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A prospective observational study to assess the functional and radiological outcomes of high tibial osteotomy in medial compartment osteoarthritis in younger population

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Abstract
Introduction: Medial compartment osteoarthritis is a common entity leading to significant morbidity in geriatric population. High tibial osteotomy is a time tested knee preserving operation. The fixation methods vary from internal fixation like plates and screws, to external fixators like dynamic uniaxial fixators and Ilizarov.
In this study we have analysed the outcomes of medial opening wedge osteotomy using a unilateral dynamic external fixator (Orthofix) using the principle of hemi-callostasis.
Method: We conducted a prospective cohort study involving 20 patients with medical compartment osteoarthritis. Medial HTO was performed using Orthofix^{TM} external fixator in 20 patients (20 knees) and were followed up between January 2019 to February 2021.Functional and radiological outcomes were assessed using the KSS and KOOS scores and the alignment xrays respectively.
Results: Out of 20 patients included in the study, the majority (18) were females the mean age in the group was 50.75 years (+6.06years) at time of surgery. The involvement of right knee was seen in 12 patients and left knee was involved in 8 patients. The average improvement in th HKA was 13+1.2 degrees. The Average corrected HKA was 183.05+4.2 degrees. There was significant improvement in the mean KSS score at 2years, from (44.15 ± 6.13) pre-operatively to (86.15 ± 6.41) post-operatively and was statistically significant ($p<0.001$). An average KOOS score was (45.81±4.38) pre-operatively which improved to (89.20±4.24) in the post-operative period which was statistically significant ($p < 0.001$).
There was positive correlation between pre and post operative KSS values which was significant at $p < 0.05$ that is, patients with better pre operative KSS scores had Better post operative functional outcome.
Conclusion: High tibial osteotomy is a good option for young physiologically active patients with medial compartment osteoarthritis. The dynamic external fixator allows accurate correction of HKA angle postoperatively. Appropriate patient selection, good pre-operative planning, patient education and precise surgical techniques are essential for success of HTO. Achieving HKA angle between 183 -186 degrees is the key for good functional outcome and pain relief.

Keywords: Radiological outcomes, high tibial osteotomy, medial compartment osteoarthritis

Introduction
Osteoarthitis of knee is a chronic, painful and debilitating condition. Overall prevalence in the Indian population is 28.7% and is projected to increase sharply over the next two decades [1-3].
Knee joint has three compartments-medial, lateral and patellofemoral. Medial compartment osteoarthritis is a common entity and is associated with genu varum, medial joint space narrowing, medial joint laxity, quadriceps weakness, as well as sclerosis and attrition of subchondral bone [4].
In the initial stages of the disease, non-surgical treatments such as lifestyle modification, weight reduction and physiotherapy may be tried but as the disease progresses to medial compartment osteoarthritis, surgical line of management is often warranted. The surgery could be either knee preserving or knee replacing.
Knee preserving procedures include arthroscopic lavage and debridement, osteochondral transplantation techniques, corrective osteotomy to name a few.

Knee replacement procedures include Unicompartmental Knee Arthroplasty and Total Knee Arthroplasty. Arthroplasty is a good option for old age population with less functional demands.Less invasive procedures like intraarticular injections or joint debridement do not give long lasting relief.

High tibial osteotomy is an accepted surgical technique for the treatment of medial compartment arthritis of knee with varus deformity in younger patients [5-7].

Successful outcome after HTO depends on appropriate patient selection, careful preoperative planning and accurate surgical techniques. HTO can be medial opening wedge, lateral closing wedge or a focal dome osteotomy. The advantages of medial open wedge osteotomy over other techniques are that it offers a more precise correction smaller surgical exposure without any muscle detachment, freedom from peroneal nerve complications, need for fibular osteotomy, lack of limb shortening and does not hinder future total knee arthroplasty.

The aim of this procedure is to alter the mechanical axis so that the Weight Bearing Line (WBL) is shifted from medial to the lateral compartment of the knee joint, thereby reducing load through the affected medial compartment [8].

Various implants such as staples, circular external fixators, unilateral dynamic external fixators and plates may be used, each having its own advantages and disadvantages.

In this study we have analysed the outcomes of medial opening wedge osteotomy using an unilateral dynamic external fixator (Orthofix). This is based on the biomechanical principle of hemicallotasis – gradual biological angular distraction of unilateral callus. Leaving the lateral cortex intact encourages neohistogenesis and gradual correction of varus deformity. This changes the line of weight transmission from medial side of the knee to the lateral aspect.

Materials and Methods

A prospective cohort study was designed that included patients with isolated medial compartment osteoarthritis presenting at the Orthopaedics out- patient department of a tertiary care hospital in Kerala. Medial HTO was performed using Orthofix external fixator in 20 patients (20 knees) and were followed up between January 2019 to February 2021. Follow-up during COVID-19 lockdown from March 2020 to October 2020 was done over the mobile phone and social networking applications.

1. Inclusion criteria:

- patients with isolated medial compartment osteoarthritis
- age less than 65 years
- both males and females
- flexion contracture of less than 15 °
- consenting for the study.

2. Exclusion criteria

- knee flexion less than 90 °
- genu varum deformity more than 20 °
- bi-compartmental or tri-compartmental osteoarthritis, inflammatory arthritis, post traumatic arthritis [8-10].

Institutional ethics approval was obtained before starting the study. Informed written consent was taken from all subjects.

No funding was required.

A standardized proforma was used to collect patient details including demographic and personal data. A thorough clinical examination was performed to look for medial joint line tenderness, range of movement at the knee, varus and valgus stress test for ligament laxity and gait examination. Hip joint examination was done to rule out arthritis or any other pathology. Spine examination to rule out any spinal origin of knee pain or referred pain. Routine blood investigations including complete blood count, Erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) and Rheumatoid factor (RF) were assessed to rule out inflammatory or infective pathology.

Radiographic evaluation

Full length weight bearing three joint (hip, knee, ankle) antero-posterior and lateral plain radiographs of both lower limbs with patella facing forwards. A digital analysis was done using the HOROS™ software. Mechanical axis deviation, amount of varus (from mechanical tibio-femoral angle), medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA), joint line congruence angle (JLCA), Hip knee angle (HKA) angle were calculated.

A standing 30° flexion PA view (Rosenberg's view) was taken to assess the joint space. Skyline view was taken to assess the patella-femoral joint status. True lateral view of knee in maximum possible extension was taken to assess sagittal plane deformity and flexion contracture by assessing the proximal posterior tibial angle (PPTA). Valgus and varus stress x-ray of knee AP was taken to assess ligament laxity.

A pre-operative physiotherapy protocol was followed to maintain strength in the hip abductors and knee extensors, to improve range of movement around knee joint and to aid faster post-operative recovery and to improve the gait. A minimum of three months of pre-operative quadriceps strengthening exercises were advised for optimal post operative rehabilitation.

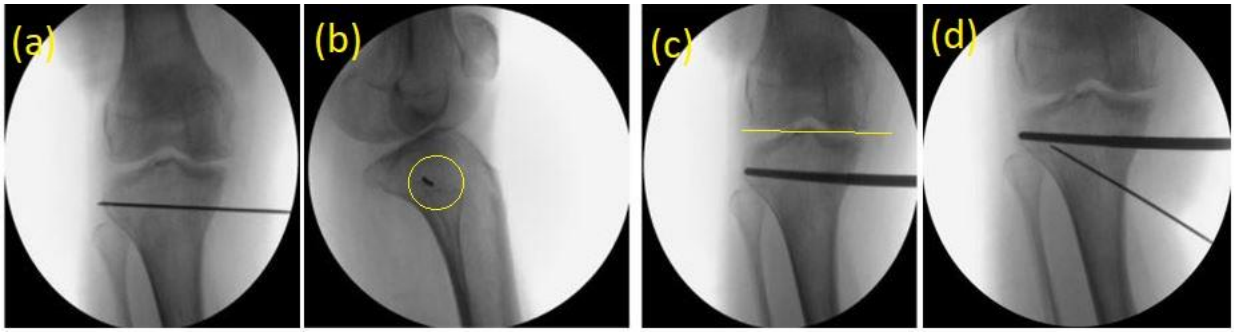
Surgical technique

All the patients were operated in supine position under spinal anaesthesia. The surgeon stood on the side contra-lateral to the affected knee to get better access to the medial surface of tibia.

Position

The knee was positioned with the patella facing straight up. Pillows were positioned under the greater trochanter to prevent external rotation of the limb, under the thigh and ankle to ensure adequate gap between calf and the operating table. This position prevents iatrogenic injury to the posterior neurovascular structures while performing an osteotomy. Tourniquet was not used in any of the cases. Orthofix™ (dynamic uniaxial external fixator) was templated over the limb such that the central body locking nut faced upwards to align the hinge axis perpendicular to the plane of the deformity. Central body was kept slightly distracted (3-5mm) to allow for some compression later. Under C-arm guidance, a guide wire was passed approximately 1 cm below and parallel to the joint line at the level of fibular head in the antero-posterior view. [Figure 1 (a)] It was also made sure that the entry point was as near as possible to the posterior border of the tibia. This ensured that atleast 2 well-spaced pins could be placed in the proximal tibia. In the experience of the operating surgeon it was observed that in maximum number of cases only 1st and 3 rd holes could be used for Schanz pin placement. This is possibly due to the small AP measurement of tibia in Indian population. After drilling over the guide wire with 4.5mm cannulated drill bit, a Schanz pin of size 6mm x 150 mm× 50/60 mm threaded area was introduced in

the drill hole. A second Schanz pin of 6mm x150 mm× 60 mm threaded area was then inserted parallel to the first Schanz pin but anterior to it in lateral view. This was inserted using the T clamp of dynamic axial fixator as a guide. Later two more Schanz pins 6mm x110/130 mm x 30mm were applied to the anteromedial surface of the distal tibia, parallel to the floor and perpendicular to the tibial surface while maintaining the axis of distraction of the proposed osteotomy site. The dynamic axial fixator was attached to the Schanz pins and tightened in the pre-determined distraction mode. The fixator was adjusted such that a guide wire when passed through the hole in the fixator would be perpendicular to the shaft of the tibia before distraction. A 40 mm compression-distraction unit was attached to the dynamic axial fixator. A guide wire was then passed from the osteotomy site towards the fibular head. With the help of an osteotome, an infratubercular oblique osteotomy was done under C-arm guidance, keeping the lateral cortex intact, using the guide wire to direct it towards the fibular head. A gradual and controlled valgus stress was applied to open the osteotomy site with due care not to breach the lateral cortex. Gradual distraction was done until the varus deformity was corrected and mechanical axis passes through the lateral tibial spine of the knee. The final correction was checked under C-arm and the mechanical axis marked using a cautery wire as a guide, passing through the lateral tibial spine. The osteotomy site was closed to maintain initial varus position of the limb. Sterile pin track dressing was applied.



(a) First guide wire parallel and below the joint line proximally
(b) End on view showing 1st guide wire close to the posterior cortex.
(c) 1st pin placed along the path of 1 st guide wire.
(d) Osteotomy guide wire placed along the predetermined trajectory aiming towards the proximal tibio fibular joint.

Fig 1: Showing the intra-operative radiograph images

Post-operative protocol

Intra-venous antibiotics were administered for three days. Adequate analgesics (NSAIDs) given for proper mobilization and physiotherapy. Static quadriceps, ankle and toe movements were started in the evening after surgery. Knee mobilization was begun in the following days. Touch down weight bearing was allowed on day 5 after good quadriceps control was attained. Post-operative plain radiographs (AP view and lateral view) of the knee were taken to confirm the level and closure of the osteotomy site. Serial radiographs were taken during the distraction period. First change of dressing was done after 48 hours and daily pin tract cleaning was advised. Patient was discharged from the hospital once he or she was independent in terms of ambulation, and comfortable in terms of pain, usually by 5-7days i.e. at the end of the distraction period. NSAIDs, antacids, calcium, vitamin supplements were prescribed at discharge. Distraction started on post operative day 8, at a rate of ¼ turn every 6 hours so that 1mm/day distraction was obtained. Patient was followed up at 2 weeks after surgery for suture removal and repeat radiograph was taken to look for opening up of osteotomy site. Further follow-up sessions were timed depending on the amount of distraction required for attaining the pre-determined valgus correction. Distraction was stopped once proper correction was attained by drawing the mechanical femoral-tibial angle any undue post-operative varus or valgus was corrected by adjusting the compression-distraction unit appropriately. Patients were then followed up every three weeks till the distraction site was fully consolidated (usually about 2-4 months) and full weight bearing with the fixator in-situ was advised.

Prior to removal, a clinical stress test for gradual disassembly was performed. Trial of unassisted full weight-bearing looking for pain, limp and instability. After measuring the amount of distraction on the fixator, the central locking nut is loosened and the compression-distraction (CD) unit taken out. If the fracture is united, there should be no pain or limp and not more than 1-2 mm collapse as measured by checking the fixator reading. The fixator is then removed and the patient allowed to walk full weight bearing again with the half pins still in situ. If there is pain or limp, the fixator just needs to be slipped on again, and maintained for a few days more. Finally, if there is no pain on the previous step, the half pins are removed. Thereafter, a compression bandage is applied and the patient is made to rest for 15-20 min with the leg elevated to allow coagulation in the pin tracks. From this point onwards patient resumes gradual daily activities. Follow-up should be done after 2 weeks to confirm that the pin site healing. Thereafter a 6 monthly review was done to look for the opening up of joint space in the medial compartment that indicates healing up of the cartilage, maturation and remodeling of the regenerate, and the filling up of pin sites. At the end of one year full-length radiographs are taken to confirm the maintenance of the realigned axis.

Assessment of Outcomes

Knee society Score (KSS)

The KSS contains questions in 2 sections: knee joint-pain, range of motion, stability (7 items) and function- walking distance, ability to climb stairs (3 items). Both sections were scored from 0 to 100 with lower scores being indicative of worse knee conditions and higher scores being indicative of better knee conditions. When calculating the score, deductions are made for assistive devices and flexion contractures, misalignment, or extension lag [11].

Knee Injury and Osteoarthitis Outcome Score (KOOS)
KOOS consists of 42 items in 5 subscales; pain, other symptoms, acitivity of daily living (ADL), function in sport and recreation and knee related quality of life (QOL). Standardized answer options are given (5 Likert boxes) and each question is assigned a score from 0 to 4. It is self-administered, user friendly, and takes about 10 minutes to complete. A normalized score (100 indicating no symptoms and 0 indicating extreme symptoms) was calculated for each subscale [12].

Results

The study included 20 patients of which, 2 were male and 18 were female. The mean age in the group was 50.75 years (+6.06years) at time of surgery. The involvement of right knee was seen in 12 patients and left knee was involved in 8 patients.

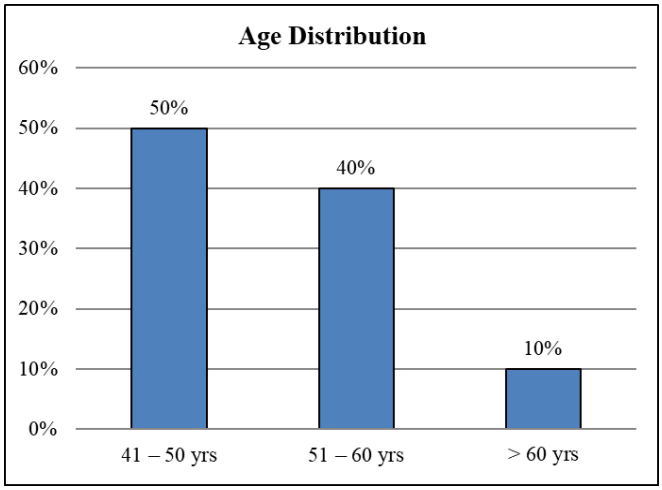


Fig 1: Age distribution of patients

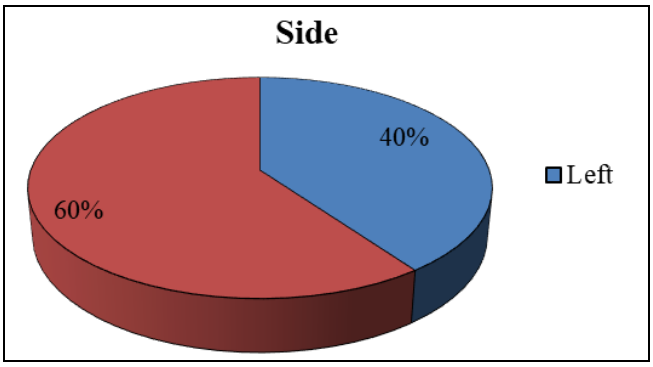


Fig 2: Distribution of side of OA.

There was significant improvement in the mean KSS score at 2years, from (44.15 ± 6.13) pre-operatively to (86.15 ± 6.41) post-operatively as analyzed by paired t-test and was statistically significant ($p<0.001$). An average KOOS score (45.81±4.38) was found pre-operatively which improved to (89.20±4.24) in the post-operative period which was statistically significant as analyzed with the help of student t test ($p < 0.001$).

Table 1: Statistical correlation between the pre (before) and post (after) operative Knee society Scores.

Test	Mean	S.D.	n	Mean change	t	df	Significance (*p*-value)
Before	44.15	6.13	20	42.0	30.77	19	$p<0.001$***
After	86.15	6.41					

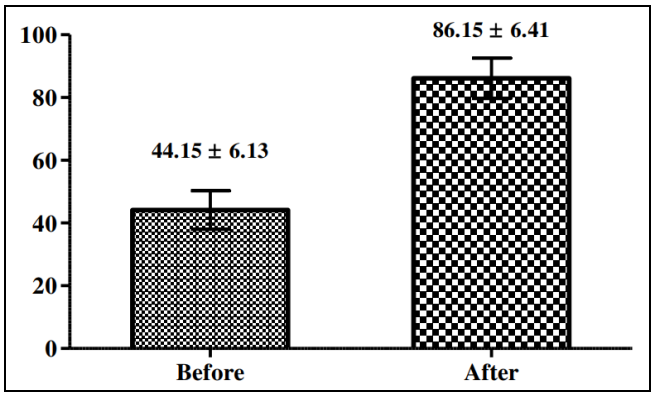


Fig 3: Histogram comparing pre and post-operative mean KSS scores

Table 2: Showing the correlative statistics between pre(before) and post(after) operative KOOS scores.

Test	Mean	S.D.	n	Mean change	t	df	Significance (*p*-value)
Before	45.81	4.38	20	43.39	40.82	19	$p<0.001$***
After	89.20	4.24					

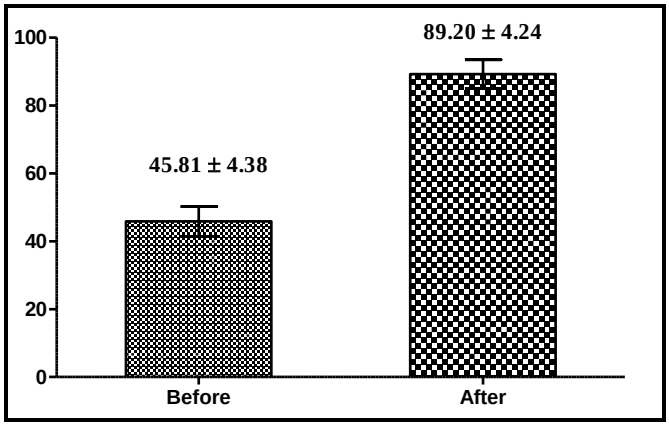


Fig 4: Histogram comparing pre and post-operative mean KOOS scores

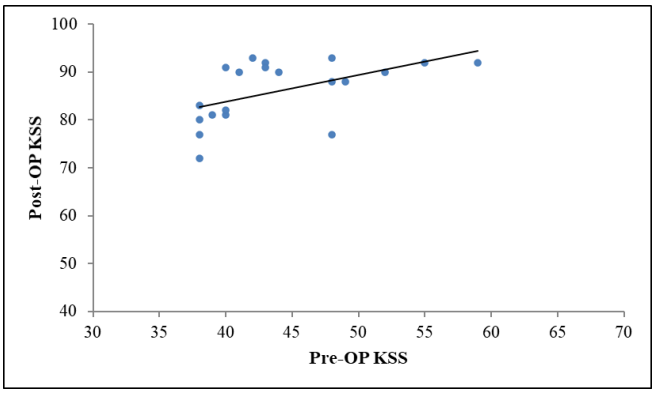


Fig 5: Scatter plot showing linear correlation between Pre and post-operative KSS scores

The correlation coefficient for pre and post-operative scores+0.527 was significant at $p < 0.05$. This shows that there was a significant positive correlation between pre-operative KSS and post-operative KSS i.e. post-operative KSS was better among patients with better pre-operative KSS. In our study we attempted to achieve a Hip knee angle 183-186 ° in accordance with the findings in the study by Hernigou *et al*. 17 patients (85%) attained adequate valgus correction postoperatively and 3 patients (15%) had under correction.

Three patients (15%) had superficial pin tract infection which resolved on conservative management with antibiotics, regular sterile dressings and rest for few days.

KSS score was poor (less than 60) in all the patient preoperatively and post operatively.

75% had excellent and 25% had good outcome.

Case: 33-year-old female with right sided knee pain since past 5 years diagnosed as medial compartment osteoarthritis.

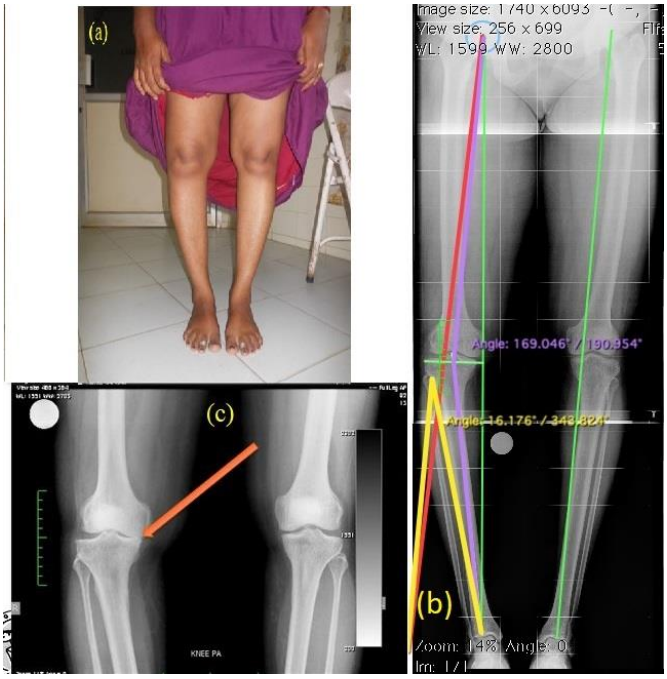


Fig 1: (a) Clinical photograph - varus deformity of right knee.
(b) Malalignment test was done on a long leg film. Following were the angles calculated: Medial proximal tibial angle (MPTA)-82°, Lateral distal tibial angle (LDTA)-81°, Joint line congruence angle JLCA-4° and Tibio-femoral angle-169°. Correction planned was 16° to achieve a 5° postoperative valgus.
(c) Standing antero-posterior radiograph of knee - narrowed medial joint space (Red arrow), subchondral sclerosis and mild lateral subluxation of tibia.

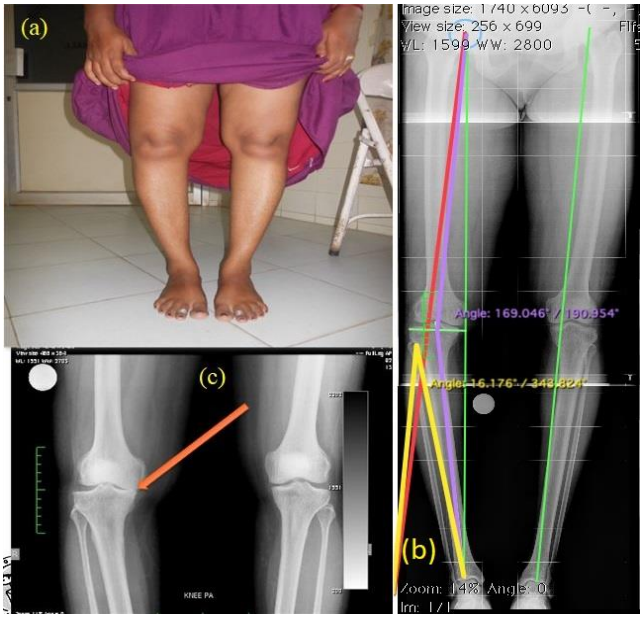


Fig 2: (Left) Showing the oblique osteotomy with lateral hinge at the proximal tibio-fibular joint. (Center) Post-operative follow-up at 3 weeks with completed distraction of the osteotomy site. (Right) 3 joint radiograph showing corrected mechanical axis passing through the lateral tibial spine (Fujisawa point).

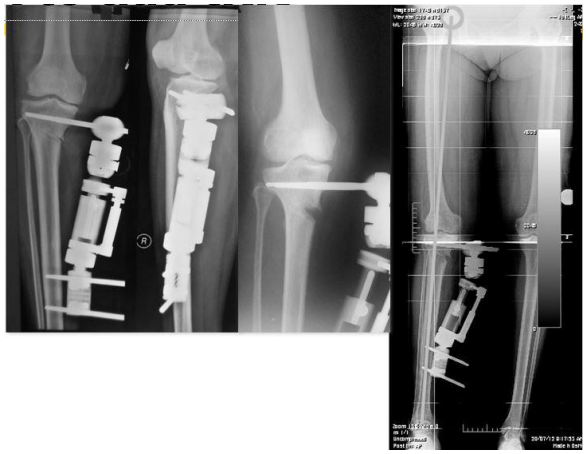


Fig 3: Improving range of motion with painless flexion possible upto 90° and clinically acceptable correction.

Fig 4: Two years after fixator removal showing union at the osteotomy site and patient having corrected alignment and improved function.

Discussion

Medial open wedge High tibial osteotomy with an external fixator is a good option as it avoids the complications associated with closed wedge osteotomy and implant related complications. The treatment with external fixator allows for accurate correction of the varus deformity leading to realignment of the mechanical axis such that the weight bearing line passes through the Fujisawa point - lateral tibial spinous process of the knee.

The ability to alter the fixator in the postoperative period to improve limb alignment has been one of the most appealing aspects of using external fixators with osteotomies. Both monolateral external fixators and Ilizarov ringed fixators have

been designed to perform gradual limb realignment. Other advantages offered by the fixator

- Stability - allows early walking,
- Limits the discomfort of the initial prohibition of weight bearing that must be prescribed in the case of plates.
- External fixator removal is easy, hassle free and can be done as an outpatient procedure.

The procedure carries risk of lateral cortex fracture during osteotomy, possibility of delayed union or non-union and pin tract infection. Intra-articular fracture can occur if the apex of the osteotomy is nearer to the subchondral bone than to the lateral tibial cortex. Care must also be taken when distracting the osteotomy site to ensure that no opening in the sagittal plane occurs, as this will both increase the tibial slope and cause difficulty closing the soft tissues.

High tibial osteotomy has become an established procedure for the treatment of medial compartment osteoarthritis in young patients while Total Knee Arthroplasty is more popular for osteoarthritis in older age groups. In younger and active patients with higher functional demands early TKA is unsuitable on account of need for multiple revisions and risk of implant loosening. The goal of HTO is to reduce excessive loading of the medial compartment of the knee by correcting the varus deformity, thereby reducing pain and improving function.

The biomechanical basis for the optimal degree of correction has been disputed and the recommended postsurgical knee alignment varies widely. There is a consensus among authors that slight overcorrection in HTO produces more satisfying results. However, the optimal degree of valgus angulation is still controversial.

Coventry suggested anatomical axis correction of 8-10° valgus [13]. Hernigou *et al* suggested a mechanical axis correction of 3-6° valgus [14]. Ivarsson suggested mechanical axis of 3-6° valgus [15].

According to several previous studies sufficient post-operative valgus is the most important determinant that decides the clinical and survival outcomes of medial opening wedge osteotomies. Springer *et al* in their study concluded that patients with 8-16° of valgus correction had 10-year survival of 90% [16].

In a study of 146 HTOs by Koshino *et al* it was concluded that valgus >5° correlated with full cartilage regeneration and increased medial joint space. 91% of their patients had partial or full medial coverage [17].

Wade *et al* studied the relationship between the gait analysis and the clinical outcome after HTO in 32 patients followed up for six years. They concluded that pre-operative peak adductor moment did not correlate with clinic-radiological outcome, provided that adequate valgus correction has been achieved. Their study also emphasized that the clinical outcome was only based on the correction of the [18].

In an article by Kanamiya *et al* 58 HTOs were studied with their outcomes determined by arthroscopic analysis of the knee. They concluded upto 55% of partial or full medial compartment coverage by fibrocartilage when correction of pre-operative mechanical axis correction was done to minimum of 74% across the plateau. They also concluded that sufficient valgus correction was the most important parameter for cartilage regeneration and better functional outcome [19].

Perhaps use of diagnostic arthroscopy along with clinico-radiological analysis can be an effective outcome for assessing the long term outcomes of high tibial osteotomies [20].

Table 1: Shows in author name, methodology and outcoms

Author	Methodology	Outcomes
Coventry *et al*. [13]	Analyzed 213 knees for deformity, pain, function and motion.	more than 60% patients were relieved of pain and had good functions, even 10 yrs after the operation
Ivarsson, in 1990 [15]	reported sixty-five high tibial osteotomies	43 per cent good results and 60 per cent acceptable results at 11.9 years after the procedure had been performed
Nagel, in 1996 [20]	Reported outcomes of HTO done on 34 patients	82 per cent of the 34 patients treated with high tibial osteotomy had good pain relief
Manfred Pfahler *et al*. [21]	reviewed retrospectively the results in patients who had undergone one hundred and four high tibial lateral osteotomies	49 patients (62 knees) with an average follow-up of 10.2 years (range 6-14 years) 90% had excellent Knee Society Score.
Rudan *et al*. [22]	Analyzed 128 knees in 107 patients with osteoarthrosis treated by valgus high tibial osteotomy reviewed from three to 15 years postoperatively.	79.6% good and excellent results.
Hernigou *et al*. [23]	Reported a 10-13 year follow-up of 93 knees treated with a medial opening wedge osteotomy and bone grafting.	20 patients were corrected to 3-6 ° of valgus, with a good result.
Amendola [24]	retrospective study in their compared primary TKR with TKR following HTO	They concluded that previous osteotomy does not affect the outcome of TKR.
In current study	Analysed 20 patients for functional and radiological outcome following medial opening wedge osteotomy using unilateral dynamic external fixator.	75% had excellent and 25% had good outcome as per post operative KSS and KOOS scores. Mean corrected HKA was183.05+4.2 degrees

The choice of fixation for open wedge osteotomies depend on several factors including patient compliance and local skin condition.

External fixation and gradual correction is suitable in certain situations. Accuracy of correction and postoperative adjustability are high, this is particularly helpful when there is an abnormal joint line convergence contributing to the deformity

For simple uni-planar tibial deformities, we can use a monolateral hemicallatosis frame with a hinge. No fibular osteotomy is needed as the proximal tibia fibula joint and lateral tibial cortex act as the hinge for the gradual opening wedge correction.

For more complex deformities such a as oblique plane deformity, flexion contracture of the knee, rotational deformities, lateral collateral ligament laxity, and knee instability a ringed external fixator with hinges and gradual distraction is preferred as it gives better stability and higher versatility to achieve adequate correction.

The presence of lateral compartment disease has classically been taught to jeopardize the results after HTO. Miller and Sterett have observed that gradual correction to neutral

alignment of the varus arthritic knee containing small areas of grade IV chondromalacia laterally has yielded reliably good results [25].

Patellofemoral compartment arthritis has been considered a relative contraindication for High Tibial Osteotomy (HTO). Although many patients with medial gonarthritis experience anterior knee discomfort related to patellofemoral chondromalacia, many authors note that the presence of Outerbridge grade III to IV changes of the patellofemoral articular surfaces has not affected the final outcome after HTO [13, 26].

Limitation of our study include small sample size, short duration of follow-up. Usage of MRI and arthroscopy maybe done to improve the understanding of cartilage damage pre-operatively and cartilage regeneration post-operatively.

Conclusion

1. High tibial osteotomy is a good option for young physiologically active patients with medial compartment osteoarthritis
2. The dynamic external fixator allows accurate correction of postoperative valgus.
3. Appropriate patient selection, good pre-operative planning, patient education and precise surgical techniques are essential for success of HTO.
4. Achieving HKA angle between 183 -186° is the key for good functional outcome and pain relief.

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