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Published via Directorate of Research, N.K.P Salve Institute of Medical Sciences & Research Centre

Treatment of Varus Knee Osteoarthritis in Young Adults by Medial Opening-Wedge High Tibial Osteotomy Combined With Arthroscopic Medial Meniscus Repair

Received 08/06/2026
Review began 10/03/2026
Review ended 10/17/2026
Published 10/25/2026

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DOI: 10.7759/cureus.118548

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Abstract

Background

Varus malalignment increases load across the medial compartment of the knee and contributes to the progression of medial compartment osteoarthritis and associated meniscal damage. Medial opening-wedge high tibial osteotomy (MOWHTO) can correct lower-limb alignment and unload the medial compartment, while simultaneous meniscal repair may preserve meniscal function in young patients with repairable tears.

Objective

The objective of this study is to evaluate changes in pain scores and the short-term radiological and clinical outcomes over six months following medial opening-wedge high tibial osteotomy combined with arthroscopic medial meniscal repair in young adults with varus medial-compartment knee osteoarthritis and repairable medial meniscal tears.

Methods

This prospective case series was conducted in the Department of Orthopaedics at Lata Mangeshkar Hospital, Nagpur, from May 2025 to April 2026. Fifteen patients aged 20-40 years with symptomatic medial compartment knee osteoarthritis, varus alignment, and repairable medial meniscus tears were included. All patients underwent arthroscopic meniscus repair followed by MOWHTO with correction targeted at approximately 50% of the tibial plateau width.

Results

The mean age of the patients was 33.53±3.46 years, and eight (53.3%) were women. At six months, the mean hip-knee-ankle angle was 2.74±0.79° valgus, and the mean weight-bearing-line position was 58.8%±4.8% of the total tibial plateau width measured from the medial edge. The mean medial proximal tibial angle and mechanical lateral distal femoral angle were 91.11±2.04° and 88.05±0.91°, respectively. Mean visual analog scale (VAS) score decreased from 6.87±0.92 preoperatively to 3.33±1.05 at six weeks, 1.87±0.74 at three months, and 0.73±0.88 at six months. The reduction in pain over time was statistically significant (χ^2=38.48; p<0.001). During the six-month follow-up, no nonunion, documented delayed union, infection, implant failure, neurovascular injury, thromboembolic event, loss of correction, or reoperation was recorded. No hinge fracture or clinically significant hardware complication was documented. Radiographic follow-up demonstrated maintenance of the achieved correction and osteotomy healing within the follow-up period.

Conclusion

Combined MOWHTO and arthroscopic medial meniscal repair was associated with improvement in pain scores over six months and postoperative correction of varus alignment. No major complications were recorded in this small case series during the six-month follow-up. Given the absence of a control group and the short follow-up period, these findings should be interpreted as preliminary observations rather than evidence of established effectiveness or safety.

Categories: General Surgery, Public Health, Orthopedics
Keywords: high tibial osteotomy, knee osteoarthritis, medial meniscus repair, varus knee, visual analog scale

How to cite this article
Deshpande S, Mitra R, Taneja D, et al. (October 25, 2026) Treatment of Varus Knee Osteoarthritis in Young Adults by Medial Opening-Wedge High Tibial Osteotomy Combined With Arthroscopic Medial Meniscus Repair. Cureus 18(10): e118548. DOI 10.7759/cureus.118548

Introduction

Osteoarthritis (OA) of the knee is a progressive chronic degenerative disease that involves the loss of cartilage, remodeling of the subchondral bone, formation of osteophytes, pain, and limitation of function [1]. It is one of the most important contributors to musculoskeletal disabilities globally and represents a significant socioeconomic burden to healthcare systems. The burden of knee OA is influenced by population ageing, increasing obesity, reduced physical activity, and longer life expectancy [2]. While total knee arthroplasty (TKA) is a reliable treatment for advanced disease, its use in younger, physically active patients may be limited by concerns regarding implant longevity and the potential need for revision surgery. Therefore, joint-preserving procedures such as high tibial osteotomy (HTO) may be considered in carefully selected younger patients with medial compartment osteoarthritis and varus malalignment [3]. Varus malalignment is one of the most important biomechanical factors responsible for the development and progression of medial compartment knee osteoarthritis. Malalignment causes an increase in the mechanical axis, which leads to more load-bearing in the medial tibiofemoral compartment. Overloading also speeds up the deterioration of cartilage and can lead to damage of the meniscus and set the stage for further cartilage loss. Previous biomechanical experiments have shown that the varus deformity, even as small as 5°, is enough to cause significant stress increase in the medial compartment and is a risk factor for the development of symptomatic knee OA [4]. The medial meniscus plays a crucial role in load distribution, shock absorption, joint stability, and preservation of articular cartilage. When the meniscal integrity is lost, hoop stress transmission within the knee is reduced and focal contact pressures within the knee are increased [5]. Therefore, tears of the meniscus have been linked to early cartilage degeneration and deterioration of the OA [6]. The current trend for orthopaedic care is to preserve the meniscus whenever possible, although the choice between repair and partial meniscectomy depends on tear characteristics and repairability [7].

Conservative management of medial compartment osteoarthritis involves activity modification, weight loss, physiotherapy, analgesics, non-steroidal anti-inflammatory drugs (NSAIDs), bracing, and intra-articular injections [8]. These actions can help reduce symptoms, but they will not resolve the underlying mechanical abnormality that is the cause of the progression of the disease. In selected patients, surgery including unicompartmental or total knee arthroplasty can be effective but may not be optimal in younger patients due to fear of implant longevity, revision surgery, and limitations on activities of daily living [9]. High tibial osteotomy (HTO) continues to be an important joint-saving procedure in patients with medial compartment osteoarthritis and varus alignment [10]. HTO redistributes load away from the diseased medial compartment of the knee and shifts weight-bearing forces to relatively preserved areas. Since that time, the surgical planning, fixation and rehabilitation techniques have evolved, making the procedure more predictable and successful [7]. Many studies have shown that HTO can help alleviate pain, enhance function and delay the need for arthroplasty in patients that are well selected [11,12]. The most popular of the osteotomies is the medial opening-wedge high tibial osteotomy (MOWHTO). Some benefits of this include preservation of bone stock, avoiding fibular osteotomy, precise correction of deformity and allowing for future conversion to a total knee arthroplasty if necessary [13]. Locking-plate systems provide stable fixation following medial opening-wedge high tibial osteotomy, supporting osteotomy healing [14]. The radiological and functional results of MOWHTO have been reported as good in all clinical studies performed in patients with varus knees with OA [15].

The aim of the present prospective study was to assess the six-month clinical and radiological outcomes of MOWHTO for young adults with varus medial-compartment knee osteoarthritis and tears of the medial meniscus that were amendable to treatment with arthroscopic medial meniscus repair. The outcomes included changes in Visual Analogue Scale (VAS) pain scores, postoperative radiographic alignment, knee range of motion, and reported postoperative complications.

Materials And Methods

Study design and setting

This prospective interventional case series was conducted in the Department of Orthopedics at Lata Mangeshkar Hospital, Nagpur. The overall study period was May 2025 to April 2026. The single-arm case series evaluated the short-term clinical and radiological outcomes following MOWHTO combined with arthroscopic medial meniscal repair in young adults with medial compartment knee osteoarthritis and reparable medial meniscus tears. No control group was included.

Ethical approval and informed consent

The study was approved by the Institutional Ethics Committee of N.K.P. Salve Institute of Medical Sciences and Research Centre and Lata Mangeshkar Hospital (Approval No. LMH/IEC/7/2025; approval date: March 27, 2025). Written informed consent was obtained from all participants before enrolment and surgery. Participants were informed about the study procedures, follow-up requirements, potential risks and benefits, and their right to withdraw without affecting their clinical care. Separate written consent for publication of anonymized clinical and radiological images was obtained from participants whose images are included in the manuscript. The timeline for recruitment, operative period, follow-up and analysis included recruitment and surgery undertaken from May to August 2025, last participant's six-month assessment

follow-up completed in February 2026 and data-analysis undertaken from March to April 2026.

Participant flow

During the study period, 25 patients were screened, of whom 20 were eligible and 15 were enrolled and underwent surgery. Five eligible patients were not enrolled; three declined participation and two were unable to commit to the scheduled postoperative follow-up. No enrolled participant was excluded after surgery because of failure to complete follow-up. All 15 enrolled patients completed the planned six-month follow-up, and no participant was lost to follow-up. The consecutive sampling technique was used for the recruitment of patients who presented to the orthopedics outpatient and inpatient clinics during the study period.

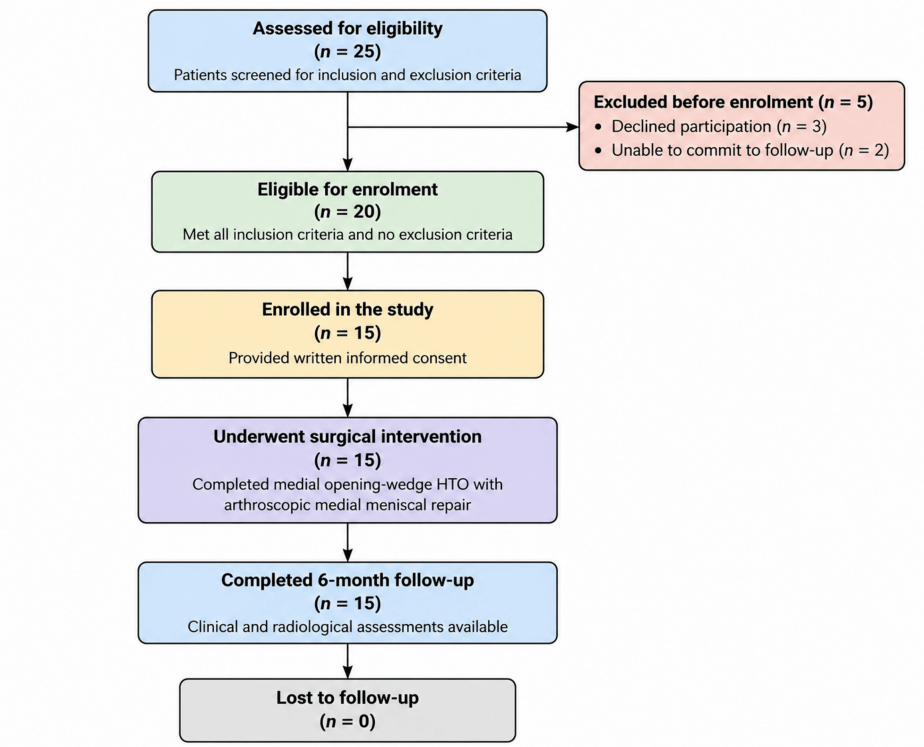

FIGURE 1: Patient flow diagram

Selection criteria

Fifteen patients (eight women and seven men) were enrolled. Eligible were young adults with symptomatic knee OA in the medial compartment (Kellgren-Lawrence grade II/III) and varus alignment whose medial meniscus tear was repairable. Patients included were aged between 20 and 40 years and had symptomatic medial compartment knee OA with varus alignment. The medial meniscus tear was noted on magnetic resonance imaging (MRI) and confirmed during arthroscopy and was repairable. Patients had to be experiencing persistent knee pain and functional limitation despite at least three months of satisfactory conservative management and be prepared to undergo surgery, post-operative rehabilitation and regular post-operative review. Excluded patients were those with advanced tricompartmental, lateral compartment, severe patellofemoral osteoarthritis, irreparable meniscal tears, and previous meniscectomy. Other exclusions included inflammatory arthritis, infection or malignancy around the knee, and severe ligamentous instability that required staged reconstruction, a prior osteotomy or fracture around the proximal tibia. Patients who were unwilling or unable to commit to the scheduled postoperative follow-up were excluded before enrollment.

Data collection

Patients enrolled in the study were subjected to a detailed clinical evaluation, which included age, sex, occupation or activity level, side involved, duration of symptoms and body mass index. Some of the clinical measurements performed were lower-limb deformity, range of motion of the knees, joint-line tenderness, ligamentous stability, and gait abnormalities.

Radiographic Assessment and Measurement Reliability

Radiographic parameters were assessed on standing long-leg radiographs using the anatomical landmarks and measurement conventions. Baseline radiological testing included weight-bearing anteroposterior (AP) and lateral knee views, long-leg standing radiograph for mechanical-axis assessment and magnetic resonance imaging of the knee to evaluate meniscal pathology and chondral lesions. The severity of osteoarthritis was assessed by the Kellgen-Lawrence classification [16]. The medial proximal tibial angle (MPTA), mechanical lateral distal femoral angle (mLDFA), posterior tibial slope, preoperative hip-knee-ankle angle, proposed correction angle, and required osteotomy gap were calculated using long-leg radiographs.

The planned mechanical-axis correction was towards neutral to slight valgus, with the weight-bearing axis targeted at approximately 50% of the tibial plateau width from the medial edge. This represented the predefined planning target rather than a strict postoperative acceptance threshold. This conservative correction target was chosen over the classical Fujisawa point of 62.5% to lessen loading of the medial compartment without going into too extreme of valgus correction in younger patients undergoing meniscal repair. Intraoperative alignment was checked with an alignment rod or cable from the center of the femoral head to the center of the ankle joint, using fluoroscopy. The recorded measurements were used to evaluate preoperative deformity and postoperative correction, including changes in lower-limb alignment and relevant tibial and femoral angles. Measurement reproducibility was not independently quantified and should be considered when interpreting the radiographic findings.

Patients were all operated under spinal or combined anaesthesia, supine and tourniquet-controlled. Initial arthroscopy was performed for evaluation of the tear pattern of the medial meniscus, evaluation of the status of the articular cartilage, and assessment of intra-articular pathology. Meniscal repairability was determined intraoperatively based on tear pattern, tissue quality, vascularity, reducibility, and the ability to achieve stable anatomical approximation without excessive tension. Longitudinal tears were repaired using an all-inside or inside-out suture technique as appropriate to tear location, while horizontal and bucket-handle tears were repaired using an appropriate combination of all-inside and/or inside-out sutures after reduction. Posterior medial meniscal root tears were treated with transtibial pullout repair using nonabsorbable sutures passed through the meniscal root and secured over the anterior tibial cortex. The transtibial tunnel trajectory and tibial fixation were planned in relation to the subsequent medial opening-wedge osteotomy to avoid tunnel convergence with the osteotomy and the proximal tibial fixation plate.

On the anteromedial surface of the proximal tibia, a 5-7 cm longitudinal incision was created distally from the joint line, following arthroscopy. The pes anserinus process was identified and retracted and the superficial fibres of the medial collateral ligament (MCL) released subperiosteally to allow controlled opening of the osteotomy. Two Kirschner wires were inserted based on fluoroscopic guidance from the medial tibial cortex into the proximal tibiofibular joint to establish the osteotomy plane. The osteotomy was made at a level about 3-4 cm below the medial joint line and was oriented towards a 1-1.5 cm medial point 1 cm lateral to the lateral cortex; the lateral cortex was preserved as a hinge. An oscillating saw and osteotomes were then used to perform a biplanar medial opening wedge osteotomy. The horizontal cut was placed at an angle toward the proximal tibiofibular joint and the anterior ascending cut was made behind the tibial tuberosity to enhance rotational stability while maintaining the mechanics of the patellar tendon. About 1 cm of the lateral cortex was retained in order to preserve the integrity of the hinges and to minimise the likelihood of fracture. Calibrated osteotomes or wedge spreader were used to progressively open the osteotomy.

Postoperative Complications and Osteotomy Healing

Patients were assessed clinically and radiographically at six weeks, three months, and six months post surgery. At each visit, wound status, evidence of infection, neurovascular status, and implant-related complications were assessed. VAS [17] was used to assess pain at every follow-up visit. Knee range of motion (ROM) was assessed preoperatively and at the six-week postoperative follow-up. Later postoperative ROM measurements were not available for analysis. Radiographs were evaluated for osteotomy healing, maintenance of correction, lateral hinge integrity, and hardware-related problems. Delayed union, nonunion, hinge fracture, loss of correction, infection, thromboembolic events, neurovascular injury, hardware failure, and reoperation were recorded when present. Osteotomy union was defined by progressive bony bridging across the osteotomy gap on serial radiographs, supported by absence of pain or tenderness during weight-bearing; delayed union referred to inadequate radiographic progression by approximately six months; nonunion denoted persistent failure of progressive healing, commonly assessed at nine to 12 months; and loss of correction was defined as a deterioration of more than 3° in the hip-knee-ankle angle compared with the postoperative value. Time to union was not systematically recorded as a separate outcome.

At the six-month follow-up, all 15 participants underwent standing scanography to reassess the hip-knee-ankle angle, weight-bearing-line position, medial proximal tibial angle, mechanical lateral distal femoral angle, and posterior tibial slope. The results of all findings were documented with a standardized study proforma. The postoperative weight-bearing-line position was expressed as the percentage of the total tibial plateau width measured from the medial edge, with 0% representing the medial edge and 100% representing the lateral edge. This parameter represents the weight-bearing-line ratio and was not interpreted as an angular mechanical-axis deviation. Hip-knee-ankle angles were expressed as varus or valgus according to

the direction of deviation from the mechanical neutral axis, with varus values reported separately from valgus values. After satisfactory correction had been achieved, the osteotomy gap was maintained and stabilized using a locking proximal tibial plate. Screws were inserted under fluoroscopic guidance, both to provide cortical screws and locking screws for stability. Final fluoroscopic imaging verified the intended correction of the coronal plane, position of the implants, lateral cortical hinge and stability of fixation. Irrigation and closure of wound was done in layers and where necessary, a suction drain was placed. Thereafter, a sterile dressing and compression was made.

Postoperative Rehabilitation

A standardized, staged rehabilitation protocol was followed, balancing protection of the meniscal repair with progressive loading of the healing medial opening-wedge high tibial osteotomy. A hinged knee brace was used during ambulation for the initial six weeks. During the first two weeks, knee flexion was restricted to approximately 0°-90°, with gradual progression to 0°-110° by four weeks and near-full flexion by six weeks, provided pain and swelling were controlled. For posterior medial meniscal root repairs, a more protective protocol was followed. The knee was maintained in a hinged brace with flexion restricted to 0°-90° for four to six weeks, and toe-touch/very limited weight bearing was maintained initially, followed by gradual progression to partial weight bearing after four to six weeks. Full weight bearing was permitted only after radiographic evidence of satisfactory osteotomy healing. For longitudinal, horizontal, and bucket-handle repairs, the same overall osteotomy-protection protocol was followed, but motion was progressed somewhat more rapidly when clinically tolerated. Flexion was generally limited to 90° during the initial two to four weeks, followed by progressive increase in range of motion. Quadriceps-setting, straight-leg-raising when appropriate, ankle-pump exercises, and other non-impact exercises were initiated early. Partial weight bearing with crutch support was progressively increased according to pain, swelling, clinical examination, and radiographic evidence of osteotomy healing. Patients were advanced to full weight bearing after satisfactory radiographic healing of the osteotomy. Running, jumping, deep squatting, and other high-impact activities were avoided during the early healing period. Range of motion (ROM) exercises were performed within the prescribed flexion limits and were progressed according to pain, effusion, wound status, and clinical recovery. It was permitted to place a partial load with support for four to six weeks to gradually load the bone to full weight-bearing after the radiographic healing of osteotomy. Patients were instructed not to force flexion beyond the prescribed limit or to exercise through significant pain.

Study outcomes

The primary outcome was change in VAS pain score from the preoperative assessment to six months after combined MOWHTO and arthroscopic medial meniscus repair. VAS scores were recorded preoperatively and at six weeks, three months, and six months postoperatively. Secondary outcomes included radiographic alignment parameters (hip-knee-ankle angle, weight-bearing-line position, medial proximal tibial angle, mechanical lateral distal femoral angle, and posterior tibial slope), knee range of motion, osteotomy healing and maintenance of correction, and postoperative complications, including infection, delayed union, nonunion, hinge fracture, loss of correction, implant failure, neurovascular injury, thromboembolic events, and reoperation.

Statistical analysis

Data were entered and analysed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized using mean and standard deviation; medians and ranges were also reported where appropriate. Categorical variables were summarized as frequencies and percentages. VAS scores at the preoperative, six-week, three-month, and six-month assessments were compared using the Friedman test, a non-parametric test for repeated measurements in the same participants. The Friedman test assessed the overall difference across the four assessment points. No post hoc pairwise comparisons were performed; therefore, the result was interpreted as an overall change over time rather than evidence of differences between specific time points. The association between osteotomy gap size and operative duration was assessed using Pearson's correlation coefficient (r). The analysis evaluated the direction, magnitude, and statistical significance of the linear association. All tests were two-sided, and $p<0.05$ was considered statistically significant. The correlation analysis was not adjusted for potential confounders. Data completeness was checked before analysis. All 15 participants had complete VAS observations through the six-month assessment; therefore, no imputation was required. The Friedman test was applied to the complete set of repeated measurements. No multiplicity adjustment was applied.

Results

Of the 25 patients screened, 15 were enrolled and underwent surgery. All 15 patients completed the six-month follow-up, with no loss to follow-up. The mean age was 33.53±3.46 years with a median of 34 years and a range of 27-39 years. The mean body mass index was 27.53±2.09 kg/m², while the mean duration of symptoms was 17.53±3.87 months. Preoperatively, the mean knee range of motion was 127.40±6.27°, and the mean hip-knee-ankle angle demonstrated 9.04±1.84° of varus alignment. Baseline demographic and clinical characteristics of 15 patients are depicted in Table *1*. A representative standing radiograph demonstrating bilateral grade 2 Kellgren-Lawrence medial compartment osteoarthritis is illustrated in Figure *2*.

Variable	Mean±SD	Median (min-max)
Age, years	33.53±3.46	34 (27-39)
Body mass index, kg/m²	27.53±2.09	27.4 (24.3-30.7)
Symptom duration, months	17.53±3.87	19 (9-23)
Preoperative range of motion, degrees	127.40±6.27	128 (118-137)
Preoperative hip-knee-ankle varus angle, degrees	9.04±1.84	8.6 (6.7-12.5)

TABLE 1: Baseline demographic and clinical characteristics (n=15)

SD: standard deviation; Min: minimum; Max: maximum

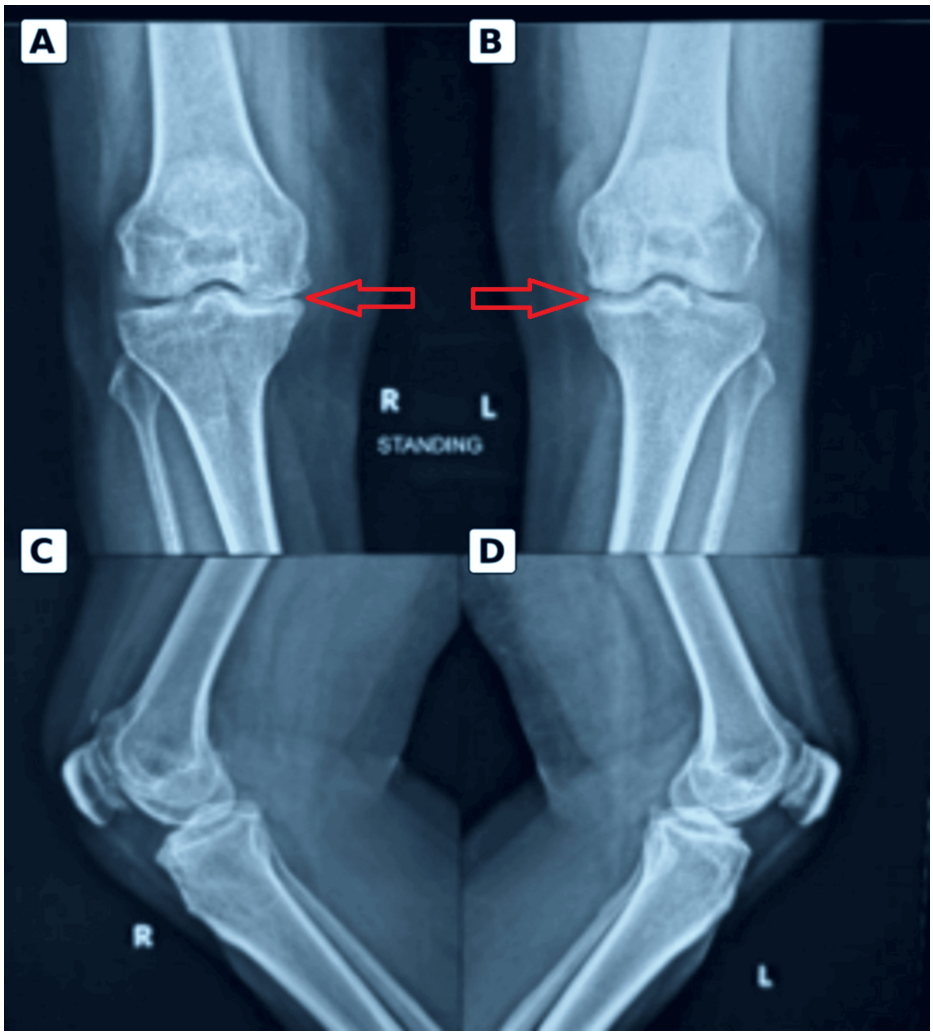

FIGURE 2: Anteroposterior and lateral standing radiographs showing bilateral grade 2 Kellgren Lawrence medial compartment osteoarthritis.

Anteroposterior and lateral standing radiographs demonstrating bilateral grade II Kellgren-Lawrence medial compartment osteoarthritis. A: Right knee anteroposterior view; B: left knee anteroposterior view; C: right knee lateral view; D: left knee lateral view. Arrows indicate medial tibiofemoral joint-space narrowing.

A standing scanogram demonstrating the varus deformity and the mechanical-axis measurements is shown in Figure 3.

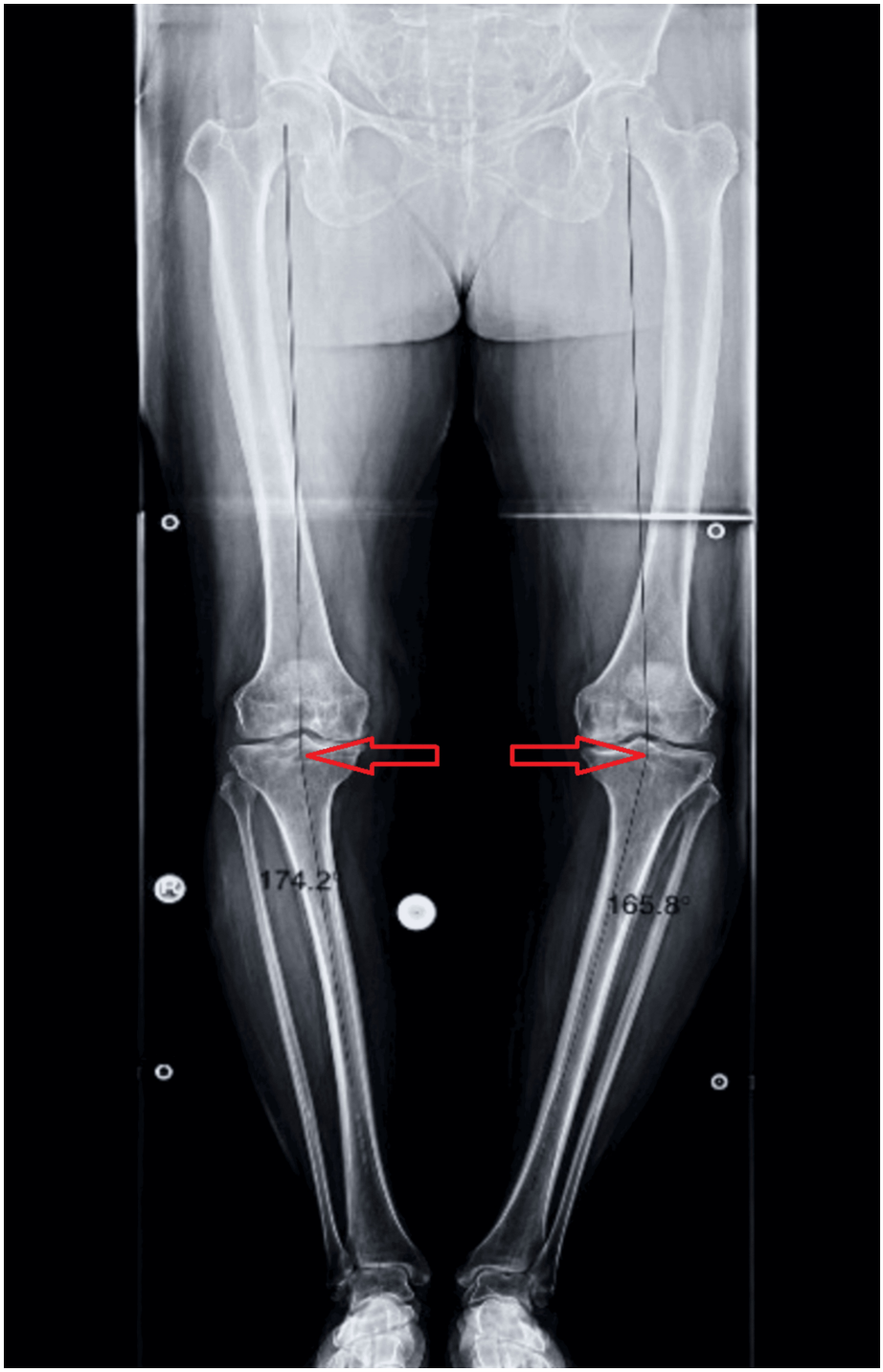

FIGURE 3: Standing full-length lower-limb scanogram demonstrating bilateral varus alignment

Arrows indicate the measured hip-knee-ankle (HKA) angles of 174.2° on the right and 165.8° on the left.

The cohort included eight women (53.3%) and seven men (46.7%). The right knee was involved in eight patients (53.3%), while the left knee was involved in seven (46.7%). Most patients had Kellgren-Lawrence grade II osteoarthritis, accounting for 12 (80.0%) cases, whereas three (20.0%) had grade III disease. The categorical characteristics of the study population are summarized in Table *2*. The radiographic measurements of the medial proximal tibial angle and mechanical lateral distal femoral angle are illustrated in Figures *4*, *5*, respectively.

Characteristic	Category	n (%)
Sex	Male	7 (46.7)
Sex	Female	8 (53.3)
Operated side	Right	8 (53.3)
Operated side	Left	7 (46.7)
Kellgren-Lawrence grade	Grade II	12 (80.0)
Kellgren-Lawrence grade	Grade III	3 (20.0)

TABLE 2: Categorical characteristics of the study population (n=15)

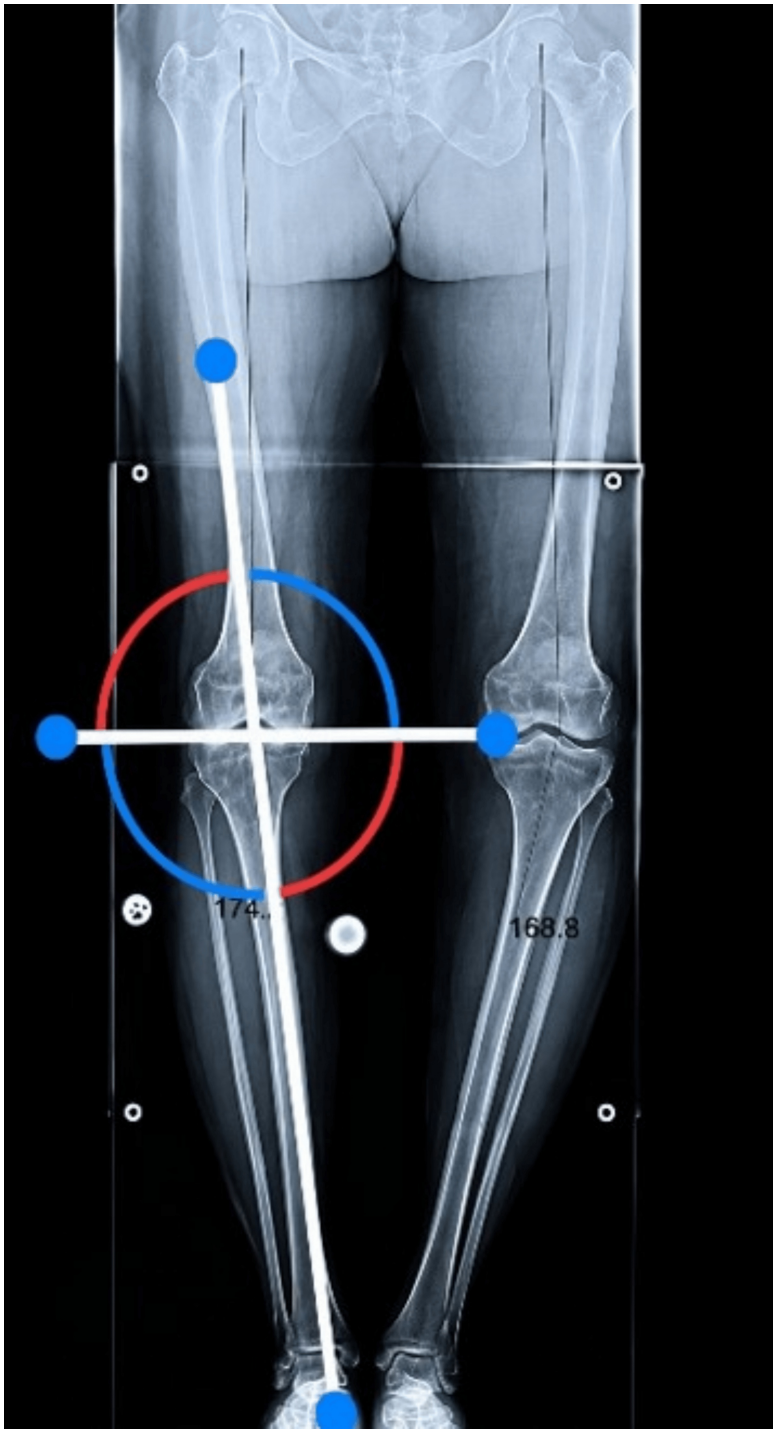

FIGURE 4: Calculation of medial proximal tibial angle (MPTA)

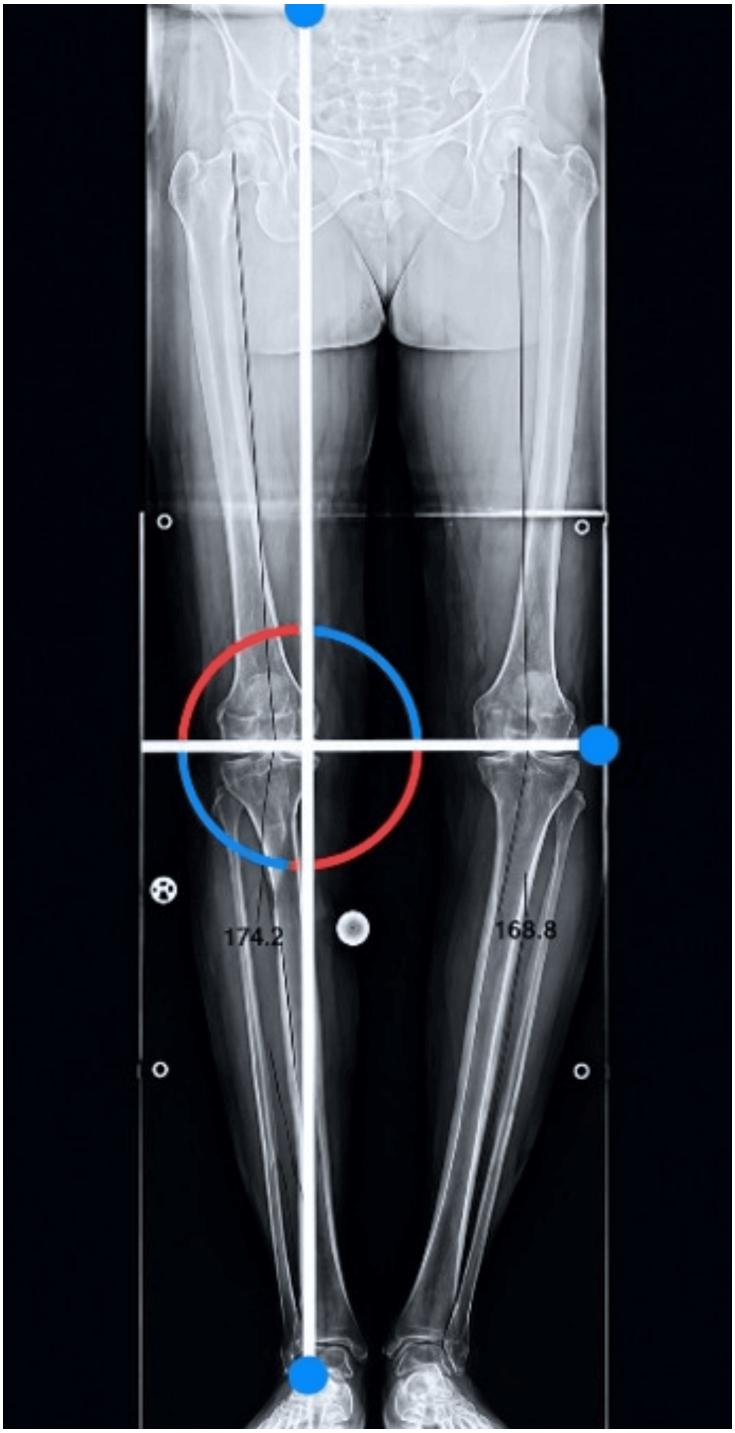

FIGURE 5: Calculation of lateral distal femoral angle (LDFA)

Arthroscopic assessment demonstrated posterior medial meniscal root tears in five (33.3%) patients, longitudinal tears in four (26.7%), horizontal tears in three (20.0%), and bucket-handle tears in three (20.0%). Cartilage abnormalities depicted in Table 3 were documented using the grading terminology recorded during arthroscopic assessment. Nine (60.0%) patients were documented as having International Cartilage Repair Society (ICRS) [18] grade II lesions, while one (6.7%) had an ICRS grade III lesion. In five (33.3%) patients, the cartilage lesion was recorded using the Outerbridge grade II classification. Because ICRS and Outerbridge classifications represent different grading systems, these findings were reported separately and were not considered interchangeable.

Cartilage classification	Grade	n (%)
ICRS	Grade II	9 (60.0)
ICRS	Grade III	1 (6.7)
Outerbridge	Grade II	5 (33.3)

TABLE 3: Cartilage classification

ICRS: International Cartilage Repair Society

The preoperative meniscal findings are summarized in Table 4. The posterior tibial slope measurement is illustrated in Figure 6.

Finding	n (%)
Posterior medial meniscal root tear	5 (33.3)
Longitudinal meniscal tear	4 (26.7)
Horizontal meniscal tear	3 (20.0)
Bucket-handle meniscal tear	3 (20.0)

TABLE 4: Preoperative meniscal pathology (n=15)

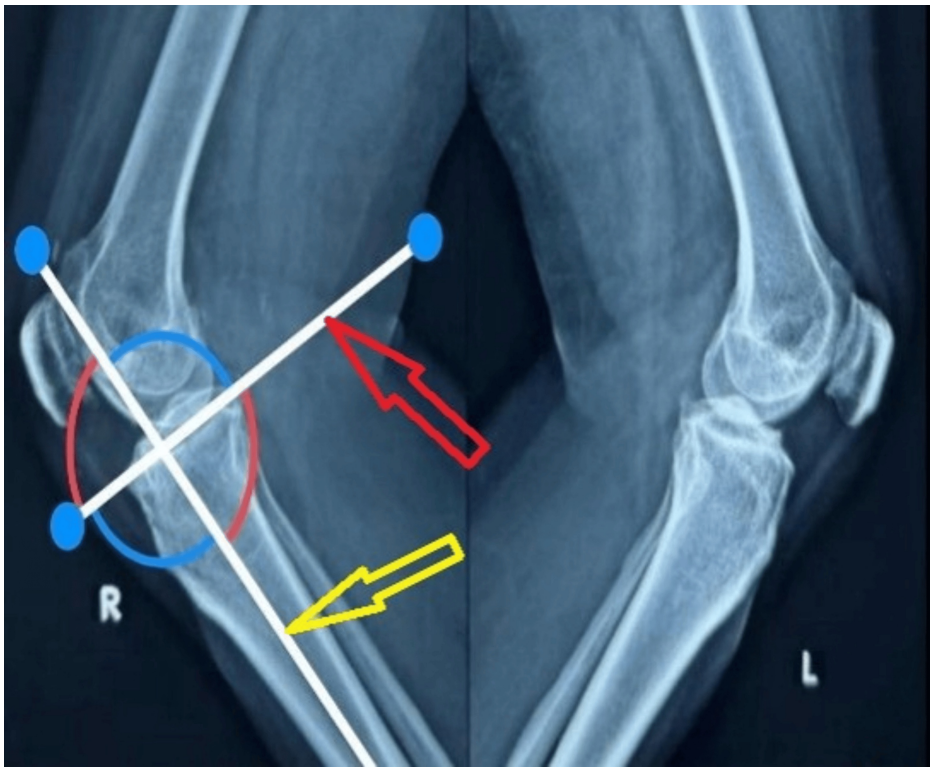

FIGURE 6: Measurement of posterior tibial slope on lateral radiograph

The red arrow indicates the tibial plateau reference line, and the yellow arrow indicates the tibial shaft reference line used for measurement of the posterior tibial slope.

The mean osteotomy gap size was 11.91±1.63 mm, and the mean operative duration was 106.40±11.20 minutes. At the six-month radiographic assessment, the mean hip-knee-ankle angle was corrected to 2.74±0.79° of valgus alignment and the mean weight-bearing-line position was 58.8%±4.8% of the total tibial plateau width measured from the medial edge, with individual values ranging from 52.9% to 67.0%. Although the planned correction target was approximately 50% of the tibial plateau width, the mean postoperative weight-bearing-line position was 58.8%±4.8%, indicating variation between the planned and achieved correction. The mean postoperative medial proximal tibial angle was 91.11±2.04°, while the mean mechanical lateral distal femoral angle was 88.05±0.91°. The mean change in posterior tibial slope was 1.94±0.77°. The operative and six-month postoperative alignment parameters are summarized in Table 5.

Variable	Mean ± SD	Median (Min-Max)
Osteotomy gap size, mm	11.91 ± 1.63	11.9 (9.1-14.3)
Operative duration, minutes	106.40±11.20	111 (80-118)
Postoperative hip-knee-ankle valgus angle, degrees	2.74±0.79	2.6 (1.6-3.9)
Weight-bearing-line position, % of tibial plateau width from medial edge	58.8±4.8%	58.9 (52.9-67.0)%
Medial proximal tibial angle, degrees	91.11±2.04	91.3 (87.7-94.4)
Mechanical lateral distal femoral angle, degrees	88.05±0.91	88.2 (86.8-89.3)
Change in posterior tibial slope, degrees	1.94±0.77	2.0 (0.5-2.9)

TABLE 5: Operative parameters and six-month postoperative alignment measurements (n=15)

A representative preoperative magnetic resonance imaging image demonstrating the medial meniscus tear is shown in Figure 7. Pain scores improved progressively throughout follow-up. The mean preoperative Visual Analog Scale score was 6.87±0.92, which decreased to 3.33±1.05 at six weeks, 1.87±0.74 at three months, and 0.73±0.88 at six months. This represented mean reductions of 3.53, 5.00, and 6.13 points, respectively, from baseline. The mean preoperative knee range of motion was 127.40±6.27°, compared with 121.33±8.14° at six weeks postoperatively, representing a numerical decrease of 6.07° in the group means. The clinical outcomes during follow-up are summarized in Table 6.

FIGURE 7: Representative preoperative magnetic resonance imaging demonstrating a medial meniscus tear.

The red arrow indicates the medial meniscus tear.

Outcome	Mean±SD	Median (Min-Max)	Change from Baseline
Preoperative Visual Analog Scale score	6.87±0.92	7 (6-8)	Baseline
Visual Analog Scale score at 6 weeks	3.33±1.05	3 (2-5)	-3.53
Visual Analog Scale score at 3 months	1.87±0.74	2 (1-3)	-5.00
Visual Analog Scale score at 6 months	0.73±0.88	0 (0-2)	-6.13
Range of motion at 6 weeks, degrees	121.33±8.14	121 (107-134)	-

TABLE 6: Clinical outcomes during follow-up (n=15)

Postoperative anteroposterior and lateral radiographs demonstrating correction of varus malalignment and fixation after medial opening wedge high tibial osteotomy are shown in Figure *8*. The Friedman test demonstrated a statistically significant overall difference in VAS scores across the four assessment points (χ^2=38.48; p<0.001). No post hoc pairwise comparisons were performed; therefore, the analysis was

interpreted as evidence of an overall change across follow-up rather than evidence of differences between specific time points. The correlation between osteotomy gap size and operative duration was positive but weak-to-moderate and not statistically significant (r=0.376; p=0.167). The statistical analysis of pain scores and operative parameters is presented in Table 7.

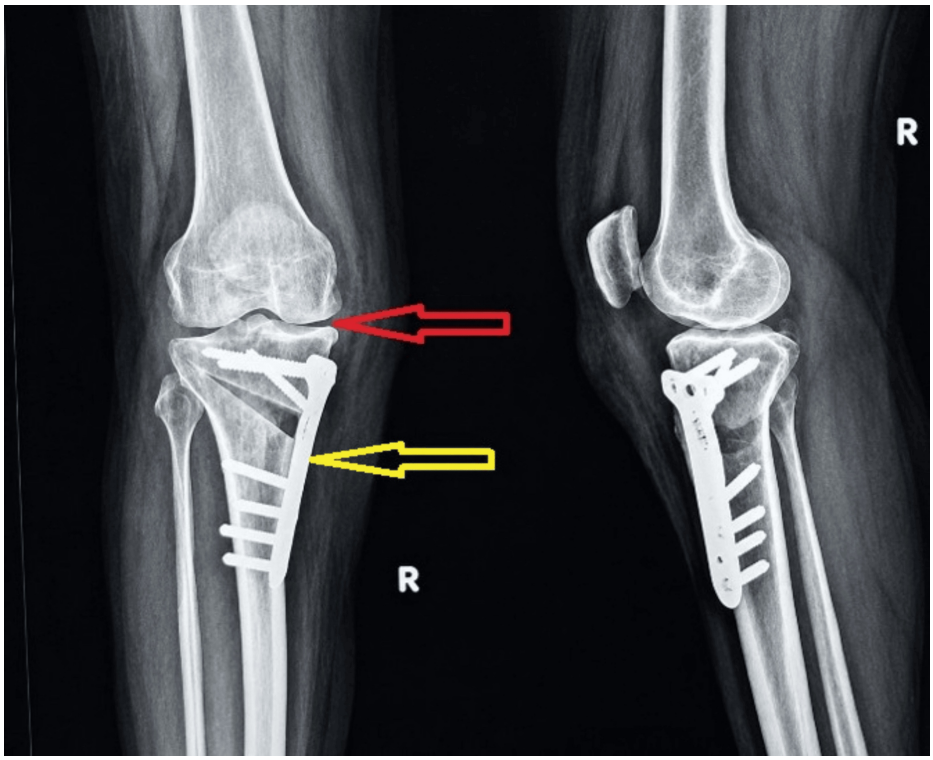

FIGURE 8: Postoperative anteroposterior and lateral radiographs following medial opening-wedge high tibial osteotomy.

The red arrows indicate the proximal tibial osteotomy/correction site, and the yellow arrows indicate the fixation plate and screws.

Analysis	Test Statistic	p-value	Interpretation
Visual analog scale scores across four time points	Friedman χ^2=38.48	<0.001	Significant reduction over time
Osteotomy gap size versus operative duration	Pearson r=0.376	0.167	No statistically significant correlation

TABLE 7: Statistical analysis of pain and operative parameters

To summarize, radiographic follow-up demonstrated osteotomy healing and maintenance of the achieved correction within the observation period. All the participants (15/15, 100%) demonstrated radiographic osteotomy healing during the six-month follow-up, with no documented delayed union, nonunion, loss of correction, hinge fracture, infection, implant failure, neurovascular injury, thromboembolic event, or reoperation. No clinically significant hardware complication was documented. Time to union was not systematically measured; therefore, the time required to achieve union could not be quantified, so the findings describe radiographic healing observed during follow-up rather than a formally measured time to union.

Discussion

Using the short follow-up data from the presented prospective interventional case series, the clinical and radiological results of MOWHTO associated with arthroscopic medial meniscus repair in young adults with varus medial compartment knee osteoarthritis were assessed. The operation was associated with short-term improvement in VAS pain scores over six months and satisfactory postoperative correction of varus alignment. Knee range of motion was lower at six weeks than at baseline, and longer follow-up is needed to

assess subsequent recovery. No complications were recorded during the six-month follow-up; however, the small sample of 15 patients limits conclusions regarding the safety of the procedure.

In these patients, our findings provide preliminary evidence of short-term outcomes following combined joint-preserving surgery in carefully selected young patients for whom a delay in total knee arthroplasty (TKA) is desirable [19]. However, the uncontrolled study design and small sample size do not establish the effectiveness or comparative benefit of the procedure.

The mean VAS score decreased from 6.87±0.92 preoperatively to 3.33±1.05 at six weeks, 1.87±0.74 at three months, and 0.73±0.88 at six months. The Friedman test showed the pain decreased significantly during follow- up (χ^2=38.48, p<0.001). This was one of the most important findings of the present study. These observations describe the outcomes following the combined intervention but do not establish a causal relationship between the procedure and the observed changes. The findings are broadly consistent with studies investigating HTO, meniscal root repair, and combined surgical approaches. However, differences in patient selection, meniscal tear patterns, surgical techniques, outcome measures, and follow-up duration limit direct comparisons across studies. As the present study had no comparison group, it cannot establish whether adding meniscal repair provides greater clinical benefit than HTO alone.

MOWHTO has been shown to provide substantial improvement in knee function and pain reduction in patients with medial compartment osteoarthritis by Bonasia et al. [20]. Similarly, Duivenvoorden et al. [8] found that valgus-producing osteotomy led to significant pain reduction and satisfactory patient-reported functional outcomes at the medium-term follow-up. The main goal of performing a high tibial osteotomy is to restore the mechanical alignment.

The mean hip-knee-ankle angle of 9.04±1.84° varus was corrected to 2.74±0.79° valgus at six-month follow-up radiographic assessment. The postoperative weight-bearing-line position was 58.8%±4.8% of the tibial plateau width (range: 52.9-67.0%), compared with the planned target of approximately 50%. No predefined acceptable postoperative correction range was specified; therefore, the achieved alignment is reported descriptively, without categorically excluding overcorrection. Intraoperative alignment was checked under fluoroscopy, while the reported postoperative alignment values represent the six-month radiographic measurements. These results are in line with previous studies by Kim et al. who stressed that correct mechanical axis correction is one of the most important factors in having good clinical results after high tibial osteotomy [15]. The postoperative medial proximal tibial angle (91.11±2.04°) and mechanical lateral distal femoral angle (88.05±0.91°) describe the achieved coronal alignment. These findings should be interpreted in the context of the study's small sample size and short follow-up. Meticulous planning and controlled correction were also found to be important for the preservation of joint biomechanics and for long-term survival of the native knee [6].

Lee et al. compared different correction targets following open-wedge HTO and reported similar clinical outcomes between the Fujisawa-point and lateral tibial spine groups, although the degree of correction and changes in patellofemoral cartilage differed [21]. Separately, Allaire et al., in a cadaveric biomechanical study, demonstrated that posterior medial meniscal root tears increased medial compartment contact pressure, while root repair restored contact pressure toward that of the intact knee [22]. These findings support the biomechanical rationale for restoring meniscal root attachment and circumferential hoop-tension transmission to improve load distribution across the knee. However, they do not establish that valgus correction slows osteoarthritis progression or demonstrate the independent clinical benefit of combining meniscal repair with HTO.

In all of our patients, arthroscopic medial meniscus repair and MOWHTO were used together. This has important implications for meniscal preservation since the medial meniscus plays a significant role in load transmission, shock absorption, joint stability and protection of cartilage. Feucht et al. [23] reviewed arthroscopic transtibial pullout repair for posterior medial meniscal root tears, highlighting the role of meniscal root repair in restoring meniscal function. However, this review does not, by itself, establish the superiority of combining root repair with high tibial osteotomy (HTO) over HTO alone. Jing et al. [24] evaluated 27 patients who underwent MOWHTO combined with all-inside repair of medial meniscal posterior root tears. At second-look arthroscopy, 11 patients demonstrated complete healing and 16 demonstrated lax healing. Clinical outcomes did not differ significantly between the two healing groups. As the study did not include an HTO-alone control group, it does not establish the comparative benefit of adding meniscal repair to HTO.

Postoperative MRI or second-look arthroscopy was not performed to directly assess meniscal healing in the present study, but the good clinical results achieved indicate that simultaneous repair can be incorporated in the joint-preserving surgical approach [25]. Maintaining mobility of the knee after combined surgery is crucial for rehabilitation. Weight bearing is still an important facet of postoperative rehabilitation, which is maintained with early mobilization. Mean knee range of motion was 127.40±6.27° preoperatively and 121.33±8.14° at six weeks postoperatively, representing a numerical decrease of 6.07° in the group means. This finding should be interpreted in the context of the early postoperative assessment and should not be described as improvement in range of motion.

Clinical implications

Clinically, the findings provide preliminary information on the short-term outcomes observed after combined HTO and arthroscopic medial meniscal repair in selected young adults with varus medial-compartment knee osteoarthritis and repairable medial meniscal tears. The observed pain changes and radiographic correction may help inform discussion of this treatment approach with appropriately selected patients. The results of the study should be interpreted as descriptive clinical observations rather than evidence of comparative effectiveness or the incremental benefit of adding meniscal repair to MOWHTO. The observed improvements may reflect the effects of osteotomy, meniscal repair, rehabilitation, other postoperative care, or their combination.

Limitations

This study has several limitations. It was a small, single-centre prospective case series involving 15 participants and had no control group. The findings describe short-term outcomes in a selected group and cannot establish comparative effectiveness or be generalized confidently to all patients with medial compartment osteoarthritis and meniscal tears. The small sample also limits the precision of estimates and the ability to characterize uncommon complications. Follow-up was limited to six months, precluding assessment of long-term functional outcomes, durability of correction, progression of osteoarthritis, long-term osteotomy survival, or later conversion to TKA. Postoperative MRI and second-look arthroscopy were not performed; therefore, meniscal healing was not directly confirmed. Validated knee-specific functional measures, including the Knee injury and Osteoarthritis Outcome Score (KOOS) [26], the International Knee Documentation Committee (IKDC)[27] subjective score, and the Lysholm score [28], were not collected. Pain was assessed using VAS, which does not capture the full range of patient-reported function. The absence of a comparison group prevents separation of the effects of osteotomy, meniscal repair, and postoperative rehabilitation. Furthermore, the reproducibility of radiographic measurements was not formally quantified, which should be considered when interpreting the alignment and angular measurements. Postoperative knee ROM was reported only at the six-week assessment, so the subsequent recovery at three and six months could not be evaluated. Larger multicentre prospective comparative studies with longer follow-up, validated functional measures, and standardized radiographic assessment are needed to confirm these findings.

Conclusions

This prospective case series demonstrates that in young patients with tibia-dominant varus deformity and a repairable medial meniscus tear, combined medial opening wedge HTO and arthroscopic meniscal repair was associated with short-term improvement in VAS pain scores over six months and satisfactory postoperative correction of varus alignment. Knee range of motion was lower at six weeks than at baseline. However, the absence of control, small sample size, and short follow-up limit causal interpretation. Meniscal healing was not directly assessed, and comprehensive functional recovery cannot be established from the outcomes measured. These findings represent short-term observations and do not establish comparative effectiveness or modification of osteoarthritis progression or long-term joint preservation. The contribution of meniscal repair cannot be separated from that of osteotomy and postoperative rehabilitation. The literature needs larger, prospective studies with validated functional outcome measures, direct assessment of meniscal healing, and longer follow-up to conclusively determine whether combined procedures alter the natural history of medial compartment OA and delay conversion to total knee arthroplasty beyond what HTO alone achieves.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Ethics Committee, N.K.P. Salve Institute of Medical Sciences and

Research Centre and Lata Mangeshkar Hospital, Nagpur issued approval LMH/IEC/7/2025; approval date: March 27, 2025. The Institutional Ethics Committee has approved the proposal of project titled "Medial Opening Wedge High Tibial Osteotomy for Varus Knee Osteoarthritis with Arthroscopic Medial Meniscus Repair in a Repairable Medial Meniscus Root Tear in Young Adults", to be conducted at N.K.P. Salve Institute of Medical Sciences and Research Centre and Lata Mangeshkar Hospital, Nagpur, with Dr. Satyajit Deshpande, Asst. Prof., Department of Orthopedic, as Principal Investigator. . **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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