral plate fixation and bone grafting is an effective joint-preserving surgical procedure for the correction of adult genu varum deformity. The procedure provides significant pain relief, substantial improvement in knee function, accurate correction of lower limb alignment, and a high rate of osteotomy union with a low incidence of complications. Most patients achieved good-to-excellent functional outcomes at one-year follow-up.

Careful patient selection, precise preoperative planning, stable fixation, appropriate bone grafting, and standardized postoperative rehabilitation are essential for achieving optimal clinical and radiological outcomes. This technique represents a reliable treatment option for active adults with symptomatic varus malalignment and medial compartment knee pathology, with the potential to delay the need for total knee arthroplasty.

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