Opening Wedge High Tibial Osteotomy

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Abstract

In the era of Joint replacement surgery, Medial High Tibial Osteotomy is a time tested and successful surgical procedure for treatment of mild to moderate knee osteoarthritis. The success of this procedure lies in proper patient selection, an excellent surgical technique, a rigid internal fixation and early rehabilitation. There are a lots of research articles published in literature, many systematic reviews and meta-analysis on this specific topic. In this review article we discuss mainly the recent trends in the medial open wedge osteotomy for treatment of knee osteoarthritis.
Keywords: MOWHTO, Osteoarthritis, Osteotomy, Surgical treatment

Introduction

In the era of joint replacement surgery for the treatment of severe tri-compartmental knee osteoarthritis, Joint preservation surgery present a very relevant option to treat patients with mild to moderate knee osteoarthritis [1, 2]. High tibial osteotomy (HTO) is one such widely performed procedure to treat medial compartment knee arthritis. Many published studies on HTO report good long-term results when done with proper patient selection [1, 3]. Despite this procedure being around for decades, the challenge always remains at the proper patient selection and the surgical execution. In this review article, we have discussed recent trends in open medial wedge high tibial osteotomy (MOWHTO) for the treatment of knee osteoarthritis.

This article focused on select issues related to HTO; patient selection for HTO, a surgical technique for the planning of MOWHTO, desired angle of deformity correction, to graft or not to graft, the graft options for opening wedge osteotomy, the fixation device, the comparison between functional outcomes of unicompartmental knee arthroplasty and whether HTO significantly affects the need for a subsequent total joint replacement surgery.

[A] Patient Selection for MOWHTO

Precise indication, preoperative planning, and operative technique selection are essential to achieve good functional outcomes after MOWHTO. HTO technique was first introduced by Jackson and Waugh in 1961, and high tibial osteotomy (HTO) was popularized by Coventry [4]. Since 1965 this has been an excellent treatment modality for the management of medial compartment osteoarthritis of the knee with varus deformity, the important goals of MOWHTO have been to reduce knee pain and improve the functional outcome by transferring weight-bearing loads to the relatively unaffected lateral compartment in varus knees, and to delay the necessity for a knee replacement by slowing or stopping the further destruction of the medial joint compartment in cases of varus knee osteoarthritis [1–3].

There has been a debate to have a proper selection of patients for MOWHTO to have a better functional outcome and minimize failures and complications post MOWHTO. Primary or secondary medial compartment degenerative arthritis is the most common indication for MOWHTO for varus osteoarthritis of the knee joint [5–7].

A protocol was developed by ISAKOS (International Society of Arthroscopy, Knee Surgery, and Orthopedic Sporctional outcomes Medicine) in 2004 for patient selection [8]. An ideal patient for MOWHTO is a moderately active high-demand (but not jumping or running), young (between 40-60 years old) with isolated medial joint line tenderness, BMI< 25°, nearly full range of motion (ROM), near-normal lateral and patellofemoral compartments, without ligamentous instability, non-smoker, and with some level of pain tolerance [8].

MOWHTO has been contraindicated in patients older than 65, severe OA of the medial compartment (Kellegran & Lawrence Grade III or higher), tricompartmental knee OA, severe patellofemoral OA, flexion deformity >10°, diagnosed inflammatory arthritis, a large area of exposed bone on the tibial and femoral articular surface (>15x15mm), and heavy smokers [6, 8].

Good prognostic factors include

- Pre-operative TBVA>5°,
- Postoperative obliquity of tibiofemoral joint line in a narrow range close to 0°,
- Aatomical valgus alignment of ≥8° at five weeks post-operation,
- Age <50 years.
- Non-smokers.

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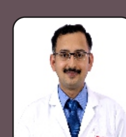
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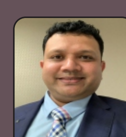
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Poor prognostic factors include

- Severe joint destruction (≥Ahlback grade III),
- Age ≥65 years,
- Advanced patellofemoral arthritis,
- <90° of ROM,
- ≥15° of flexion contracture,
- Joint instability
- ≥1 cm lateral tibial thrust,
- ≥20° of varus correction
- Rheumatoid arthritis
- Obesity (BMI > 26)

The patient's age, level of activity, previous history of surgery on the knee, and expectations should be taken into consideration before deciding upon surgery. The range of motion of the knee joint, the degree of deformity, ligamentous instability, and leg length discrepancy should be assessed through a thorough physical examination before planning for MOWHTO [1, 2, 9].

Adjacent hip joint pathologies also affect the outcome of MOWHTO. Hip abduction that occurs during the stance phase, increases stress on the lateral compartment of the knee, hence pathologic affections of the hip stabilizers (gluteus maximus, tensor fascia late, and biceps femoris) results in higher forces on the lateral compartment of the knee and hence can affect the outcome after MOWHTO [4]. Therefore, hip abductor muscle weakness or movement restriction of the hip joint or ankylosis of the hip joint should be treated before MOWHTO [1, 2].

Most authors agree that HTO is more appropriate than unicompartmental knee arthroplasty for overweight patients, but the influence of body mass index on the results of HTO remains controversial [10]. Which grade of arthritis shall progress to the advanced stage remains debatable and there are no specific guidelines to identify the same, hence patient selection for MOWHTO remains a challenge [4, 7, 10].

[B] Surgical technique for the planning of MOWHTO,

Once the proper patient selection has been made for MOWHTO, the next task that remains is the surgical planning for it. This involves a thorough clinical assessment, radiology assessment, and calculating the deformity angles and its surgical correction planning.

1. Clinical assessment – A thorough clinical assessment of the knee joint and adjacent joints is to be done. Assessment of varus deformity, flexion deformity, range of motion of knee joint, associated ligamentous laxity, patella-femoral joint assessment, the integrity of medial and lateral collateral ligaments needs to be done. Analyzing the patients' gait is of prime importance to assess the varus thrust and loading pattern of the knee joint. In cases with advanced varus knee osteoarthritis, it has been seen that the stress concentrates on the medial side and the lateral side stretches out leading to progressive varus and subluxation of the knee joint. Hence in such cases, the MOWHTO does not lead to lateral compartment stress redistribution and correction of mechanical axis in loading [11].

2. Radiological assessment - Multiple radiographic views should be obtained for preoperative radiographic assessment, these include –

- Scanogram of both legs with full-length lateral view of the affected leg,
- Bilateral weight-bearing anterior-posterior views in full extension,
- Rosenberg views with the knee in 45° of flexion,
- Lateral views and Skyline views.

Patellar height can be measured from the lateral views using Insall-Salvati, Blackburne-Peel, or Caton-Deschamps index [12]. A severe patella Alta may necessitate the combined use of tibial tubercle osteotomy and MOWHTO.

Magnetic resonance imaging (MRI) can be of big help in detecting intraosseous lesions, meniscal tears, ligamentous lesions, osteochondral defects, osteonecrosis, or subchondral edema, cartilage mapping can give us an idea about cartilage erosions and involvement in the medial and lateral compartment [3]. MRI is also appropriate in terms that it shows all the necessary changes in the menisci, cartilage, ligamentous and osseous lesions thus avoiding the role of an invasive arthroscopy evaluation. The majority of the time the MRI is done to assess lateral compartment changes which are not evident on the routine radiological evaluation [3, 13].

3. Planning for Wedge calculation and correction – In normal lower limb alignment axis i.e., the mechanical axis from the center of the hip joint to center of ankle joint centers over the center of knee joint. Restoration of this mechanical axis is of prime importance in corrective osteotomy. The ideal postoperative lower limb alignment is considered as 3°-5° of valgus from the mechanical axis or 8°-10° of anatomical valgus in most studies [6, 7, 14].

Fujisawa et al [4, 15, 16] reported that the postoperative mechanical axis should pass through the lateral one-third of the tibial plateau i.e.,

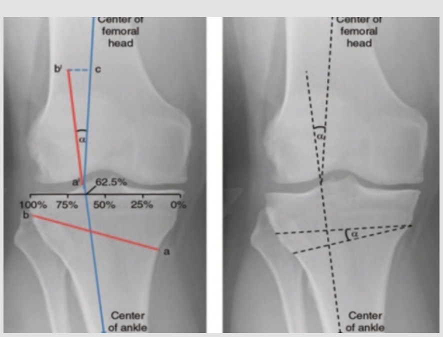

Figure 1: X-ray of Knee joint demonstrating the Fujisawa Point and planning for angle of medial open wedge.

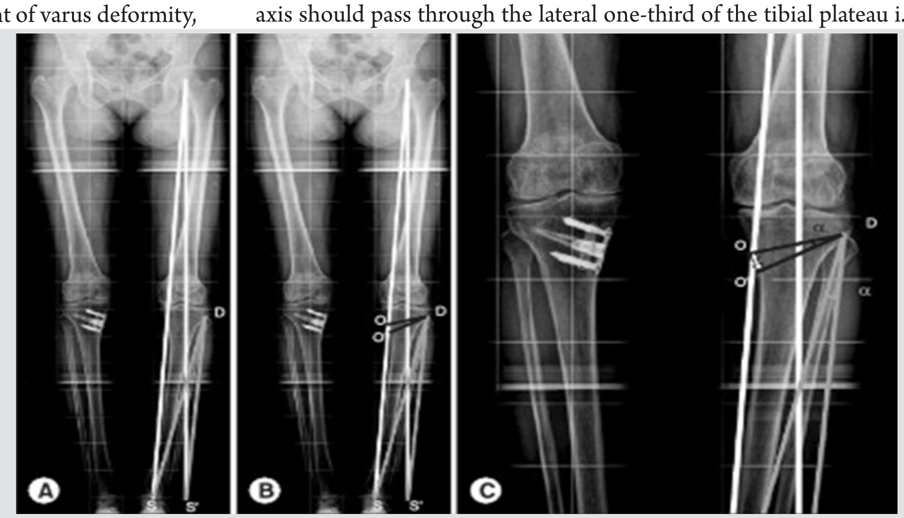

Figure 2: Scanogram of both legs showing calculation of deformity correction angle by Miniaci's Technique, calculation of wedge angle and reciprocating it on the proximal tibia for correction of deformity.

62% of the tibial plateau width (Figure 1). Jakob and Jacobi [4] suggested that correction of the mechanical axis depends on the thickness of the cartilage in the medial compartment: if one-third of the medial cartilage is lost, the mechanical axis should pass 10-15% lateral from the center of the tibial plateau; if two-thirds of the cartilage is lost, the axis should pass 20-25% lateral; and if all is lost, the axis should pass 30-35% lateral [4, 10, 17].

To calculate the wedge angle and deformity correction angle many surgical methods were described, of which Miniaci method was popular using a picture archiving and communication system [18, 19](Figure 2).

(A) On the preoperative anteroposterior full-length lower limb radiograph, the lower limb weight-bearing line (line 1, S) was drawn.

(B) After calculating the 62.5% point from the medial border along the longest medial-to-lateral width of the tibial plateau, an extension line connecting the hip center and the calculated point (line 2, S') was drawn.

(C) Then, a line connecting the lateral tibial osteotomy site and the center of the ankle joint (line 3, DS) was drawn.

(D) Another line connecting the osteotomy site and line 2 (line 4, DS') was drawn. The angle formed by lines 3 and 4 was determined to be the predicted correction angle (B, C).

A predicted osteotomy line (O) was drawn from the proximal extremity of the fibular head to the predicted medial osteotomy site (approximately 4 cm inferior to the medial border of the tibial plateau). A predicted opening line (O') was drawn from Line O at the determined correction angle (wedge angle, α). The predicted correction gap (wedge gap, mm) at the cortical bone of the posteromedial tibia was measured.

After the proper patient selection and adequate pre-op planning, next comes is the execution of the surgical plan and getting the deformity correction done. As a standard rule, it's advisable to do a quick arthroscopic assessment of the knee joint with identifications of meniscus, ligamentous and cartilaginous pathologies associated with medial osteoarthritis of the knee joint [20]. It also gives an insight into the lateral compartment of the knee joint and its cartilage condition. Many of the times HTO has been abandoned in cases where arthroscopy showed significant involvement of the lateral compartment of the knee joint [4, 9]. Higher Outerbridge grades were associated with poor outcomes than lower Outerbridge grades of involvement of lateral compartment during arthroscopy assessment of varus osteoarthritis of the knee joint. This was shown by Heinz et al in

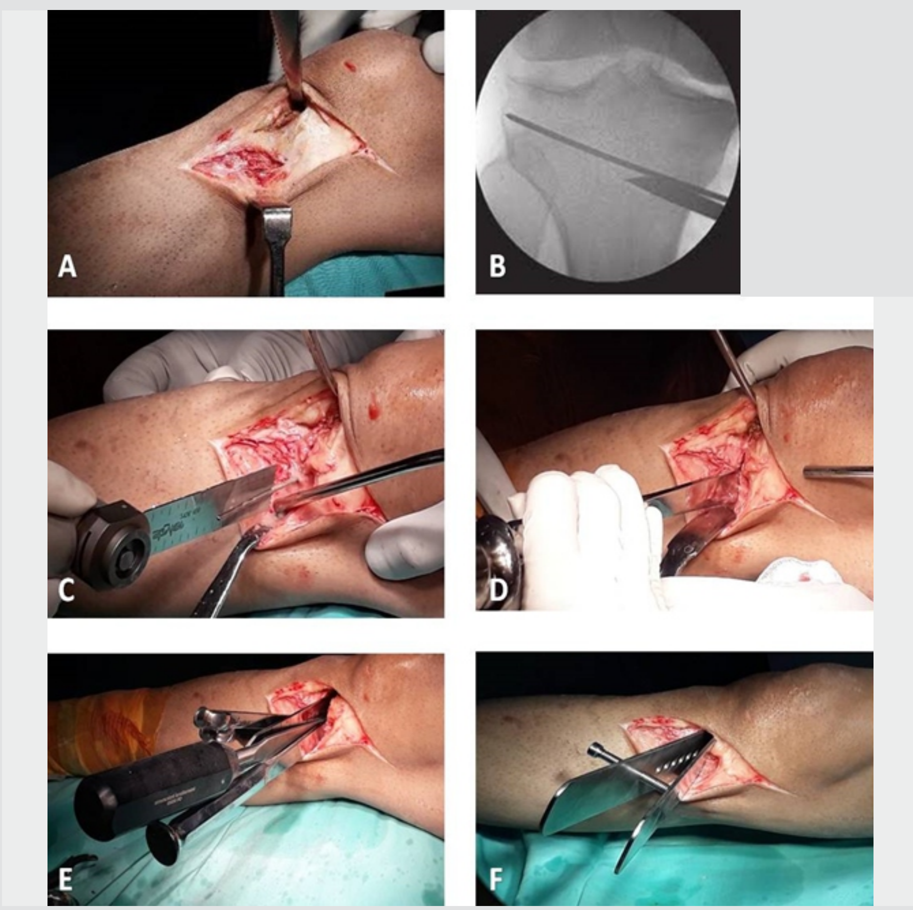

Figure 3: Medial exposure of the proximal tibia, raising the periosteal sleeve and a spike below the patellar tendon to protect it (A). A guidewire is placed exiting above the fibular head starting around 4 cm distal to the joint line, confirmed under c-arm guidance (B). The medial cortex is cut with the oscillating saw (C) and osteotomes are used to complete the osteotomy taking care to keep the lateral hinge intact (D). Multiple stacked osteotomes are then inserted to increase the osteotomy width (E). The osteotomy spreader device is used to keep the osteotomy open and to confirm the desired correction (F). The desired correction wedge base of 14 mm was measured on the medial cortex the further correction was halted. The wedge base was calculated preoperatively using the trigonometric formula.

Figure 4: Scanogram of both legs with right knee healed medial open wedge osteotomy, red line – corrected mechanical axis of right leg.

their articles in 2021 that indication to do MOWHTO should be based on the involvement of lateral compartment on MRI as well as arthroscopy assessment [21].

The surgical technique involves a medial approach to the proximal tibia. With an incision is made between the posteromedial border of the tibia and the medial aspect of the tibial tuberosity, the sartorius fascia is cut and retracted medially to expose the medial collateral ligament (MCL). It is necessary to peel off the MCL from its insertion to unload the medial compartment after osteotomy [1, 6].

Two K-wires are inserted 4 cm below the medial joint line directed toward the safe zone of the lateral cortex of the tibia aiming at the tip of the fibula under fluoroscopy guidance. Once confirmed under fluoroscopy for proper positioning of K-wires (Figure 3), the osteotomy is done below and parallel to the k-wires using an oscillating saw leaving the 10 mm lateral hinge intact. The lateral cortex hinge is kept intact while only two-thirds of the medial and posteromedial cortex is cut. Thin osteotomes are used to gradually open the osteotomy and finally, a calibrated osteotome is used to achieve the desired correction. The base of the wedge depending on the angle of deformity correction is reciprocated intra-operatively. Keeping the spacer osteotomes in place the deformity correction is assessed by using the cautery cord method.

[C] The desired correction of deformity,

Overcorrection and under-correction are reported complications after MOWHTO, hence optimal correction within the standard deviation range is important for excellent surgical outcomes after MOWHTO. Valgus malalignment is cosmetically also unacceptable and leads to overloading of the lateral compartment of the knee joint [4, 17, 22] (Figure 4).

If the over or under-correction is noticed intra-operatively then just adjusting the wedge before fixation helps in achieving the desired angle of correction. Care should be taken to avoid overcorrection, which can be certainly achieved by proper pre-operative planning. Intraoperative assessment about the desired correction is difficult to be done but can be achieved by a cautery test or by an alignment rod test.

Over corrected knees are more difficult to revise to TKR. Valgus deformities need aggressive soft tissues releases while conversion to TKR [8, 14].

[D] To graft or not to graft MOWHTO,

Staubli et al studied bone healing using radiography after HTO without filling the osteotomy gap. They showed that healing starts from the lateral hinge and gradually progresses toward the medial [23]. 3 months are required to see callus formation and ossification after surgery. The new bone fills 75% of the gap 6 months after surgery. Almost 90% of the patients achieve full consolidation on radiography, CT scan, and MRI in one year [23].

Hence many studies show that bone grafting is not necessary. Added advantage of bone grafting or using bone substitutes is that it acts as a scaffold on which the new bone forms and also it avoids the premature collapse of the osteotomy site. Further debates on which graft options to be used were also studied in many papers. Allograft vs bone substitutes is a topic of debate as discussed below.

[E] Graft options for opening wedge osteotomy,

Many surgeons prefer to fill the osteotomy gap with grafts or bone substitutes to enhance stability and accelerate healing. Onodera et al studied 38 patients undergoing MOWHTO using locking plate fixation and ceramic spacers [24]. They found that post-operative alignment and clinical outcome were comparable between hydroxyapatite (HAp) and beta-tri-calcium phosphate (TCP), but TCP was significantly superior for osteoconductivity and bio absorbability after 18 months [24].

Gaasbeek et al evaluated the site of osteotomy during plate removal after MOWHTO using Tomofix fixation and TCP filler. They observed that TCP was completely absorbed, and the new bone got remodeled and incorporated into the native bone [25].

The autogenous iliac bone graft should be considered as a good option in patients who are at risk of nonunion such as smokers and obese patients [17, 22, 26]. Results with autograft were much better with lower complications in comparison with allograft and bone substitutes such as the calcium-phosphate ceramic spacer [27].

[F] Fixation device for MOWHTO,

Once the desired correction is achieved, the next step is the selection of the fixation device. To date, there have been many different types of fixation devices used and are evolving based on the added benefits and disadvantages of the used implants. Right from staples to fixed-angle

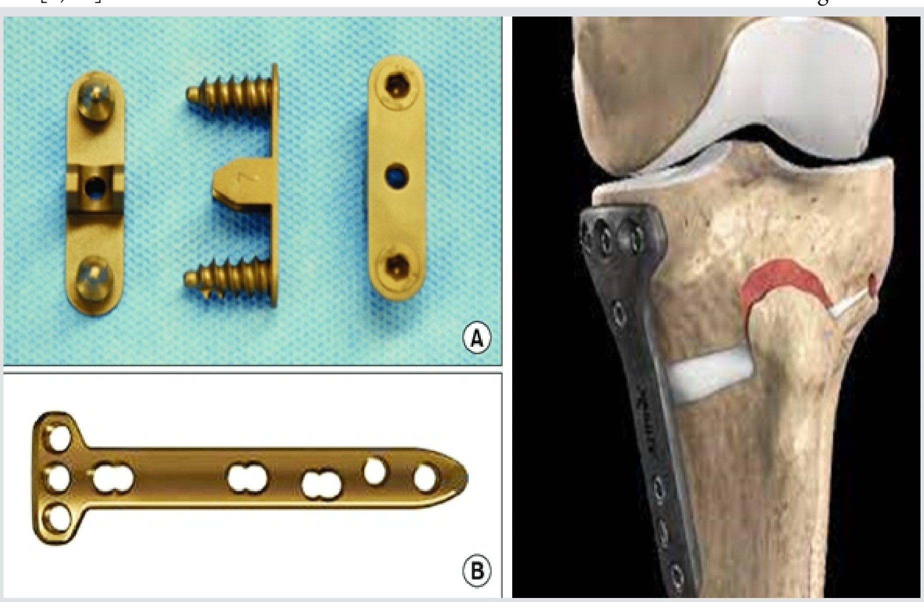

Figure 5: Implants used for fixation of MOWHTO [A] Low profile spacer plates [B] Tomofix & [C] Peek plates.

plates to variable angle plates, locking plates, spacer plates, peek plates have been used and studied in various articles in the literature.

Plate fixation - Spacer plates (i.e., the Puddu plate and Aescula plate) are small, low-profile implants that require small incisions for insertion with less soft tissue damage (Figure 5). However, these plates are less rigid with the possibility of delayed union, nonunion, and failure of fixation leading to the increased posterior tibial slope which necessitates a longer period of non-weight bearing for at least 6 weeks after surgery. These plates also were modified later on to have spacer wedges below to plate to keep the osteotomy open with cortical hold and to prevent collapse [9, 20, 21].

This disadvantage was overcome by the introduction of a more rigid internal fixator in form of a Tomofix plate which worked on the principle of locking compression plate. This allowed early mobilization and weight-bearing. Studies reporting the results of the Spacer plate and Tomofix Plate fixators (i.e., The Tomofix plate) are based on the locking compression plate (LCP) concept which offers an advantage of rigid fixation, which makes it possible to weight-bear early after two weeks, and early start of motion while the normal preoperative PTS is maintained [17, 24]. A minimum of 8 locking bolts are required for a rigid fixation with four proximal and four distal to the osteotomy site. The proximal bone segment is fixed first and a lag screw is then inserted in the first distal hole below the osteotomy, this increases the stability by applying compression on the lateral hinge of the osteotomy. The remaining screws are inserted in the three remaining bolts mostly Unicortical screws [8, 18].

Agnes kirchner et al in their study of the biomechanics of 3 spacer plates with different lengths, two with locking bolts, and one was the Tomofix fixator [28]. The Tomofix plates were superior at single load-to-failure and cyclical load-to-failure tests and had the maximum residual stability after the failure of the lateral cortex. Also, motion at the osteotomy gap was the least with the Tomofix plate. Other studies have shown that the Tomofix plate was superior to the spacer plates in achieving rigid fixation and allowing early weight-bearing [1, 27, 28].

These locked plates were further low-profile locked plates and the most prominent disadvantage of artifacts on MRI after surgery was replaced by PEEK plates. Peek plates had added advantage of being radiolucent, thus without interfering with the radiology assessment in the future [29, 30].

Postoperative rehabilitation protocol mainly depends on the rigidity of the fixation. In terms of fixation with plate fixators, patients are allowed to start partial weight-bearing immediately after surgery depending on the amount of pain and wound healing while full weight-bearing is allowed after 4 weeks. Partial weight-bearing is being allowed at least 6 weeks after surgery as the spacer plates are less stable [1, 6, 31].

[G] Survival rates of MOWHTO

Long-term results of MOWHTO for varus osteoarthritis of the knee are closely accelerated rehab protocol. 10-year survival rates for closed wedge osteotomy were reported from 51% by Kim et al [4] to 93.2% by Koshino et al [32]. The best results by Koshino were related to some post-operation factors including no flexion contracture, valgus anatomical angle of 10°, and concomitant patellofemoral decompression procedure if indicated. Coventry et al also reported a 10-year delay in total knee arthroplasty in 75% of patients if overcorrection to at least 8° of valgus was achieved. Studies on MOWHTO showed a 10-year delay in arthroplasty in 63% of 73 patients, and 85% of 203 patients Longer delay in arthroplasty can be achieved if patients are selected based on TBVA [33].

Schallberger et al [34] followed 54 patients with isolated medial compartment OA for a median of 16.5 years that were treated by either MOWHTO and found 24% conversion to total knee arthroplasty. He showed no significant difference in score outcome and survival between open medial and closed lateral high tibia osteotomy.

With the increasing use of MOWHTO in the treatment of varus osteoarthritis of the knee joint, there was an equal increase in complications following MOWHTO which was reported from about 8% to 55% [17, 22, 26]. Breakage of the lateral cortex, premature collapse before the union, non-union at osteotomy site, implant-related complications, progression of arthritis in the lateral compartment are some of the known complications after MOWHTO. Lateral cortex breakage led to the failure of fixation, and subsequent collapse of the osteotomy, which might result in at least 4° of loss of correction. Giuseppe et al evaluated 100 consecutive MOWHTO with a follow-up of 4 years where they found that allograft combined with platelet-rich plasma and/or demineralized bone matrix increased the risk of nonunion [35].

The rate of second surgery was about 3%. Common adverse events post MOWHTO were more commonly seen in patients with diabetes, those with active smoking, displaced lateral hinge fractures with the intra-articular extension of osteotomy, and patients with failure to comply with the rehab protocol [22, 26, 36].

[H] Comparison between functional outcomes of unicompartmental knee arthroplasty and MOWHTO.

An ideal treatment for osteoarthritis in a single compartment of the knee joint has been always debated. MOWHTO, UKA, and TKA are the known surgical procedures for treating this condition. Pain relief with the restoration of function and improved quality of life are the desired outcomes in this treatment. Mid and long-term follow-up studies show satisfactory outcome and survival rates. Although HTO is preferred modality of treatment in patients of younger age as compared to elderly age where UKA is preferred. There are no statistically significant differences in the treatment outcomes in many studies published in literature. Revision of UKA to TKA is easier as compared to MOWHTO [5, 19, 37]. Faster return to functional activity is seen with patients treated with UKA as compared to HTO [5].

[I] Long term outcomes for MOWHTO

Many previous studies have reported excellent outcomes of MOWHTO, with 5-year survival rates ranging from 71% to 95% and 10-years survival rates ranging from 51% to 98% [6, 31]. Bonasia et al. in 2014 showed excellent outcomes of MOWHTO using Puddu spacer plate with 98.7% survival at 5 years and 75.9% at average follow up of 7 years [38, 39]. Bode et al. in their series in 2013 showed 96%, 5-year survival of OWHTO with the use of TomoFix [40].

The ultimate fate of a patient with HTO is the progression of arthritis in the lateral and medial compartment and the development of pain and stiffness(22,26,37). These patients get converted to total knee replacement surgery. The outcomes of revision of HTO to TKR vary and depend on many factors. This topic is beyond the scope of this article and hence not discussed here(26).

Summary

1. Medial open wedge high tibial osteotomy is a viable solution to address lower limb malalignment with concomitant OA, meniscal deficiency, focal chondral defects, and/or ligamentous instability.
2. A comprehensive history and physical examination, precise patient selection and preoperative planning, using the appropriate fixation technique and rehabilitation protocol could help to achieve a good long-term outcome.
3. Bone grafting with autograft is preferred over bone substitutes for fixation of osteotomy.
4. Newer fixation devices like the locking low profile plates, PEEK plates are commonly used in addition to the TomoFix implants.
5. Locking plates allow early weight bearing and early rehabilitation as compared to non-locking spacer plates.
6. UKR and HTO share similar indications, but MOWHTO is preferred over UKR in younger patients with excellent long term survivorship in well selected patients.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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