

Original Research Article

Functional outcomes of medial open wedge high tibial osteotomy in rural Indian patients with medial compartment osteoarthritis and varus deformity: a prospective study

Mukund Sharma*, Prafulla G. Herode, Rajendra Fiske

Department of Orthopaedics, Dr. Balasaheb Vikhe Patil Rural Medical College, Loni, Maharashtra, India

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*Correspondence:

Dr. Mukund Sharma,

E-mail: mukundraajsharma@gmail.com

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ABSTRACT

Background: Osteoarthritis of the knee is a leading cause of disability in rural India, where cultural practices and delayed presentation often complicate treatment. High tibial osteotomy (HTO) represents a joint-preserving alternative to total knee arthroplasty, particularly suitable for younger patients with medial compartment disease. This study aims to evaluate the functional outcomes of medial open wedge high tibial osteotomy in rural Indian patients with medial compartment osteoarthritis and varus deformity.

Methods: This 24-month prospective study at Dr. BVP Rural Medical College, Loni, Maharashtra, evaluated 50 patients with symptomatic medial compartment osteoarthritis undergoing medial open wedge HTO using TomoFix plates. Outcomes were assessed using Visual Analog Scale (VAS), Knee Society Score (KSS) and Knee Society Functional Score (KSFS) over 6-month follow-up.

Results: Significant improvements occurred across all measures. Mean VAS improved from 6.7 ± 1.1 to 1.8 ± 0.9 ($p < 0.001$). KSS improved from 54.7 ± 5.8 to 82.8 ± 6.1 ($p < 0.001$) and KSFS from 55.2 ± 4.9 to 83.8 ± 5.7 ($p < 0.001$). Walking distance increased from 178 ± 65 to 575 ± 90 meters ($p < 0.001$). Mechanical axis was corrected from $7.2^\circ \pm 1.3^\circ$ varus to $2.1^\circ \pm 1.1^\circ$ valgus. All patients achieved radiological union by 12 weeks. Minor complications occurred in 22% with no major complications.

Conclusions: Medial open wedge HTO provides significant functional improvement in rural Indian patients with medial compartment osteoarthritis, offering a cost-effective, culturally appropriate alternative to total knee arthroplasty while preserving traditional sitting postures and occupational activities.

Keywords: High tibial osteotomy, Joint preservation, Knee surgery, Medial compartment osteoarthritis, Rural healthcare, Varus deformity

INTRODUCTION

Osteoarthritis (OA) of the knee is one of the leading causes of chronic disability and reduced quality of life in aging populations across the globe. In India, the burden of this condition is particularly pronounced in rural areas, where socioeconomic limitations, lack of early screening and cultural practices such as squatting and sitting cross-legged often exacerbate disease progression.¹ The medial

compartment of the knee is most commonly affected, especially in patients who perform physically demanding activities like farming, manual labor or frequent stair climbing, activities typical of the Indian rural demographic.

These individuals often present late with advanced symptoms, joint deformities and poor access to continuous physiotherapy or surgical intervention. In the early stages,

knee OA tends to affect a single compartment, most frequently the medial side, often due to habitual loading and age-related degeneration. Medial compartment OA is typically associated with varus deformity, which shifts the mechanical axis medially and further aggravates the degenerative cycle.² If uncorrected, the disease progresses to involve the entire joint, ultimately requiring total knee arthroplasty (TKA). However, for younger and more active individuals with isolated medial compartment disease, joint-preserving strategies are often preferred to delay or avoid prosthetic replacement. In many rural Indian communities, patients prefer procedures that allow them to maintain their traditional sitting postures and avoid the cost and lifestyle changes associated with arthroplasty.

High tibial osteotomy (HTO) is one such joint-preserving surgical technique aimed at correcting varus alignment and unloading the degenerated medial compartment.³ This procedure involves a calculated angular realignment of the proximal tibia, shifting the weight-bearing axis laterally toward the relatively intact lateral compartment. The realignment reduces pain and improves function by restoring a more physiological distribution of joint forces.

Among the available techniques for HTO, medial open wedge HTO has gained increasing favor due to its surgical simplicity, lower risk of neurovascular injury, preservation of the fibula and ease of conversion to TKA in the future.⁴ Compared to the lateral closing wedge technique, the medial approach allows for more accurate intraoperative correction and avoids shortening of the tibia. The development of rigid internal fixation systems, such as the TomoFix plate, has further enhanced the biomechanical stability of the osteotomy, enabled early mobilization and reduced the need for bone grafting in most cases.⁵

Although the benefits of HTO have been well documented in literature from developed nations, there is limited data on its effectiveness in the Indian rural setting, where both patient expectations and systemic challenges differ. Rehabilitation infrastructure is often inadequate, patient follow-up may be inconsistent and post-operative physiotherapy is usually self-directed. Additionally, cultural expectations regarding knee function, particularly the ability to squat, kneel and sit cross-legged, are far more stringent than those in the West, where TKA is often the default surgical option for OA.

This study was undertaken to evaluate the functional outcomes of medial open wedge high tibial osteotomy in patients with medial compartment OA with varus deformity living in a rural region of India. We aimed to assess clinical improvements in pain, mobility and joint function using standardized scoring systems- the visual analog scale (VAS), knee society score (KSS) and knee society functional score (KSFS), alongside radiological correction of varus alignment. By focusing on this specific population, the study also seeks to add to the body of evidence supporting HTO as a practical, affordable and

culturally compatible alternative to early TKA in developing healthcare systems.

METHODS

Study design and setting

This prospective interventional study was conducted over a 24-month period from July 2022 to July 2024 at the Department of Orthopaedics, Dr. Balasaheb Vikhe Patil Rural Medical College, Loni, Maharashtra. The hospital is a tertiary-care teaching institute catering primarily to rural populations. The study was conducted in accordance with the ethical standards of the institutional review board and written informed consent was obtained from all patients in their native language.

Patients between the ages of 45 and 75 years with symptomatic medial compartment osteoarthritis and associated varus alignment were included. Eligibility was confirmed through clinical examination and radiographic assessment. Only those patients who failed to respond to conservative management, including physiotherapy, analgesics and lifestyle modifications, were considered for surgical intervention.

Inclusion criteria

Age between 45 and 75 years. Clinical and radiographic evidence of medial compartment OA (Kellgren-Lawrence Grade II or III) 6. Varus deformity $\leq 15^\circ$. Intact lateral compartment and cruciate ligaments. Flexion contracture $< 15^\circ$. Ability to ambulate independently prior to surgery. Willingness to comply with follow-up protocol.

Exclusion criteria

Tri-compartmental or lateral compartment osteoarthritis. Rheumatoid arthritis or other inflammatory joint diseases. Severe obesity (BMI $> 35 \text{ kg/m}^2$). Prior knee surgeries. Flexion deformity $> 15^\circ$. Fixed varus deformity $> 15^\circ$. Systemic illness or co-morbidities making surgery unsafe.

Preoperative evaluation

Each patient underwent a comprehensive preoperative evaluation.

Clinical assessment

Range of motion, joint line tenderness, varus alignment and ligamentous stability were assessed.

Radiological assessment

Standard AP, lateral and skyline views were obtained, along with long-leg standing radiographs for deformity analysis. Mechanical axis deviation, joint line convergence angle, lateral distal femoral angle, medial proximal tibial angle and tibio-femoral angle were recorded.

Functional scores

The visual analog scale (VAS) for pain, knee society score (KSS) and Knee Society Functional Score (KSFS) were recorded as baseline measures.

Planning

Correction angle was calculated using the Miniaci method. 7 Target mechanical axis was aimed at the Fujisawa point (62.5% lateral from the medial tibial plateau) for optimal offloading of the medial compartment.

Surgical technique

All procedures were performed under spinal and epidural anesthesia with the patient in supine position and a tourniquet applied to the proximal thigh. A longitudinal incision was made over the medial aspect of the proximal tibia (Figure 1a and b).

After elevating the pes anserinus, a biplanar osteotomy was marked approximately 3.5-4.0 cm below the joint line. The osteotomy was performed using an oscillating saw under fluoroscopic guidance, carefully preserving the lateral cortex as a hinge (Figure 2a and b).

Once the osteotomy was complete, a laminar spreader was used to gradually open the gap to the pre-calculated correction angle. Alignment rods were used intra-operatively to ensure appropriate correction relative to the mechanical axis. The osteotomy gap was stabilized using a TomoFix medial high tibial locking plate, ensuring angular stability (Figure 3). Bone grafting was performed only when the gap exceeded 10 mm.

Postoperative protocol

All patients followed a standardized rehabilitation protocol.

Day 1-2: Static quadriceps, ankle pumps and isometric exercises.

Day 2 onward: Toe-touch weight-bearing using a walker.

Week 2: Partial weight-bearing initiated; sutures removed.

Week 6: Progression to full weight-bearing based on radiographic evidence of union.

Week 12: Return to independent ambulation and gradual resumption of functional activities. Patients were counselled to avoid squatting and kneeling in the early postoperative period, although many resumed culturally typical sitting postures after 4-5 months.

Follow-up and outcome measures

Patients were followed up at 6 weeks, 3 months and 6 months. At each visit, the following were assessed VAS

for pain, KSS and KSFS. Walking distance (using a modified 6-minute walk test). Radiographs to evaluate union, alignment and any implant-related issues. Complications such as infection, non-union, loss of correction or hardware issues were recorded and managed accordingly.

Case illustration

A 57 years old female, housewife, moderately obese with pain in right knee since, 4 years with 4-degree varus underwent medial open wedge high tibial osteotomy. Pre-operative X-rays shown in Figure 4(a), (b) and (c). Post operative X-rays shown in Figure 5(a), (b) and (c).

Statistical analysis

Statistical analysis was performed using SPSS version 25.0. Continuous variables were expressed as mean±standard deviation. Pre-AND POST-OPERATIVE scores were compared using paired t-tests. A p value<0.05 was considered statistically significant.

RESULTS

Patient demographics

A total of 50 patients underwent medial open wedge high tibial osteotomy and were included in the study. The cohort consisted of 34 females (68%) and 16 males (32%), with a mean age of 61.2 years (ranging between 48 to 75 years).

The mean body mass index (BMI) was 26.4±3.2 kg/m², with 64% of patients classified as overweight (BMI between 25 to 29.9). The majority (72%) were engaged in physically demanding occupations such as agriculture or household labor. All patients were independently mobile prior to surgery and none had prior knee surgeries or contralateral knee disability. No patients were lost to follow-up.

Clinical outcomes

Pain (VAS)

The mean pre-operative VAS score was 6.7±1.1, which improved significantly to 1.8±0.9 at the 6-month follow-up (p<0.001). All patients reported a subjective improvement in pain. 42 patients (84%) had a VAS score≤2 at final follow-up. No patient reported worsening pain post-operatively.

Functional scores (KSS and KSFS)

Knee society score (KSS) improved from 54.7±5.8 to 82.8±6.1 (p<0.001) (Figure 12) and Knee Society Functional Score (KSFS) improved from 55.2±4.9 to 83.8±5.7 (p<0.001) (Figure 13). Patients showed consistent improvement in stair climbing, range of motion

and stability scores. 92% patients had KSS>80 at final follow-up. All patients regained near-full extension and at least 120° of flexion.

Walking distance

The average pre-operative walking distance was 178±65 meters, which improved to 575±90 meters post-operatively ($p<0.001$). Pre-operatively, only 6 patients (12%) could walk >400 meters. At 6 months, 44 patients (88%) were able to walk >500 meters comfortably. Patients aged ≤60 years showed slightly better gains than older patients, though not statistically significant ($p=0.06$).

Radiological outcomes

Pre-operative mechanical axis deviation (MAD) was $7.2^\circ \pm 1.3^\circ$ varus while the post-operative MAD was $2.1^\circ \pm 1.1^\circ$ valgus. Average correction angle was $9.3^\circ \pm 2.1^\circ$. Radiological union at the osteotomy site was observed in 100% of patients by 12 weeks. There was no evidence of implant loosening, hardware failure or osteotomy site collapse. No patient developed lateral compartment degeneration during the 6-month follow-up.

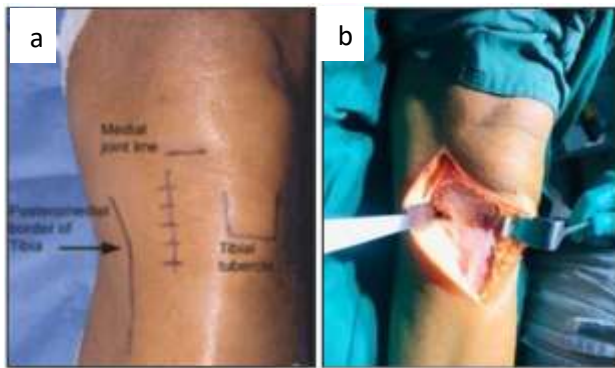


Figure 1 (a and b): Incision site markings and soft tissue dissection after incision.

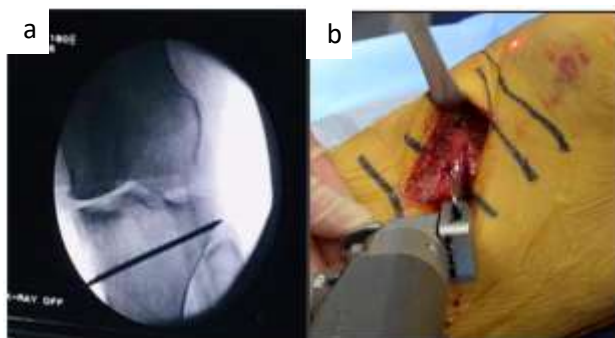


Figure 2 (a and b): Marking and performing the osteotomy.

Complications

A total of 11 patients (22%) developed minor complications post-operatively. Hardware prominence

was the most common complication, affecting 8 patients (16%). Under correction with less than 5° valgus occurred in 6 patients (12%). Superficial infection developed in 2 patients (4%). No cases of deep infection, non-union or implant failure were observed in this study cohort.



Figure 3: Stabilisation of osteotomy with Tomofix locking plate.



Figure 4: (a) Pre-operative X-ray right knee AP, (b) lateral and (c) long leg full weight bearing x-ray of bilateral lower limb, showing existing hip-knee-ankle (HKA) axis (red line) and planned-future HKA axis passing through Fujisawa point (blue line).

Hardware prominence was more common in patients with lower BMI and thin soft-tissue envelopes. Two patients underwent implant removal after union. Under correction was typically due to intra-operative underestimation or soft-tissue laxity but did not affect pain or function. Superficial wound infections resolved with oral antibiotics

and local dressings. No patient required re-operation or experienced neurovascular complications.



Figure 5 (a-c): Post-operative X-ray right knee AP (a), Lateral (b) and long leg full weight bearing X-ray (c) of bilateral lower limbs showing post operative corrected HKA axis, passing through Fujisawa Point.

Subset analysis

Patients aged <60 years had slightly better post-operative KSS and KSFS scores (mean +3.1 points), though not statistically significant. Overweight patients (BMI >25) had similar pain relief but reported slightly less improvement in walking distance. No significant difference was observed between genders in terms of pain, function or complication rates.

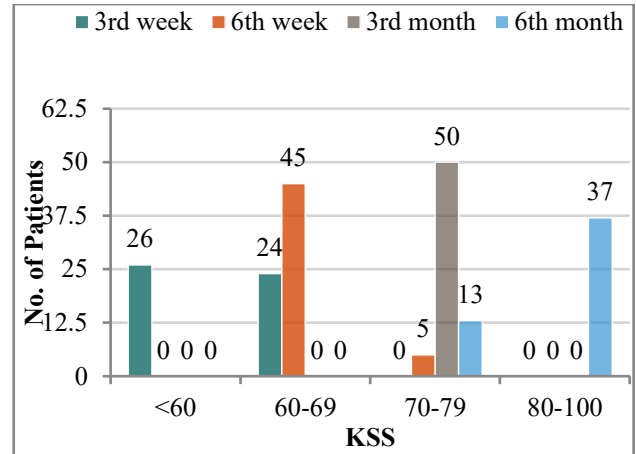


Figure 6: Post-operative KSS.

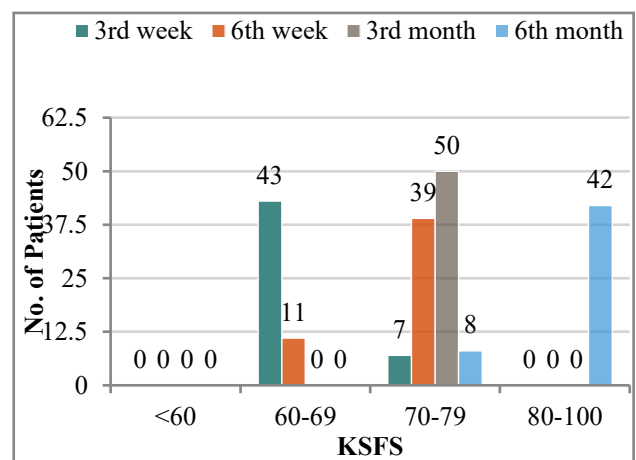


Figure 7: Post-operative KSFS.

Table 1: Pre- and post-operative findings of clinical outcomes.

Parameter	Pre-operative value (Mean±SD)	Post-operative value at 6 months (Mean±SD)	P value
VAS Score	6.7±1.1	1.8±0.9	<0.001
KSS	54.7±5.8	82.8±6.1	<0.001
KSFS	55.2±4.9	83.8±5.7	<0.001
Walking distance	178±65 meters	575±90 meters	<0.001

Table 2: Post-operative complications.

Complication	No. of patients	%
Hardware prominence	8	16
Under correction (<5° valgus)	6	12
Superficial infection	2	4
Deep infection	0	0
Non-union	0	0
Implant failure	0	0

DISCUSSION

This study affirms the clinical and functional benefits of medial open wedge HTO for patients with isolated medial compartment OA and varus deformity, particularly within

a rural Indian healthcare setting. Over a six-month follow-up, we observed substantial improvements in pain (VAS), joint-specific outcomes (KSS), functional ability (KSFS) and walking distance, all of which are critical metrics for patient satisfaction and quality of life in this demographic.

While TKA is widely regarded as the definitive solution for end-stage osteoarthritis, it may not be ideal for all patient populations, particularly those in rural or economically constrained environments. In rural India, many patients delay seeking care until significant pain or deformity sets in and access to arthroplasty is often limited due to financial, logistical or cultural reasons.⁸ Activities such as squatting, kneeling and sitting cross-legged remain essential for daily living and TKA imposes restrictions on these positions. In contrast, HTO preserves the native joint, maintains proprioception and allows for continued participation in traditional functional postures.

Our findings mirror results from several large studies conducted in high-resource settings. Study by El-Azab et al, demonstrated comparable improvements in Knee Society Scores following medial open wedge HTO using the TomoFix plate and Duivenvoorden et al, reported similar gains in walking distance and functional mobility.^{3,4} In our study, the mean KSS improved from 54.7 to 82.8 and KSFS from 55.2 to 83.8, indicating significant recovery in both joint function and ambulatory capacity.

Based on the knee society score, excellent and good results were observed in 30% and 55% of patients, respectively. Overall, our results are comparable to those reported by Kolb et al and Sen et al.^{15,18} The VAS score improvement from 6.7 to 1.8 (a reduction of 5 points) reflects robust pain relief consistent with the biomechanical unloading of the medial compartment after HTO. Studies by Coventry et al, Mukherjee et al and Ogden et al, have reported sustained pain relief and functional improvement post HTO, emphasizing the procedure's ability to preserve knee function and delay the need for more invasive surgeries.^{9,10,16,17}

Additionally, mild to moderate obesity, as measured by BMI, did not appear to adversely affect the functional outcomes in our cohort, supporting the notion that BMI alone should not be an exclusion criterion. The average correction angle of 9.3°, with mechanical axis realignment from 7.2° varus to 2.1° valgus, falls within accepted parameters for optimal outcome. This reinforces the importance of preoperative planning and intra-operative alignment verification to achieve reproducible results. In our study, we aimed for a valgus correction of 3–4°, which aligns with the 3–5° correction recommended by Dugdale et al.¹³ The angle of correction was calculated using the Miniaci technique. This method has been reported to yield larger correction angles than the Dugdale technique and is associated with superior functional outcomes, as supported by Umit Aygun et al.¹⁴

Use of a locking compression plate (TomoFix) offered several advantages, including high angular stability, reduced risk of loss of correction and facilitation of early mobilization.¹¹ All patients in our cohort achieved radiographic union by 12 weeks. A bone graft was used in one case in our series where the opening wedge exceeded 1 cm. However, all osteotomy sites, including the one with

grafting, showed radiological union within 3 months, which concurs with the findings of Kolb et al, indicating that bone grafting may not be essential for all patients undergoing MOWHTO.¹⁵

None of the patients developed lateral compartment OA or instability during follow-up. These results support the continued use of stable fixation constructs in HTO, particularly when physiotherapy access is limited which is a common issue in rural areas. The overall complication rate of 22% in our study is comparable to existing literature and involved mostly minor, self-limiting issues.¹² Hardware prominence was the most frequent issue, particularly among lean patients with less soft-tissue coverage. These cases were managed conservatively, with only two requiring elective implant removal.

Under correction was noted in six patients (12%), usually due to intra-operative estimation errors or unexpected soft-tissue behavior. However, none of these cases required revision and pain relief remained satisfactory. No major complications such as neurovascular injury, deep infection or non-union were observed, a reflection of meticulous surgical technique and strict adherence to postoperative protocols. HTO is uniquely positioned to meet the needs of patients in settings where TKA is either not available or culturally resisted. The cost of HTO is significantly lower than that of arthroplasty and the postoperative demands, though significant, are more compatible with rural patients' expectations. Many of our patients resumed farming, household work or community activity within 4 to 5 months of surgery. Moreover, despite limited access to formal physiotherapy, most patients in our study followed home-based rehabilitation instructions effectively, achieving outcomes comparable to urban patients with institutional rehab. This highlights the adaptability and self-efficacy of rural patients when provided with clear guidance.

Given the growing burden of osteoarthritis in rural India and similar settings globally, medial open wedge HTO deserves greater attention as a frontline surgical solution in selected patients. It offers a functionally meaningful, cost-effective and culturally acceptable alternative to early TKA, particularly in middle-aged individuals with isolated medial disease. Although traditionally HTO has been advocated primarily for younger patients, our study demonstrated that favourable outcomes can also be achieved in older individuals, provided there is isolated medial compartmental disease. Older patients with medial compartment OA with patellar pain, can be recommended MOWHTO combined with patellar neurectomy for good functional outcome, provided that the lateral compartment is not involved. These findings suggest that chronological age alone should not contraindicate the procedure. With proper surgical technique, patient selection and follow-up, HTO can restore independence and mobility and in rural populations, this often means restoring dignity and livelihood.

In this study, patients demonstrated significant improvements in pain, functional capacity and walking

ability, with a low incidence of complications and a 100% union rate within 12 weeks. HTO offers several advantages in the Indian rural context: it is cost-effective, preserves native joint biomechanics and aligns with functional demands such as squatting, kneeling and prolonged walking. Unlike total knee arthroplasty, it does not restrict culturally important postures and allows patients to resume occupation-related physical activities.

This study has its limitations including short 6-month follow-up, absence of a control group for comparison with other methods of high tibial osteotomy, TKA or conservative therapy, lack of objective gait analysis or advanced imaging and variable rehabilitation due to limited rural physiotherapy infrastructure. However, the significant improvements observed in this resource-constrained rural setting strongly support the effectiveness of HTO in such populations. The results of this study reaffirm the value of MOWHTO as a frontline surgical solution in early to mid-stage osteoarthritis of the knee, especially when total knee replacement is either delayed, inaccessible or functionally inappropriate. Long-term follow-up and comparative studies are needed to further establish its durability, but its short-term efficacy and cultural adaptability make it highly suitable for broader implementation in rural orthopaedic practice.

CONCLUSION

Medial open wedge high tibial osteotomy (MOWHTO) is a reliable surgical option for the management of isolated medial compartment osteoarthritis of the knee, particularly in the rural population. It results in significant pain relief and improvement in functional outcomes. The procedure also has the advantage of potentially delaying or even avoiding the need for TKR and does not preclude future TKR if required. Bone grafting is not necessary in all cases and should be reserved for large corrections (>1 cm). Importantly, a mildly to moderately elevated BMI and advanced chronological age should not be considered absolute contraindications, provided the patient has isolated medial compartment involvement.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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