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Clinical, Functional, and Radiological Outcomes and KOOS-Derived Patient Satisfaction After Medial Opening-Wedge High Tibial Osteotomy for Medial Compartment Knee Osteoarthritis: A Prospective Observational Study

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Abstract

Introduction: Varus-related medial compartment osteoarthritis (MCOA) of the knee disables many working-age adults. High tibial osteotomy (HTO) shifts the weight-bearing axis away from the worn medial compartment and toward the healthier lateral side, so it can relieve pain while preserving the native joint. This study evaluated short-term knee function (primary outcome), pain relief, radiological correction, range of motion (ROM), complications, and patient satisfaction after medial opening-wedge HTO, with satisfaction derived from the patient-reported outcome category rather than measured separately.

Methods: We conducted a prospective observational cohort study at a tertiary care teaching hospital in Western India from August 2024 to February 2026. Thirty consecutive patients aged 31-50 years with Kellgren-Lawrence grade II-III MCOA, varus deformity below 15°, and an intact lateral compartment underwent medial opening-wedge HTO with tricortical iliac crest autograft and locking plate fixation. Pain was measured with the visual analog scale (VAS), function with the Knee Society Score (KSS; primary outcome at six months), and patient-reported outcome with the Knee injury and Osteoarthritis Outcome Score (KOOS). Assessments were made before surgery, immediately after surgery, and at two weeks and one, two, three, and six months. Paired t-tests or Wilcoxon signed-rank tests compared each time point with baseline, with Bonferroni correction for six comparisons (significance $p < 0.0083$).

Results: Most patients were women (18, 60%). The 46-50-year age group was largest (12, 40%), and 16 patients (53.3%) were overweight. Mean VAS fell from 6.92 ± 0.60 before surgery to 0.66 ± 0.55 at six months ($p < 0.0001$). Mean KSS rose from 104.36 ± 12.21 to 155.81 ± 14.92 over the same period ($p < 0.0001$), and 28 patients (93.3%) reached good or excellent KSS grades. Preoperative varus of 8°-11° was corrected to neutral or valgus in 29 knees (96.7%), most often to 2° valgus (11, 36.7%). Knee ROM was preserved. At six months, 26 patients (86.7%) had good or excellent KOOS-based outcomes and were therefore, by definition, classed as satisfied or highly satisfied. Complications were few: residual pain in three patients (10%), one superficial infection (3.3%), and one loss of correction (3.3%).

Conclusions: Short-term results were encouraging. In this uncontrolled series of 30 patients, medial opening-wedge HTO was followed by significant pain relief and functional improvement, reliable correction of varus alignment, preserved knee motion, and a low early complication rate. Durability remains unproven. Longer controlled studies, using a separate validated satisfaction measure, are needed to confirm these findings.

Categories: Radiology, Physical Medicine & Rehabilitation, Orthopedics
Keywords: high tibial osteotomy, joint preservation, knee society score, koos, medial compartment osteoarthritis, patient satisfaction, varus knee, visual analog scale

Introduction

Knee osteoarthritis (OA) is a chronic and progressive disease of the whole joint. Cartilage breakdown is its hallmark, but altered joint loading and low-grade inflammation act together to drive it forward because mechanical overload raises local cartilage stress while inflammatory mediators weaken the matrix that must resist it [1]. The scale of the problem is large. A global pooled analysis estimated the prevalence of knee OA at 16% in adults aged 15 years and over, with an incidence of 203 per 10,000 person-years [2], and Indian population studies have reported prevalence figures between 22% and 39% [3].

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The medial compartment is especially vulnerable. During normal gait, it carries most of the load that crosses the knee, and any varus malalignment pushes that load further medially, which explains why isolated medial compartment osteoarthritis (MCOA) is so common [4]. Varus alignment is not only a marker of disease. In a large population-based cohort, it predicted both the development and the progression of radiographic knee OA, creating a vicious circle in which cartilage loss increases varus and varus accelerates cartilage loss [4].

Surgical options for symptomatic MCOA include high tibial osteotomy (HTO), unicompartmental knee arthroplasty, and total knee arthroplasty (TKA) [5]. Arthroplasty works well in older, low-demand patients [6]. Younger and more active patients are a different case, since implant longevity and activity restrictions remain real concerns, whereas HTO preserves the native joint and does not prevent later conversion to TKA [5,7]. By moving the mechanical axis from the overloaded medial compartment to the relatively healthy lateral compartment, HTO reduces medial contact pressure and creates conditions in which fibrocartilage repair of the medial femoral condyle has been documented on second-look assessment [8,9].

Indications have widened. HTO was once reserved for mild-to-moderate disease in patients under 50 years, yet a recent systematic review reported high survivorship and good clinical outcomes even in radiologically advanced medial OA [10], and functional results in patients over 50 have been comparable to those of younger patients [9]. Early recovery is less well described. Between 75% and 92% of patients are satisfied after TKA [11], and HTO is thought to perform at least as well, but most published HTO series report long-term results and say little about the month-by-month course of pain, function, and patient-reported outcome during the first six months, the period in which patients decide whether surgery has helped them [12,13].

This study addressed that gap. Its aim was to evaluate the clinical, functional, radiological, and patient-reported outcomes of medial opening-wedge HTO in patients with MCOA over the first six months after surgery in an Indian tertiary care setting. The primary outcome was the change in the Knee Society Score (KSS) from baseline to six months. Secondary outcomes were pain on a visual analog scale (VAS), the Knee injury and Osteoarthritis Outcome Score (KOOS) category, coronal alignment, range of motion (ROM), complications, and patient satisfaction, which was derived from the six-month KOOS category rather than measured with a separate instrument. We hypothesized that KSS and VAS would both improve significantly at six months compared with baseline.

Materials And Methods

Study design and setting

This prospective observational cohort study was carried out in the Department of Orthopedics at Dhiraj Hospital, the teaching hospital of Smt. B. K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Vadodara, India. Recruitment and follow-up ran for 18 months, from August 2024 to February 2026. The Sumandeep Vidyapeeth Institutional Ethics Committee approved the protocol on August 23, 2024. The first patient was enrolled on September 2, 2024, so no patient was recruited before approval, and every participant gave written informed consent in their own language after the study had been explained to them.

Participants

Patients were enrolled by consecutive sampling. Every patient who met the eligibility criteria and consented during the fixed 18-month study window was included, and no formal sample-size calculation was performed, so the final number of 30 reflects all eligible patients treated in that period. During this period, 38 patients with MCOA were screened, eight were excluded (bicompartmental OA n = 3, ligament insufficiency n = 2, body mass index >40 n = 1, inflammatory arthritis n = 1, declined consent n = 1), and 30 were enrolled; all 30 completed follow-up. Inclusion criteria were age 31-50 years, symptomatic MCOA of Kellgren-Lawrence (KL) grade II or III [14], varus deformity of less than 15°, an intact lateral compartment, failure of at least two months of conservative treatment, and a minimum follow-up of six months. Exclusion criteria were bicompartmental or tricompartmental OA, inflammatory arthritis, cruciate ligament deficiency, paralytic conditions that would prevent early mobilization, psychiatric illness, inability to complete six months of follow-up, and unwillingness to participate.

Preoperative assessment

Each patient underwent a structured history and knee examination. Pain, functional limitation, ROM, stability, deformity and joint-line tenderness were recorded. Radiographs included weight-bearing anteroposterior, lateral, and skyline views of the knee, along with a full-length lower limb scanogram, which was used to grade OA, measure varus deformity, and plan correction using the Dugdale method [15]. Coronal alignment was measured on this scanogram as the mechanical hip-knee-ankle (HKA) angle, and all varus and valgus values in this paper refer to that angle. The planned correction aimed to pass the weight-bearing line through a point about 62% of the tibial plateau width from its medial edge (the Fujisawa point). ROM was measured with a long-arm goniometer with the patient supine. Baseline VAS, KSS, and KOOS scores were recorded before surgery.

Surgical technique

All operations were performed by two consultant orthopedic surgeons with 10 and eight years of experience in knee osteotomy, who performed 18 and 12 procedures, respectively, using the same technique and the same implant. All procedures were performed under regional or general anesthesia with the patient supine and a thigh tourniquet inflated. A longitudinal anteromedial incision exposed the proximal tibia. The pes anserinus and the superficial medial collateral ligament were elevated subperiosteally and released as needed to allow the osteotomy to open, and posterior structures were protected with a retractor. Under fluoroscopy, a guidewire was passed obliquely from the anteromedial cortex toward the tip of the fibular head, ending about 1.5 cm below the lateral tibial plateau. A biplanar osteotomy was then made with an oscillating saw, with a transverse cut below the guidewire and an ascending anterior cut behind the tibial tubercle, and the lateral cortex was preserved as a hinge (Figure *1A*). The osteotomy was opened gradually with a laminar spreader. Wedge height was planned for each patient by the Dugdale method and ranged from 5 to 15 mm (mean 10.2 ± 2.8 mm), and the mechanical axis was checked intraoperatively with an alignment rod under fluoroscopy, aiming for slight valgus overcorrection (Figure *1B*). The gap was filled with a tricortical autograft harvested from the ipsilateral iliac crest (Figure *1C*). Fixation was achieved with a medial T-shaped locking plate and 4.5-mm locking screws placed proximally and distally (Figure *1D*).

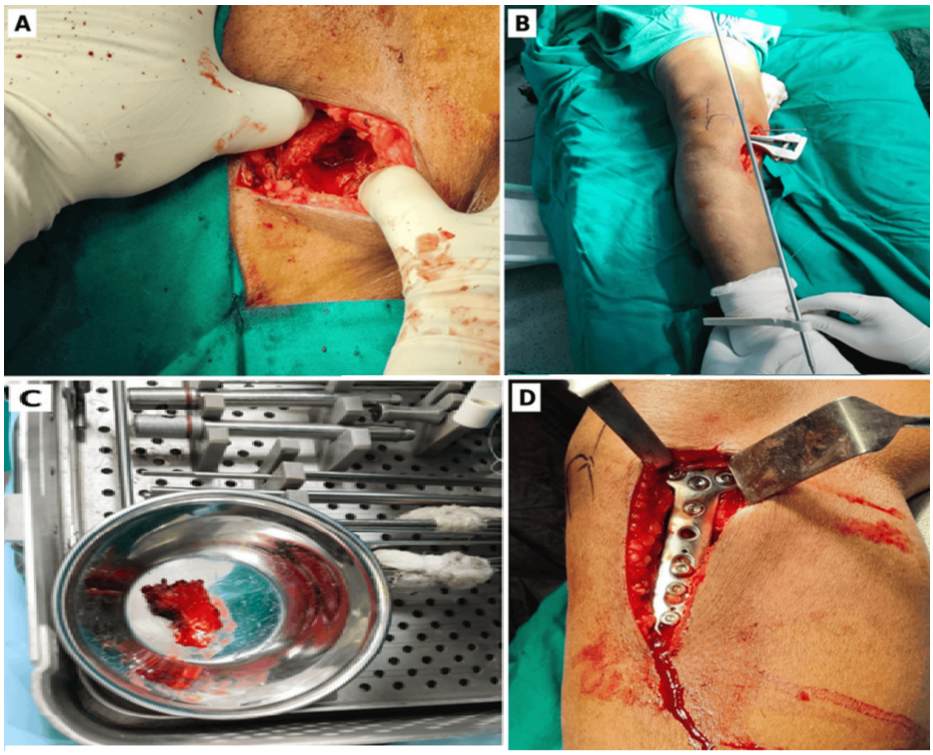

FIGURE 1: Key intraoperative steps of medial opening-wedge high tibial osteotomy

(A) Anteromedial exposure of the proximal tibia with the osteotomy opened. (B) Intraoperative check of the limb's mechanical axis with an alignment rod. (C) Tricortical autograft harvested from the ipsilateral iliac crest. (D) Medial locking T-plate fixation after graft insertion

Postoperative care and rehabilitation

Rehabilitation followed a standard protocol. Supervised physiotherapy was given three times a week for six weeks, and patients also followed a home program of quadriceps sets, straight-leg raises, heel slides and ankle pumps, 10 repetitions three times a day. For the first two weeks, patients walked non-weight-bearing or partial weight-bearing with crutches or a walker, used a knee immobilizer between exercise sessions, and began early ROM exercises, with continuous passive motion in selected cases. From two to six weeks, weight-bearing and flexion were advanced as tolerated, and from six to 12 weeks, patients progressed to full weight-bearing with strengthening exercises; return to normal daily activities was permitted between three and six months once clinical and radiological progress allowed it. Wound healing, hospital stay, and complications were documented throughout.

Outcome measures

Pain was measured on a 10 cm VAS from 0 (no pain) to 10 (worst imaginable pain) and graded as none (0),

mild (1-3), moderate (4-6), or severe (7-10). Clinical and functional status was measured with the original 1989 Knee Society clinical rating system (KSS) [16]. It has two components: a knee score (pain 50 points, stability 25 points, and ROM 25 points, with deductions for flexion contracture, extension lag, and malalignment; maximum 100) and a function score (walking distance 50 points and stair climbing 50 points, with deductions for walking aids; maximum 100), which were added to give a combined score out of 200. The combined score was graded as poor (<120), fair (120-139), good (140-160), or excellent (>160). Patient-reported outcome was assessed with the KOOS [17], which covers pain, other symptoms, activities of daily living, sport and recreation, and knee-related quality of life, each scored from 0 (extreme problems) to 100 (no problems). The mean of the five subscale scores defined the overall outcome category: excellent (≥85), good (70-84), fair (60-69), or poor (<60). These cutoffs were set by the authors for this study. They have not been validated, and the KOOS is designed to be reported by subscale. No separate satisfaction questionnaire was used. Instead, satisfaction was derived from each patient's KOOS category at six months, so an excellent outcome was classed as highly satisfied, a good outcome as satisfied, and a fair or poor outcome as not satisfied. Satisfaction is therefore a restatement of the KOOS category and not an independent outcome. All scores, together with ROM, were recorded before surgery, immediately after surgery (on postoperative day 2, before discharge), and at two weeks and one, two, three, and six months. At the immediate time point, KSS function items and KOOS activity items were scored on what the patient could actually do at that time, including walking with an aid, so they reflect early postsurgical restriction. Postoperative alignment was measured as the mechanical HKA angle on a full-length standing scanogram at six months by one orthopedic surgeon who was not blinded; inter- and intraobserver reliability was not assessed. Union was defined as bridging across at least three of four cortices on anteroposterior and lateral radiographs with no pain at the osteotomy site on weight-bearing, and the time to union was recorded. Donor-site problems at the iliac crest, lateral hinge fractures, other intraoperative events, and hardware irritation were also recorded.

Statistical analysis

Data were entered in Microsoft Excel (Microsoft Corporation, Redmond, WA) and analyzed with IBM Statistical Package for the Social Sciences Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY). Continuous variables are shown as mean ± standard deviation (SD) and categorical variables as frequency and percentage. Normality was checked with the Shapiro-Wilk test. Each postoperative VAS and KSS value was compared with the preoperative value using the paired t-test when the differences were normally distributed and the Wilcoxon signed-rank test otherwise (The paired t-test was used for both VAS and KSS, as the change scores were normally distributed (Shapiro-Wilk $p > 0.05$)). Because each score was compared with baseline at six time points, a Bonferroni correction was applied, and a p value below 0.0083 (0.05/6) was considered significant. Means are reported with 95% confidence intervals (CIs). The size of change from baseline to six months is given as Cohen's d, calculated with the average of the two SDs, and clinical relevance was judged against published minimal clinically important difference (MCID) values.

Results

Baseline characteristics

All 30 patients completed six months of follow-up. Women outnumbered men (18 vs. 12), and the 46-50-year group was the largest (12 patients, 40%). The right knee was operated on in 16 patients (53.3%). Most patients were overweight (16, 53.3%) or obese (four, 13.3%), and KL grade II disease was more common than grade III (18 vs. 12). Preoperative varus ranged from 8° to 11°, with 8° the most frequent value (Table *1*).

Variable	Category	n (%)
Age (years)	31-35	4 (13.33)
	36-40	6 (20.00)
	41-45	8 (26.67)
	46-50	12 (40.00)
Sex	Male	12 (40.00)
	Female	18 (60.00)
Operated side	Right	16 (53.33)
	Left	14 (46.67)
BMI (kg/m²)	Normal (18.5-24.9)	10 (33.33)
	Overweight (25-29.9)	16 (53.33)
	Obese (≥30)	4 (13.33)
Kellgren-Lawrence grade	Grade II	18 (60.00)
	Grade III	12 (40.00)
Preoperative varus	8	14 (46.67)
	9	9 (30.00)
	10	6 (20.00)
	11	1 (3.33)

TABLE 1: Baseline demographic and clinical characteristics (n = 30)

BMI: body mass index

Pain and knee function

Pain fell quickly and kept falling. Mean VAS dropped from 6.92 ± 0.60 before surgery to 2.30 ± 0.75 at one month and 0.66 ± 0.55 at six months, and every postoperative value was significantly lower than baseline ($p < 0.0001$, significant after Bonferroni correction). Eighteen patients (60%) had severe pain before surgery; none did after the first month, and by six months, 19 patients (63.3%) were pain-free while the remaining 11 (36.7%) reported only mild pain (Table *2*, Figure *2A*).

Time point	VAS, mean ± SD	p value	KSS, mean ± SD	p value
Preoperative	6.92 ± 0.60	-	104.36 ± 12.21	-
Immediate postoperative	5.64 ± 0.85	<0.0001	112.43 ± 14.85	0.06
2 weeks	3.86 ± 0.87	<0.0001	126.30 ± 16.90	<0.0001
1 month	2.30 ± 0.75	<0.0001	134.18 ± 19.08	<0.0001
2 months	1.65 ± 0.72	<0.0001	140.93 ± 17.10	<0.0001
3 months	1.10 ± 0.63	<0.0001	147.64 ± 15.18	<0.0001
6 months	0.66 ± 0.55	<0.0001	155.81 ± 14.92	<0.0001

TABLE 2: VAS scores and Knee Society scores across follow-up (n = 30)

p values compare each postoperative time point with the preoperative value

VAS: visual analog scale; KSS: Knee Society Score; SD: standard deviation

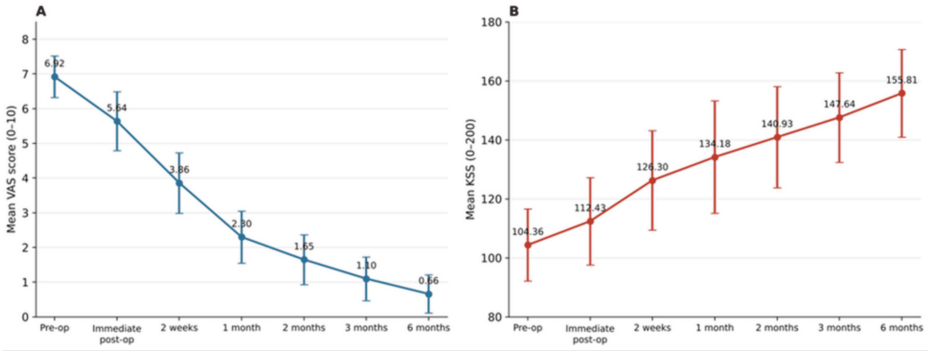

FIGURE 2: Change in mean pain and knee function after high tibial osteotomy

(A) Mean VAS score. (B) Mean KSS. Error bars show standard deviation; all postoperative values were significantly different from baseline except the immediate postoperative KSS (p = 0.06)

KSS: Knee Society Score; VAS: visual analog scale

Function improved more gradually. The immediate postoperative KSS of 112.43 ± 14.85 did not differ significantly from baseline (p = 0.06), which reflects early postsurgical restriction rather than lack of benefit, but from two weeks onward, the gain was significant at every interval, reaching 155.81 ± 14.92 at six months (p < 0.0001) (Figure *2B*). Before surgery, 27 patients (90%) had a poor KSS grade; at six months, none were poor, two (6.7%) were fair, 18 (60%) were good, and 10 (33.3%) were excellent.

The size of change was large. From baseline to six months, mean VAS fell by 6.26 points (preoperative 95% CI: 6.70-7.14; six-month 95% CI: 0.45-0.87; Cohen's d 10.9), and mean KSS rose by 51.45 points (preoperative 95% CI: 99.80-108.92; six-month 95% CI: 150.24-161.38; Cohen's d 3.79). The immediate postoperative KSS remained nonsignificant (p = 0.06), and all later comparisons stayed significant after Bonferroni correction.

Radiological correction and range of motion

Alignment was corrected in nearly every knee. Mean preoperative varus was 8.8° ± 0.9°, and mean postoperative alignment was 2.3° ± 1.4° of valgus, a mean correction of 11.1°. Twenty-eight knees (93.3%) ended in valgus, one (3.3%) was neutral, and only one (3.3%) retained 1° of residual varus; 2° valgus was the most frequent result, seen in 11 knees (36.7%) (Table *3*). Figure *3* shows one representative patient. Preoperative weight-bearing radiographs (Figures *3A*, *3B*), intraoperative fluoroscopy after plate fixation (Figures *3C*, *3D*), and postoperative anteroposterior and lateral radiographs (Figures *3E*, *3F*) document the correction. ROM at six months was the same as before surgery. Preoperatively, 23 patients (76.7%) had 0°-

120°, five (16.7%) had 0°-115°, and two (6.7%) had 0°-110°, and each patient had the same arc at six months, so no statistical test was needed for this comparison.

Postoperative alignment	n (%)
Valgus 5	2 (6.67)
Valgus 4	4 (13.33)
Valgus 3	6 (20.00)
Valgus 2	11 (36.67)
Valgus 1	5 (16.67)
Neutral	1 (3.33)
Varus 1	1 (3.33)

TABLE 3: Postoperative coronal alignment (n = 30)

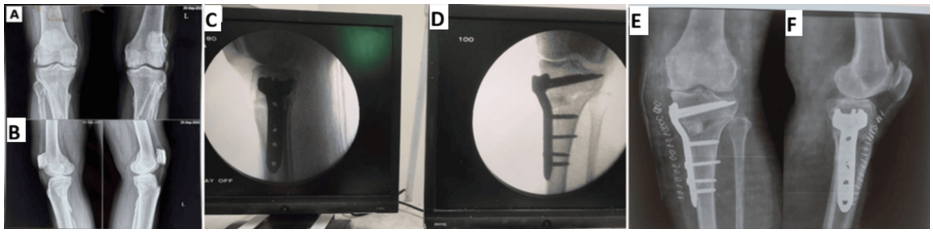

FIGURE 3: Radiographs of a representative patient

(A,B) Preoperative weight-bearing radiographic images showing medial joint-space narrowing. (C,D) Intraoperative fluoroscopic views after locking plate fixation. (E) Postoperative anteroposterior radiograph. (F) Postoperative lateral radiograph showing the opening-wedge osteotomy fixed with a medial locking plate

Patient-reported outcome and satisfaction

KOOS-based outcomes moved steadily upward. Twenty patients (66.7%) were in the poor category before surgery, and none were at six months, when 15 (50%) were good, and 11 (36.7%) were excellent (Table *4*). Because satisfaction was derived from these categories, it mirrors them exactly: 11 patients (36.7%) were classed as highly satisfied, 15 (50%) as satisfied, and four (13.3%) as not satisfied.

Category	Pre-op, n (%)	Immediate, n (%)	2 weeks, n (%)	1 month, n (%)	2 months, n (%)	3 months, n (%)	6 months, n (%)
Poor	20 (66.7)	15 (50.0)	10 (33.3)	5 (16.7)	3 (10.0)	2 (6.7)	0
Fair	10 (33.3)	12 (40.0)	12 (40.0)	10 (33.3)	8 (26.7)	6 (20.0)	4 (13.3)
Good	0	3 (10.0)	6 (20.0)	10 (33.3)	11 (36.7)	12 (40.0)	15 (50.0)
Excellent	0	0	2 (6.7)	5 (16.7)	8 (26.7)	10 (33.3)	11 (36.7)

TABLE 4: KOOS-based patient-reported outcome categories across follow-up

KOOS: Knee Injury and Osteoarthritis Outcome Score

Complications

Complications were uncommon and mostly minor. Three patients (10%) reported residual knee pain, one (3.3%) developed a superficial wound infection that settled with dressings and antibiotics, and one (3.3%) showed loss of correction with progression of OA. In this patient, loss of correction was noted at four

months, with recurrence to 3° of varus, probably due to partial graft resorption, and it was managed conservatively with activity modification and counseling for future arthroplasty if symptoms progress. There were no cases of nonunion, knee stiffness, deep infection, or neurovascular injury. Union was seen in all 30 knees at a mean of 14.2 ± 2.4 weeks. Donor-site morbidity at the iliac crest was reported in four patients (13.3%), who reported mild donor-site pain that resolved within six weeks; there were no hematomas or lateral femoral cutaneous nerve symptoms; an incomplete lateral hinge fracture (Takeuchi type I) was identified intraoperatively in two knees (6.7%), both stabilized by the locking plate without further intervention; and no patient needed hardware removal within six months.

Discussion

These results are encouraging but preliminary. Within six months, patients with symptomatic varus MCOA had large and statistically significant reductions in pain, steady gains in KSS and KOOS, reliable conversion of varus to neutral or mild valgus, unchanged knee motion, and a low early complication rate in a resource-limited setting. Without a control group, part of this improvement may reflect natural history, regression to the mean, or supervised rehabilitation, so these findings show an association with HTO rather than proof of its effect.

Our patients were middle-aged, mostly women, and mostly overweight. That profile matches the known epidemiology of knee OA, in which female sex and higher body mass are well-established risk factors [3,18,19]. The age distribution, with 40% of patients aged 46-50 years, was somewhat younger than in other Indian series, where the largest group was 51-60 years [20], and this reflects our deliberate upper age limit of 50 years. Right and left knees were affected almost equally, whereas Nikose et al. reported right-sided predominance [21]; laterality is probably of little clinical importance in either direction.

Pain relief was early and substantial. Mean VAS fell by more than six points, and no patient had severe pain after the first month, a trajectory that mirrors other reports in which preoperative moderate-to-severe pain gave way to mostly mild pain by six months [20]. Goshima et al. observed a similar fall in mean VAS, from 62.6 to 10.4 on a 100 mm scale, in 123 knees [12]. The rapid early relief is clinically meaningful. It allows earlier mobilization and return to work, which matters greatly to younger patients who depend on physical labor.

Functional recovery took longer but was sustained. The KSS gain of about 51 points is in line with Choudhary et al., who recorded an increase in overall KSS from 98.2 to 183.2 [22], and with the predominantly good and excellent KSS grades reported by Porammanavar et al. [20]. Long-term series from Japan, Germany, and Italy have likewise shown durable functional improvement after opening-wedge HTO with plate fixation [23-25]. The nonsignificant KSS change immediately after surgery is expected, since wound pain and protected weight-bearing limit early function.

Correction is the mechanism by which HTO is meant to work. In our series, 96.7% of knees reached neutral or valgus alignment, which is expected to unload the medial compartment [8], and only one knee was undercorrected. We did not test whether the degree of correction predicted VAS, KSS, or KOOS, so this study cannot show that better alignment produced better outcomes. A meta-analysis by Smith et al. found that opening-wedge and closing-wedge techniques gave comparable clinical and radiological results [26], so the choice of technique is less important than careful preoperative planning and intraoperative verification of the mechanical axis, which we performed in every case. Knee ROM was fully preserved. This agrees with studies showing maintained or slightly improved motion after HTO [22].

Satisfaction must be read with care. In our cohort, 86.7% of patients were classed as satisfied or highly satisfied, but this is the KOOS good-or-excellent rate under another name because satisfaction was derived from the KOOS category. It cannot be compared directly with the 88.6% reported by Goshima et al., who asked patients a dedicated satisfaction question and found that satisfaction was most strongly associated with met expectations and better KOOS pain scores [12]. Ahrend et al. reported high survival and patient satisfaction 12 years after opening-wedge HTO [13], and a systematic review found high survivorship even in advanced medial OA [10]. Classic long-term data show survival of 95% at five years and 79% at 10 years [7]. These figures come from other cohorts. Our six-month data cannot speak to survivorship. Defining clinically significant thresholds for HTO outcomes, as Patel et al. have done, will help future studies judge whether gains such as ours are not only statistically but also personally meaningful to patients [27].

Our complication rate was low. Adverse events after opening-wedge HTO are reported in a wide range of frequencies, largely because definitions and classification systems differ between studies [28], and a large series of 533 patients from Floerkemeier et al. likewise showed that serious complications are uncommon when the technique is standardized [29]. Residual pain was our most frequent problem, and the single case of lost correction is a reminder that graft incorporation and stable fixation must be achieved before full loading. Tricortical iliac crest autograft also carries its own donor-site morbidity, including pain, hematoma, and lateral femoral cutaneous nerve symptoms, and this cost must be weighed against allograft or synthetic wedges.

Statistical significance alone does not show benefit. The mean VAS reduction of 6.26 cm is about three times the minimal clinically important improvement of 19.9 mm on a 100 mm scale reported for knee OA [30], and the 51-point KSS gain is far larger than the MCID of about 5-6 points reported for each of the knee and function components [31]. These thresholds were derived in other populations, including arthroplasty patients, and HTO-specific thresholds [27] apply to KOOS subscale scores that we did not record, so they are only a rough guide. We also did not report the proportion of individual patients who reached the MCID.

This study has several limitations. The sample was small, no formal sample-size calculation was made, and there was no control group treated with conservative care or arthroplasty, so the improvement cannot be attributed to HTO alone. Six months is too short. It does not allow us to judge maintenance of correction, union in every case, survivorship, conversion to arthroplasty, or the long-term course of OA. Operations were performed by more than one surgeon, and outcomes were assessed by the treating team without blinding or an independent assessor. Radiographic measurements were made by a single observer without reliability testing, and medial proximal tibial angle, posterior tibial slope, weight-bearing line ratio, and patellar height were not analyzed. KOOS results were analyzed as author-defined categories rather than subscale scores, and these cutoffs are not validated. Satisfaction was not measured independently. Because it was derived from the KOOS category, it restates that result rather than adding new information. Finally, the sample was too small to test whether age, body mass index, KL grade, or achieved alignment predicted outcome. Larger controlled studies with longer follow-up, subscale-level KOOS reporting, and a validated satisfaction instrument are needed.

Conclusions

In this short-term, uncontrolled series of younger patients with varus MCOA, medial opening-wedge HTO with iliac crest autograft and locking plate fixation was followed by early and significant pain relief, functional improvement, reliable correction of varus alignment and preserved knee motion. Early complications were few. At six months, 86.7% of patients had a good or excellent KOOS-based outcome. The wider literature supports HTO as a joint-preserving option that may delay arthroplasty in carefully selected patients, but our six-month data cannot confirm that benefit, and longer controlled follow-up is needed.

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. Sumandeep Vidyapeeth Institutional Ethics Committee (SVIEC), Sumandeep Vidyapeeth (Deemed to Be University), Vadodara, India issued approval SVIEC/ON/MEDI/BNPG23/AUG/24/37. **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.

References

1. Guilak F: Biomechanical factors in osteoarthritis. Best Pract Res Clin Rheumatol. 2011, 25:815-23. 10.1016/j.berh.2011.11.013

2. Cui A, Li H, Wang D, Zhong J, Chen Y, Lu H: Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies. EClinicalMedicine. 2020, 29-30:100587. 10.1016/j.eclinm.2020.100587
3. Pal CP, Singh P, Chaturvedi S, Pruthi KK, Vij A: Epidemiology of knee osteoarthritis in India and related factors. Indian J Orthop. 2016, 50:518-22. 10.4103/0019-5413.189608
4. Brouwer GM, van Tol AW, Bergink AP, et al.: Association between valgus and varus alignment and the development and progression of radiographic osteoarthritis of the knee. Arthritis Rheum. 2007, 56:1204-11. 10.1002/art.22515
5. Dettoni F, Bonasia DE, Castoldi F, Bruzzone M, Blonna D, Rossi R: High tibial osteotomy versus unicompartmental knee arthroplasty for medial compartment arthrosis of the knee: a review of the literature. Iowa Orthop J. 2010, 30:131-40.
6. Wilson HA, Middleton R, Abram SG, et al.: Patient relevant outcomes of unicompartmental versus total knee replacement: systematic review and meta-analysis. BMJ. 2019, 364:l352. 10.1136/bmj.l352
7. Hui C, Salmon LJ, Kok A, et al.: Long-term survival of high tibial osteotomy for medial compartment osteoarthritis of the knee. Am J Sports Med. 2011, 39:64-70. 10.1177/0363546510377445
8. Liu X, Chen Z, Gao Y, Zhang J, Jin Z: High tibial osteotomy: review of techniques and biomechanics . J Healthc Eng. 2019, 2019:8363128. 10.1155/2019/8363128
9. Khakha RS, Bin Abd Razak HR, Kley K, van Heerwaarden R, Wilson AJ: Role of high tibial osteotomy in medial compartment osteoarthritis of the knee: indications, surgical technique and outcomes. J Clin Orthop Trauma. 2021, 23:101618. 10.1016/j.jcot.2021.101618
10. Dal Fabbro G, Grassi A, Agostinone P, Lucidi GA, Fajury R, Ravindra A, Zaffagnini S: High survivorship rate and good clinical outcomes after high tibial osteotomy in patients with radiological advanced medial knee osteoarthritis: a systematic review. Arch Orthop Trauma Surg. 2024, 144:3977-88. 10.1007/s00402-024-05254-0
11. Choi YJ, Ra HJ: Patient satisfaction after total knee arthroplasty . Knee Surg Relat Res. 2016, 28:1-15.
12. Goshima K, Sawaguchi T, Shigemoto K, Iwai S, Fujita K, Kataoka T, Taninaka A: Factors associated with patient satisfaction after opening-wedge high tibial osteotomy. Orthop J Sports Med. 2020, 8:2325967120967964. 10.1177/2325967120967964
13. Ahrend MD, Petzold D, Histing T, Ihle C, Schröter S, Herbst M: High survival rates and patient satisfaction 12 years after medial open wedge high tibial osteotomy surgery: a prospective cohort study. Knee Surg Sports Traumatol Arthrosc. 2025, 33:4344-52. 10.1002/ksa.70071
14. Kohn MD, Sassoon AA, Fernando ND: Classifications in brief: Kellgren-Lawrence classification of osteoarthritis. Clin Orthop Relat Res. 2016, 474:1886-93. 10.1007/s11999-016-4732-4
15. Dugdale TW, Noyes FR, Styer D: Preoperative planning for high tibial osteotomy. The effect of lateral tibiofemoral separation and tibiofemoral length. Clin Orthop Relat Res. 1992, 274:248-64. 10.1097/00003086-199201000-00025
16. Insall JN, Dorr LD, Scott RD, Scott WN: Rationale of the Knee Society clinical rating system . Clin Orthop Relat Res. 1989, 248:13-4. 10.1097/00003086-198911000-00004
17. Roos EM, Lohmander LS: The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. Health Qual Life Outcomes. 2003, 1:64. 10.1186/1477-7525-1-64
18. O'Connor MI: Sex differences in osteoarthritis of the hip and knee . J Am Acad Orthop Surg. 2007, 15 Suppl 1:S22-5.
19. Laitner MH, Erickson LC, Ortman E: Understanding the impact of sex and gender in osteoarthritis: assessing research gaps and unmet needs. J Womens Health (Larchmt). 2021, 30:634-41. 10.1089/jwh.2020.8828
20. Porammanavar ST, Gopalan NS, Vijay Kumar S, Gidaganti M: Functional outcomes of high tibial osteotomy for symptomatic medial compartment osteoarthritis in middle-aged patients: both prospective and retrospective study in Indian population in the quaternary care center. Int J Orthop Sci. 2024, 10:182-91. 10.22271/ortho.2024.v10.i1c.3519
21. Nikose SS, Nikose D, Kekatpure AL, Jain S, Saoji K, Reddy SM: Impact of medial open-wedge high tibial osteotomy for medial compartment osteoarthritis of the knee. World J Orthop. 2020, 11:606-14. 10.5312/wjo.v11.i12.606
22. Choudhary SK, Thakur SK, Singh CM, Hiremath RN, Ghodke S, Raj R: Outcomes of medial opening wedge high tibial osteotomy following concomitant arthroscopic procedures in medial compartmental osteoarthritis of knee. J Orthop Spine. 2021, 9:60-7. 10.4103/JOASP.JOASP_32_21
23. Saito T, Kumagai K, Akamatsu Y, Kobayashi H, Kusayama Y: Five- to ten-year outcome following medial opening-wedge high tibial osteotomy with rigid plate fixation in combination with an artificial bone substitute. Bone Joint J. 2014, 96-B:339-44. 10.1302/0301-620X.96B3.32525
24. Niemeyer P, Schmal H, Hauschild O, von Heyden J, Südkamp NP, Köstler W: Open-wedge osteotomy using an internal plate fixator in patients with medial-compartment gonarthritis and varus malalignment: 3-year results with regard to preoperative arthroscopic and radiographic findings. Arthroscopy. 2010, 26:1607-16. 10.1016/j.arthro.2010.05.006
25. Bonasia DE, Dettoni F, Sito G, et al.: Medial opening wedge high tibial osteotomy for medial compartment overload/arthritis in the varus knee: prognostic factors. Am J Sports Med. 2014, 42:690-8. 10.1177/0363546513516577
26. Smith TO, Sexton D, Mitchell P, Hing CB: Opening- or closing-wedged high tibial osteotomy: a meta-analysis of clinical and radiological outcomes. Knee. 2011, 18:361-8. 10.1016/j.knee.2010.10.001
27. Patel S, Haunschild E, Gilat R, et al.: Defining clinically significant outcomes following high tibial osteotomy with or without concomitant procedures. J Cartil Jt Preserv. 2021, 1:100014. 10.1016/j.jcjp.2021.100014
28. Martin R, Birmingham TB, Willits K, Litchfield R, Lebel ME, Giffin JR: Adverse event rates and classifications in medial opening wedge high tibial osteotomy. Am J Sports Med. 2014, 42:1118-26. 10.1177/0363546514525929
29. Floerkemeier S, Staubli AE, Schroeter S, Goldhahn S, Lobenhoffer P: Outcome after high tibial open-wedge osteotomy: a retrospective evaluation of 533 patients. Knee Surg Sports Traumatol Arthrosc. 2013, 21:170-80. 10.1007/s00167-012-2087-2

30. Tubach F, Ravaud P, Baron G, et al.: Evaluation of clinically relevant changes in patient reported outcomes in knee and hip osteoarthritis: the minimal clinically important improvement. Ann Rheum Dis. 2005, 64:29-33. 10.1136/ard.2004.022905
31. Lee WC, Kwan YH, Chong HC, Yeo SJ: The minimal clinically important difference for Knee Society Clinical Rating System after total knee arthroplasty for primary osteoarthritis. Knee Surg Sports Traumatol Arthrosc. 2017, 25:3354-9. 10.1007/s00167-016-4208-9