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Outcomes of medial opening wedge high tibial osteotomy following concomitant arthroscopic procedures in medial compartmental osteoarthritis of knee

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Abstract

BACKGROUND: The purpose of this study was to analyze the outcome of concomitant arthroscopic procedures followed by medial opening wedge high tibial osteotomy (HTO) in medial compartment osteoarthritis (OA) of the knee.

MATERIALS AND METHODS: Based on inclusion and exclusion criteria, a prospective observational study was carried out on 26 patients with medial compartment OA of the knee who underwent concomitant arthroscopic procedures followed by medial opening wedge HTO at one of the multispecialty hospitals in Northern India and were followed-up for one year. The mean age of the study population was 46.9 years. Preoperative values of pain score, functional score, range of motion (ROM), and tibiofemoral angle were compared with postoperative values at 6 weeks, 12 weeks, 24 weeks, and 1 year. A telephonic consultation at five-year post-op was carried out enquiring about activities of daily living and any need for knee replacement in near future.

RESULTS: There was a significant improvement in terms of pain relief and functional outcome as per the Knee Society Score. The mean ROM was improved from 120.42° preoperatively to 127.96° postoperatively. The targeted tibiofemoral angle was achieved and maintained at a one-year follow-up. The osteotomy site healed well in all patients. None of the patients developed, postoperative compartment syndrome, patella baja, instability, or peroneal palsy which are otherwise known complications. On telephonic consultation at the latest follow-up (five-year postoperative) all are comfortable with activities of daily living and none of them seek knee replacement in immediate future. In our study, one patient (3.8%) developed surgical site infection, which was treated with intravenous antibiotics and removal of the implant after the union and one patient (3.8%) had painful terminal movement at final follow-up.

CONCLUSION: Concomitant arthroscopic procedures followed by medial opening wedge HTO is a joint preserving surgery with good to excellent outcomes for the treatment of the refractory pain and disability caused by OA of knee involving the medial compartment in a mal-aligned limb in young and middle-aged active patients. The deformity correction achieved by medial opening wedge HTO is translated in terms of comfort achieved in daily living activities, relief of symptoms of OA, and improvement in function with an unimpeded lifestyle. We also conclude that overtreatment of isolated medial compartment OA of the knee can be aborted by doing HTO, which can definitely buy time before the more radical procedure is unavoidable, it cannot the risk of future total knee replacement be prevented.

Keywords:

Concomitant arthroscopy, high tibial osteotomy, medial compartment osteoarthritis, tibiofemoral angle

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Introduction

Osteoarthritis (OA) is the most common form of chronic arthritis worldwide and is a key cause of pain and disability in older adults. Although statistical data are not available in our country, OA of the knee, about twice as common as OA of the hip, is becoming an increasingly important cause of morbidity in the aging population. The natural history of knee OA and the factors leading to its progression is not fully understood. More and more people with disabling knee pain are presenting for treatment in the fourth, fifth, and sixth decades themselves.[1] Risk factors for OA include prior injury or joint inflammation, abnormalities of joint shape or mechanics, and obesity.

The goals of treatment in OA are to reduce pain and improve joint function. Nonsteroidal anti-inflammatory drugs are commonly used as first-line treatment for OA pain, along with exercise and weight loss and perhaps lifestyle modifications. Other pharmacologic options such as chondroitin-glucosamine, diacerein, and viscosupplementation have shown little or no long-term benefit in various trials and meta-analyses.[2,3] Arthroscopic lavage, with or without debridement does not improve pain and function for people with OA of the knee. The available research has found none of the abovementioned treatments to be effective for the general population with knee OA. Thus, clinicians may need to consider other alternatives.

As the disease progresses and conservative measures no longer bring relief, there is reason to explore surgical options. The surgical options that have stood the test of time are high tibial osteotomy (HTO), unicompartmental arthroplasty, and total knee arthroplasty. Determining which of these procedures is most appropriate depends on several factors, including the location, stage of OA, comorbidities, age, and activity level. Total knee arthroplasty is considered a good option for a healthier patient, older than 60 years with good long terms outcomes reported. However, concern remains regarding the longevity of the implants in younger patients.[4]

If OA is limited to one compartment, unicompartmental knee arthroplasty or unloading osteotomy can be considered.[5] The rate of proximal tibial osteotomies performed in the western world has declined significantly in recent years, whereas the rate of total and unicompartmental knee arthroplasty has steadily increased. This trend has been seen in our country as well, as health care has become more affordable and practices are driven by western interests and aspirations.

As the indications for a total knee or unicondylar knee replacement are getting stretched today, so are the numbers of complications, often devastating, of such procedures going up steadily. In the light of these complications, it might be prudent to revisit a less radical procedure with proven equivalence which has for some reason gone out of vogue.

HTO is a well-established procedure for the treatment of unicompartmental OA of the knee. Most reports have shown approximately 80% satisfactory results at five years and 60% at 10 years after HTO.[6,7] This is a significant gain if we look at a population that is not exactly old and might be offered a joint preserving surgery with an unimpeded lifestyle as compared with a joint sacrifice with its inherited lifestyle modifications/restrictions. HTO might still be a useful procedure for properly selected patients, possibly more so in the developing world where constraints of lifestyle as well as finances play an important part in decision making.

As per the review of literature,[8-10] the risk of revision in total knee arthroplasty is not affected by the previous HTO. Furthermore, we could also find out that in many studies performing total knee replacement (TKR) under skillful hands in primary patients and in patients who had already undergone HTO, the outcome did not alter much Thus, encouraging the use of HTO particularly in young patients with unicompartmental disease to buy more time before joint replacement is unavoidable. In view of the above, we carried out this study to assess the radiological, clinical, and functional outcome of HTO in patients with the unicompartmental OA of the knee.

Materials and Methods

A prospective observational study was carried out at one of the multispecialty hospitals in Northern India. A total of 26 patients (convenient sample) were selected by means of systematic random sampling based on inclusion and exclusion criteria [Table 1]. The basic profile and body mass index (BMI) status of study participants were analyzed [Table 2]. Ethical clearance was obtained from the institutional ethics committee of the hospital before the start of the study and written informed consent was obtained from each subject.

A diagnostic arthroscopy was performed in each case to assess for exclusion criteria more stringently, before subjecting the patients to medial opening wedge HTO [Figure 1].

Calculation of surgical correction

The patient was examined for correctability of varus deformity, range of motion (ROM), and ligament laxity. Radiographic assessment was done to know the mechanical axis and degree of correction. The amount of correction needed to achieve a normal valgus angle of

Table 1: Inclusion and exclusion criteria of study participants

Inclusion criteria:

- Physiologically young patients (age < 60 years)
- Pain and disability, resulting from osteoarthritis, that significantly interferes with high-demand employment or recreation
- Evidence on weight-bearing radiographs of degenerative arthritis that is confined to the medial compartment with a corresponding varus deformity.
- The patient must be able to use crutches or a walker and have sufficient muscle strength and motivation to carry out a rehabilitation program.

Exclusion criteria:

- Age: >60 years
- Narrowing of lateral compartment cartilage space
- Evidence of lateral compartment arthritis, or significant tears of the lateral meniscus
- Lateral tibial subluxation of >1 cm
- Medial compartment tibial bone loss of >2 or 3 mm
- Flexion contracture of >15°
- Knee flexion of <90°
- >20° of correction needed
- Inflammatory arthritis
- Significant peripheral vascular disease

Table 2: Basic profile and BMI status of study participants

Age distribution	Frequency	Percent
30–40 years	6	23.07
40–50 years	9	34.61
50–60 years	11	42.3
Gender distribution		
Male	6	23.1
Female	20	76.9
Side affected		
Left	6	23.1
Right	17	65.4
Bilateral	3	11.5
BMI		
Normal range (18.5–24.9)	12	46.15
Grade 1 overweight (25.0–29.9)	14	53.8
Grade 2 overweight (30.0–39.9)	0	0
Total	**26**	**100**

BMI = body mass index

5°–8° of valgus was calculated and an additional 3°–5° of overcorrection was added

Procedure

The patients were positioned supine on the operating table. A radiolucent extension is applied to enable fluoroscopic examination. A tourniquet was applied. If a large correction is anticipated, the ipsilateral iliac crest is draped, and a rolled blanket is placed under the same buttock. A quick diagnostic arthroscopy was routinely performed to verify the status of articular cartilage and meniscus and any necessary concomitant procedure, if required like meniscal balancing, partial meniscectomy, cartilage debridement, or anterior cruciate ligament (ACL) reconstruction were performed prior to osteotomy. With the knee in a 90° flexed position, a 6–8 cm long skin incision was made running from a point anterior to the insertion of pes in a posteromedial direction. Long fibers of the superficial part of the ligament were detached from the tibia. The leg was then positioned in full extension and the knee joint was adjusted exactly into AP view under fluoroscopy. Two parallel 2.5 mm k-wire were placed aiming towards the hinge point so that k-wire ends exactly at the lateral tibial cortex. Keeping the tuberosity segment 15 mm wide a biplanar osteotomy was done. Attention was paid to completing the osteotomy cut of the hard posteromedial tibial cortex. With chisels the osteotomy was spread slowly until the desired opening angle is reached, it is confirmed by comparing weight-bearingline as per preoperative (pre-op) plan. A tomofix plate was then applied to maintain the desired valgus correction and fixed screws. The wound was closed and preventive measures were taken against thrombosis.

The patients were followed up at 6 weeks, 12 weeks, 24 weeks, and 1-year intervals. Necessary records of their functional and pain scores were documented and graded as per the Knee Society Scoring System. Also, radiological assessment of knee at above intervals with documentation of a range of tibio-femoral varus/valgus angle was done and recorded [Figures 2 and 3]. The records were maintained as per pre-tested performa appended. Data were entered in an Excel sheet and was analyzed by means of Epi info version 6.0. Paired *t*-tests were applied to compare preoperative (pre-op) and postoperative (post-op) measures [Table 3].

Results

The mean age of the population was 46.9 years (range). Females were affected more (76.9%) than males. Right knee was affected more as compared with the left one. The average BMI of the population was 24.5 ± 1.76 (mean ± SD). The mean preoperative pain score was 53.12 and

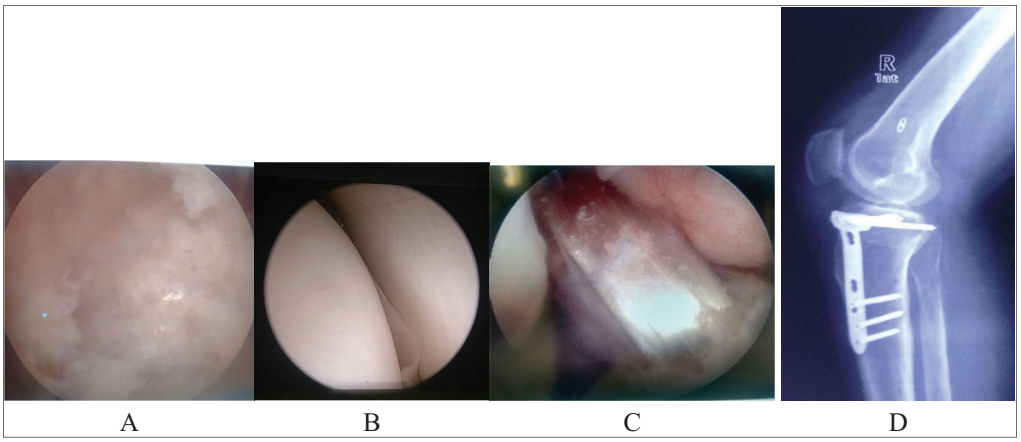

Figure 1: (A) Diagnostic arthroscopy suggestive of medial compartment OA of the knee, (B) arthroscopic normal lateral compartment (C) ACL reconstruction intraoperative status, (D) radiograph suggestive of ACL reconstruction and united proximal tibial osteotomy with the implant *in situ*

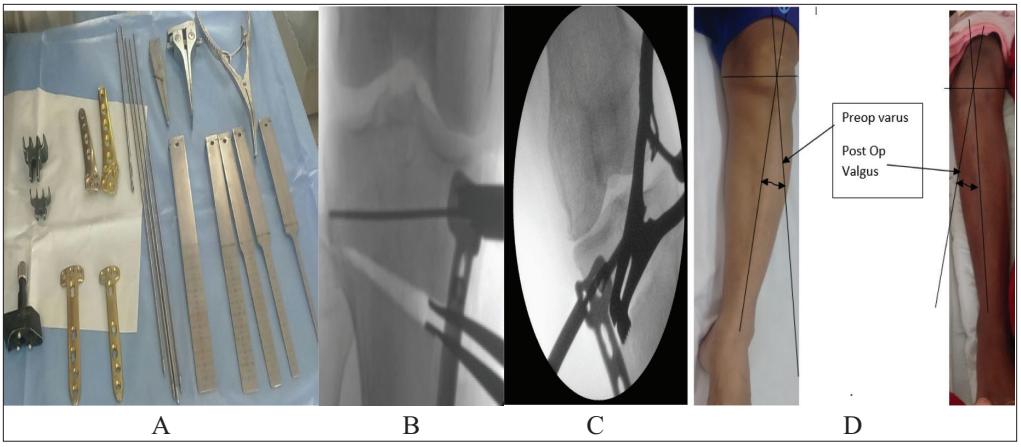

Figure 2: (A) Tomofix plate, osteotomy chisels, bone spreader, soft lock, osteotomy gap measuring device, guidewire and drill, chisels of different sizes (B) intraoperative fluoroscopic image, (C) maintained osteotomy site and fixing with Tomofix plate, (D) clinical picture of preoperative varus and postoperative valgus

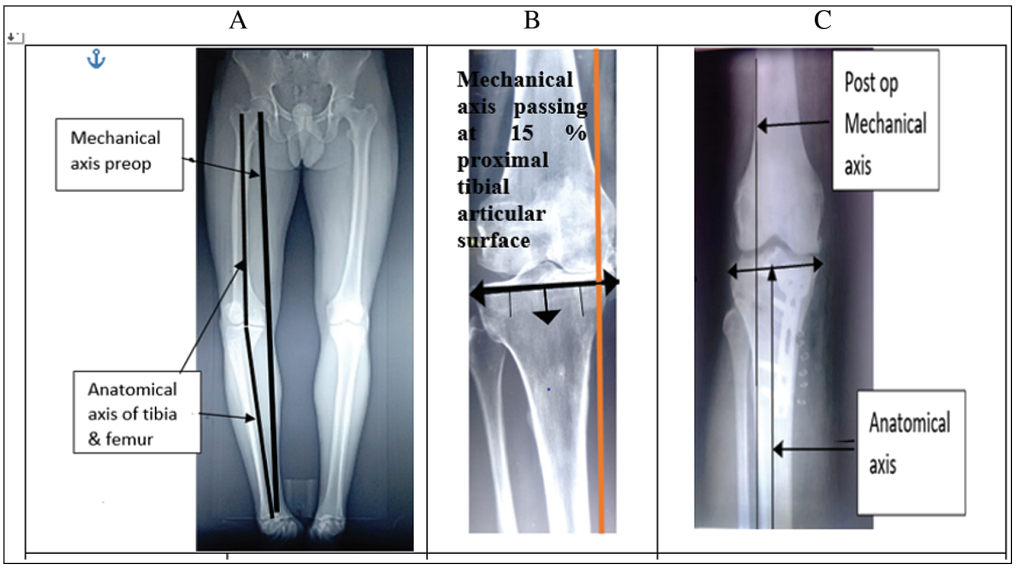

Figure 3: (A) Mechanical axis of leg and anatomical axis of femur and tibia (B) mechanical axis passing at 15% proximal tibial articular surface (C) post-operative mechanical axis

Table 3: Preop and postop comparison of range of motion (ROM) and tibiofemoral angle

		Mean	Total patients	Std. Deviation	Mean Difference	*t*-value	*P* value
Pair 1	ROM Preop	120.42	26	5.478	−7.54	8.54	<0.001
	ROM Postop	127.96	26	3.400			
Pair 2	Tibio-femoral angle Preoperative varus	6.27	26	1.343	0.31	0.82	0.42
	Tibio-femoral angle Post-operative valgus	5.96	26	1.113			

Table 4: Comparison of mean preop and postoperative pain score and functional score at 6 weeks, 12 weeks, 24 weeks, and 1 year

Pain score	Mean	Total patients	Std. Deviation	Mean Difference	*t*-value	*P* value
Preop	53.12	26	8.224	−14.77	9.593	
6 week	67.88	26	9.352			<0.001
12 week	76.65	26	10.564			<0.001
24 week	81.19	26	11.977			<0.001
1 year	82.35	26	11.009			<0.001
Functional score						
Preop	41.08	26	7.025	−18.35	11.487	
6 week	59.42	26	7.915			<0.001
12 week	75.96	26	7.486			<0.001
24 week	79.81	26	9.847			<0.001
1 year	80.19	26	9.432			<0.001

Table 5: Diagnostic arthroscopy and procedure performed

Arthroscopic finding	Numbers	Procedure performed
Chondral damage/Grade I–III Modified Outer-bridge classification	10	Left alone/Debridement of cartilage/ Micro fracturing as per requirement
Degenerative tear of medial meniscus	4	Balancing of medial meniscus
Mild degenerative tear of lateral meniscus	1	Balancing of lateral meniscus
ACL Tear	2	Arthroscopic reconstruction ACL for one and only HTO for second one
Loose bodies	3	Loose bodies removal
Normal/no significant chondral damage	6	Joint lavage
Total	26	

the mean postoperative pain score at 6 weeks, 12 weeks, 24 weeks, and 1 year were 67.88, 76.65, 81.19, and 82.35, respectively with *P*-value <0.001, which is significant [Table 4]. The mean preoperative functional (*Knee Society Score)* score was 41.08 and the mean postoperatively at 6 weeks, 12 weeks, 24 weeks, and 1 year were 59.42, 75.96, 79.81, and 80.19, respectively with *P* value <0.001, which is significant [Table 4]. The preoperative mean ROM [Table 3] of the knee joint was 120.42° ± 5.478° and the postoperative ROM was127.96° ± 3.400°, *t*-value of 8.54 and *P* value of <0.001 which is significant. The preoperative mean varus was 6.27° ± 1.343° and postoperative mean valgus was 5.96° ± 1.113°, *t*-value of 0.82 and *P* value of 0.42 [Table 3]. The arthroscopic findings and the necessary concomitant procedures performed in our study are summarized in [Table 5]. Chondral damage of medial femoral and tibial condyles was the commonest arthroscopic finding (38%) in our study. Grade I (Modified Outerbridge classification) chondral lessons were left alone and Grade II and Grade III were managed by debridement/microfracturing. Degenerative tears of the medial meniscus (15%) were managed by meniscal balancing and mild degenerative tears of lateral meniscus (3%) were left alone. Loose bodies were encountered in 12% of patients and were removed. ACL tear was present in two patients and was managed by arthroscopic ACL reconstruction along with HTO for one patient and only HTO for the second one.

In our study, one patient (3.8%) developed an infection (SSI), which was treated with intravenous antibiotics and removal of an implant after the union. One patient (3.8%) had terminally painful movement at the final follow-up. None of the patients developed postoperative compartment syndrome, patella baja, nonunion, instability, loss of valgus correction, or peroneal palsy.

Discussion

Ideal age for high tibial osteotomy

Insall *et al*.[11] recommended that high tibial valgus osteotomy be reserved for patients younger than 60 years of age. Coventry *et al*.[12] suggested that the age of the patient is irreverent for surgery and the average age of patients in the series was 49 years. Although the mean

age of participants in our study was 46.9 years, which correlate with the recommended and suggested mean age in other studies, we felt that osteotomy should not be denied to patients based on the age if the other criteria like unicompartmental involvement and stable joint with no fixed deformities are present.

Pain relief

Arnoldi *et al.*,[13] felt that the relief of pain was due to the lowering of the intraosseous venous pressure. Patients with degenerate OA knee have impaired venous drainage from the juxtachondral cancellous bone across the cortex. Intravenous phlebography showed that pain disappears when the high medullary pressure is released by osteotomy. Helal *et al.*,[14] explained that the absence of resting pain was due to decongestion.

Coventry *et al.*,[12] agreed with this hypothesis that osteotomy may lower intraosseous hypertension in the short term. The mechanical realignment of the joint with the transfer of load from the involved compartment to the opposite normal compartment is explained as the reason for the relief of pain. Here, we agree with Insall *et al.*,[15] and Vainionpaa *et al.*[16] that the effect of the pain relief is due to mechanical factors contributing to realignment with osteotomy.

Insall *et al.*,[15] reported 97% with no pain and 3% had mild pain. In Coventry *et al.*,[17] study 67% of patients had mild pain, 24% had moderate pain, and 7% had severe pain during follow-up. In our study, pain either disappeared or was relieved to a large extent after surgery. There was more pain relief in our study when compared with the Coventry *et al.*,[17] study but was less when compared with the Insall *et al.*,[15] study.

Tibiofemoral angle

The rationale behind the HTO is to shift the mechanical axis from the medial compartment to the lateral compartment which in turn will reduce the load on the medial compartment of the knee. The mechanical axis is formed by a line drawn from the center of the femoral head to the center of ankle. During normal single-leg stance, the medial compartment bears 75% of load due to inherent 2° of varus (tibiofemoral mechanical varus) of knee. As we shift the mechanical axis to 4° of valgus, the load on medial compartment decreases to 50%. And it decreases further to 40% when the mechanical axis reaches to 6° of valgus at knee. *It is not possible to unload the medial compartment completely.* So, the targeted mechanical axis is between 4° and 6° of valgus. This passes between 30% and 40% lateral to the center of the tibial spine and is known as MAD or Fujisawa point.[11]

Insall *et al.*,[15] reported that the best results were obtained in knees which had tibiofemoral angle between 10° and 14° postoperatively. They felt that postoperative valgus angle between 5° and 14° to be acceptable. Coventry *et al.*,[17] recommended 5° overcorrection beyond the normal angle of 5°–8° of genu valgum, or a final tibiofemoral valgus angle of 10°–13°. Paley *et al.*[18] showed that 2°–4° of mechanical valgus over correction achieved the best results whereas neutral alignment, under correction or significant over correction led to inferior results. They recommended ideal valgus angulation to be at 7°–9°. This finding suggests that there is individual variation and the question still remains is how much valgus angulation is correct amount. We found that the overcorrection should be at least 2°–4° of valgus but cannot specify an upper limit with certainty. We noted good results if an average tibiofemoral valgus angulation measured 5.96°, two rated poor knees in our series had valgus angulation <5°.

Regression of varus angle

In a study carried out by Pande *et al.*,[1] modular dynamic fixator couldn't make a large number of patients comfortable and noticed significant loss of correction after removal of fixator within one year with worrying observation as maintenance of correction is the most important factor to ensure good outcome in the long term. During the follow-up period no regression in varus noted in our study. Rigid fixation helps better in maintaining the valgus in the postoperative periods. In Coventry *et al.*,[17] study after five-week fall, 70% of knees showed mild regression at a rate of 1°, after five years. Insall *et al.*[15] reported regression to varus deformity after 29 of 95 osteotomies that had been performed without internal fixation.

Range of motion

In our study, the mean preoperative ROM was 120.5° and postoperatively ROM knee was 128.5°. There is an increase in ROM mean of 8°. Using paired *t*-test, the *P* value was 0.001, which implies that postoperative ROM with HTO is significantly improved. None of the patients lost any further flexion in the final follow-up. In our study, patients were mobilized on the second postoperative day with partial weightbearing mobilization after teaching active quadriceps exercises. This proportional increase in ROM was probably due to early mobilization. The same can be observed from previous studies of Weidenhielm *et al.*,[19] and Lawrence *et al.*[20] A loss of ROM was observed in Insall *et al.*,[15] and Coventry *et al.*,[17] study where the patients were immobilized in plaster cast and partial weight bearing was advised from the third day and one week, respectively.

Stability

Coventry *et al.*,[17] reported three cases of gross instability out of 76 knees after using his techniques of lateral collateral ligament reconstruction. Sixteen patients had

mild instability in Insall's *et al.*,[15] study and 10 patients had moderate instability during final follow-up. In a similar study carried out by Kyung *et al.*,[21] a firm fixation using TomoFix plate for open wedge HTO produced better radiologic results and a low complication rate than those of the Aescula spacer plate. All 26 patients of our study had undergone medial opening wedge osteotomy fixed with Tomofix plate. We found the plate was extremely convenient and there was no case of instability reported. We noticed that pain and instability were closely related. We believe that by using a rigid plate (Tomofix) for fixation of osteotomy helped in achieving the stability.

Functional outcome

In our study, 53% of the cases had good, 35% had excellent, and 12% had fair functional outcomes. Preoperative mean Functional score in Knee Society Score was 41.08 and mean Functional score postoperatively at 6, 12, 24 weeks, and 1 year was 59.42, 75.96, 79.81, and 80.19, respectively. Using student's *t*-test, *P* value is 0. 001, which shows that Knee Society Score for a functional outcome is significantly better than preoperative cases. These findings correlate with the previous studies conducted by Saito *et al.*,[22] Niemeyer *et al.*,[23] and Bonasia *et al.*,[24] which have shown significant improvement in the functional outcome after different techniques of HTO. Ultimately as per our study, the main reasons for the improved functional outcome were redistribution of loading, reducing tension on opposite stretched ligaments, reducing the impingement of degenerate meniscus on capsule, reducing capsular stretching, and tearing by correcting varus or valgus deformity and altering of blood supply specially reducing venous stasis and intramedullary pressure.

Improvement in gait

Future knee replacement

Coventry *et al.* in 1993,[17] their study was in the opinion that following valgus osteotomy TKR becomes more difficult because of overcorrection, requiring more bone resection, and various complications of soft tissue, incision, peroneal palsy, ligament laxity secondary to HTO, and flexion deformity of the knee. Preston *et al.*,[8] Badawy *et al.*,[9] and Farfalli *et al.*,[10] the risk of revision in total knee arthroplasty is not affected by the previous HTO. Furthermore, we could also find out that in many studies performing TKR under skillful hands in primary patients and in patients who had already undergone HTO, the outcome didn't alter much. In our study, on telephonic consultation at the latest follow-up (five-year post-op) of 10 patients, none of them felt the need for knee replacement and all are comfortable with activities of daily living. Although, it will be a premature notion to comment upon the difficulties in performing future TKR and its outcome, however, we can definitely tell that by doing HTO we can buy time before more radical procedures are unavoidable, if not the risk of future TKR is prevented.

Complications

Although the complication rate in our study was less, the possible reasons for the complications usually are overcorrection or under-correction of the varus deformity, bone necrosis due to improper osteotomy technique, intra-articular fracture of the tibial plateau, an osteotomy too near the joint line will not allow placement of all screws in the proximal fragment, injury to the neurovascular bundle, and postoperative compartment syndrome. In our study, one patient (3.8%) developed an infection (SSI), which was treated with intravenous antibiotics and removal of implant after the union. One patient (3.8%) had terminally painful movement at final follow-up. There was no nonunion in our series. The bony union was rapid because the osteotomy was through cancellous metaphyseal region of the tibia. Coventry *et al.*,[17] in his series of 86 knees noted no delayed or nonunion when the osteotomy was proximal to the tibial tuberosity but noted some delay in union when it was distal to the tibial tuberosity in a few cases. In our study, we didn't notice any peroneal palsy in the follow-up period.

Limitations

One of the limitations of our study was that we did only medial opening wedge HTO, while we could not compare it with lateral closing wedge osteotomy, which would otherwise give a better comparison. Second, medium-term follow-up for all cases was not possible due to the constraint of time.

Conclusion

HTO with a necessary concomitant arthroscopic procedure is a joint preserving surgery with good to excellent outcomes for the treatment of the refractory pain and disability caused by OA of knee involving the medial compartment in a mal-aligned limb in young and middle-aged active patients. The deformity correction achieved by medial opening wedge HTO is translated in terms of comfort achieved in daily living activities, relief of symptoms of OA, and improvement in function. We also conclude that overtreatment of isolated medial compartment OA of the knee can be aborted by doing HTO which can definitely buy time before more radical procedure is unavoidable, if cannot the risk of future TKR be prevented.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Pande H, Thakur K, Dubey R, Singh C. Changes in lower limb alignment and their effect on the functional outcome after treatment of varus degenerative OA knee by hemicallotasis using modular dynamic HTO fixator. J Clin Orthop Trauma 2021;14:85-93.
2. McAlindon T, Formica M, LaValley M, Lehmer M, Kabbara K. Effectiveness of glucosamine for symptoms of knee osteoarthritis: Results from an internet-based randomized double-blind controlled trial. Am J Med 2004;117:643-9.
3. Moseley JB, O'Malley K, Petersen NJ, Menke TJ, Brody BA, Kuykendall DH, *et al*. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 2002;347:81-8.
4. Feeley BT, Gallo RA, Sherman S, Williams RJ. Management of osteoarthritis of the knee in the active patient. J Am Acad Orthop Surg 2010;18:406-16.
5. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, *et al*. OARSI recommendations for the management of hip and knee osteoarthritis, part I: Critical appraisal of existing treatment guidelines and systematic review of current research evidence. Osteoarthritis Cartilage 2007;15:981-1000.
6. Amendola A, Bonasia DE. Results of high tibial osteotomy: Review of the literature. Int Orthop 2010;34:155-60.
7. Preston CF, Fulkerson EW, Meislin R, Di Cesare PE. Osteotomy about the knee: Applications, techniques, and results. J Knee Surg 2005;18:258-72.
8. Preston S, Howard J, Naudie D, Somerville L, McAuley J. Total knee arthroplasty after high tibial osteotomy: No differences between medial and lateral osteotomy approaches. Clin Orthop Relat Res 2014;472:105-10.
9. Badawy M, Fenstad AM, Indrekvam K, Havelin LI, Furnes O. The risk of revision in total knee arthroplasty is not affected by previous high tibial osteotomy. Acta Orthop 2015;86:734-9.
10. Farfalli LA, Farfalli GL, Aponte-Tinao LA. Complications in total knee arthroplasty after high tibial osteotomy. Orthopedics 2012;35:e464-8.
11. Insall JN, Shoji H, Mayer V. High tibial osteotomy: A fiveyear evaluation. J Bone Joint Surg Am 1974;56:1397-405.
12. Coventry MB. Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. J Bone joint Surg 1965;47-a:984-90.
13. Arnoldi CC, Djurhuus JC, Heerfordt J, Karle A. Intraosseous phlebography, intraosseous pressure measurements and 99mtc-polyphosphate scintigraphy in patients with various painful conditions in the hip and knee. Acta Orthop Scand 1980;51:19-28.
14. Helal B. The pain in primary osteoarthritis of the knee. Its causes and treatment by osteotomy. Postgrad Med J 1965; 41:172-81.
15. Insall JN, Joseph DM, Msika C. High tibial osteotomy for varus gonarthrosis. A long-term follow-up study. J Bone Joint Surg Am 1984;66:1040-8.
16. Vainionpää S, Läike E, Kirves P, Tiusanen P. Tibial osteotomy for osteoarthritis of the knee. A five to ten-year follow-up study. J Bone Joint Surg Am 1981;63:938-46.
17. Coventry MB, Ilstrup DM, Wallrichs SL. Proximal tibial osteotomy. A critical long-term study of eighty-seven cases. J Bone Joint Surg Am 1993;75:196-201.
18. Paley D, Maar DC, Herzenberg JE. New concepts in high tibial osteotomy for medial compartment osteoarthritis. Orthop Clin North Am 1994;25:483-98.
19. Weidenhielm L, Olsson E, Broström LA, Börjesson-Hederström M, Mattsson E. Improvement in gait one year after surgery for knee osteoarthrosis: A comparison between high tibial osteotomy and prosthetic replacement in a prospective randomized study. Scand J Rehabil Med 1993;25:25-31.
20. Kriegshauser LA, Bryan RS. Early motion with cast-brace after modified coventry high tibial osteotomy. Clin Orthop Relat Res 1985:168-72.
21. Kyung HS, Lee BJ, Kim JW, Yoon SD. Biplanar open wedge high tibial osteotomy in the medial compartment osteoarthritis of the knee joint: Comparison between the Aescula and Tomofix plate. Clin Orthop Surg 2015;7:185-90.
22. 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.
23. 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.
24. Bonasia DE, Dettoni F, Sito G, Blonna D, Marmotti A, Bruzzone M, *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.