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Review Article

Medial Opening Wedge High Tibial Osteotomy: Diagnostic Evaluation and Surgical Technique Overview

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Abstract

Medial opening wedge high tibial osteotomy (MOWHTO) is a knee-preserving surgical option for selected patients with symptomatic medial compartment osteoarthritis (OA) and varus malalignment. Successful outcomes depend on appropriate patient selection, accurate radiographic assessment, individualized correction planning, stable fixation, and careful intraoperative protection of the lateral hinge and posterior neurovascular structures. This educational review summarizes the practical steps in the evaluation and surgical planning of MOWHTO, including clinical assessment, classification of varus deformity, imaging, indications and contraindications, correction target, osteotomy orientation, hinge position, fixation options, bone grafting, drain use, and postoperative considerations. The review also compares MOWHTO with lateral closing wedge high tibial osteotomy (LCWHTO) and discusses areas where evidence remains inconclusive. Rather than proposing a single universal technique, this article emphasizes individualized decision-making based on patient anatomy, severity of OA, ligament status, patellofemoral joint condition, planned correction, and surgeon experience.

Keywords: Osteotomy; Knee; Tibial Fractures

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Background

High tibial osteotomy (HTO) is a standard treatment for patients with osteoarthritis (OA) of the medial compartment of the knee with varus knee malalignment (1). This surgery has been a widely used treatment method since the 1960s (2). It enables orthopedic surgeons to alleviate abnormal knee pressure by adjusting the alignment of the knee angles (3). With subsequent advances in surgical and imaging techniques, HTO has improved patients' quality of life (QoL) (4-6). In addition, with more accurate knowledge and proper training, surgeons can achieve better results during the procedure.

Both medial opening wedge HTO (MOWHTO) and lateral closing wedge HTO (LCWHTO) techniques can provide satisfactory clinical outcomes when appropriate indications and surgical principles are respected. LCWHTO provides direct bone contact at the osteotomy site and may allow reliable bone healing, but it is technically more demanding and may require additional procedures such as fibular osteotomy, with potential risks including peroneal nerve injury (7) and difficulties during later conversion to total knee arthroplasty (TKA). In contrast, MOWHTO is technically reproducible and preserves the proximal tibiofibular joint (PTFJ) and fibula; however, it may be associated with complications such as delayed union, nonunion, lateral hinge fracture, loss of correction, changes in posterior tibial slope (PTS), and patellar height alteration (7-9). No single HTO technique is universally superior. The choice between MOWHTO and LCWHTO should be individualized according to the location and magnitude of deformity, ligamentous status, patellofemoral joint condition, PTS, amount of planned correction, bone quality, future arthroplasty considerations, and the surgeon's familiarity with the technique (7).

Although several reviews have addressed HTO and MOWHTO, a concise step-by-step educational overview focused on practical decision-making may be useful for surgeons involved in knee-preserving procedures. Therefore, this article summarizes the diagnostic evaluation, preoperative planning, surgical technique considerations, and selected perioperative issues relevant to MOWHTO.

Literature Search Approach

This article was designed as an educational narrative review. Relevant English-language articles were identified by searching PubMed, Scopus, and Google Scholar using combinations of the following terms: "high tibial osteotomy", "medial opening wedge high tibial osteotomy", "MOWHTO", "varus knee", "medial compartment osteoarthritis", "osteotomy planning", "lateral hinge fracture", "posterior tibial slope", "biplanar osteotomy", "tourniquet", "bone graft", and "drainage". Priority was given to systematic reviews, randomized or comparative clinical studies, biomechanical studies, technical notes, and recent state-of-the-art reviews. Additional references were identified from the reference lists of relevant articles. Because this was not a systematic review, formal risk-of-bias assessment and meta-analysis were not performed.

Step 1. Patient History and Examinations

The clinical assessment should include age, body mass index (BMI), smoking status, occupation, activity level, sports demand, pain location, walking tolerance, treatment expectations, and response to previous nonoperative management. Physical examination should evaluate varus alignment, gait pattern, varus thrust, range of motion (ROM), flexion contracture, medial and lateral joint-line tenderness, patellofemoral symptoms, ligamentous stability, limb-length discrepancy, ankle or hindfoot deformity, and neurovascular status. Particular attention should be paid to the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and posterolateral corner insufficiency, because untreated instability may compromise the outcome of isolated osteotomy. Prior procedures, including meniscectomy, cartilage surgery, ligament reconstruction, or previous infection, should also be documented (10).

Step 2. Classification of Varus Deformity

Varus deformity should not be assessed only as a coronal-plane bony malalignment. In some patients, varus alignment is accompanied by lateral soft-tissue laxity, lateral joint opening, varus thrust, or posterolateral corner insufficiency. Primary, double, and triple varus phenotypes provide a useful educational framework for understanding the contribution of osseous deformity and soft-tissue instability to the overall limb alignment (11), as shown in figure 1.

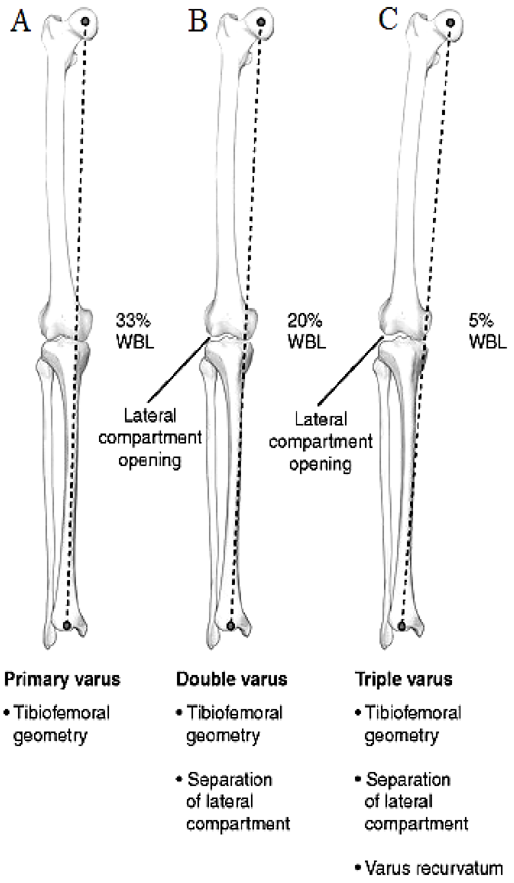

Figure 1. Schematic classification of varus knee deformity into primary (A), double (B), and triple (C) varus phenotypes. Adapted from Noyes et al. (12).

1. Primary varus is mainly caused by constitutional or acquired osseous malalignment of the tibia and/or femur, without major lateral soft-tissue laxity.
2. Double varus combines osseous varus malalignment with lateral compartment opening caused by insufficiency or laxity of the lateral soft-tissue restraints. This pattern should raise concern for associated ligamentous instability and may require stress radiographs or further ligament assessment.
3. Triple varus includes osseous varus, lateral compartment opening, and varus recurvatum, often related to chronic posterolateral ligament insufficiency or previous trauma. In this situation, isolated MOWHTO may be insufficient, and combined ligament reconstruction or staged treatment may be required.

Recognizing these phenotypes is important, because the surgical plan should correct the mechanical axis while also addressing clinically relevant instability when present.

Step 3. Preoperative Radiographic Assessment

Several views should be obtained for preoperative radiographic assessment: a standing lower-extremity hip-knee-ankle (HKA) radiograph, tunnel views with the knee flexed at 30°, Rosenberg views with the knee flexed at 45°, as well as lateral and skyline views (13). The anteroposterior (AP) views can assess the severity of medial OA and bone loss. At the same time, patellar height can be measured from the lateral views using indices such as Insall-Salvati, Blackburne-Peel, or Caton-Deschamps (14).

Step 4. Indications and Contraindications of HTO

Patients with knee OA can choose operative or non-operative treatments. Non-operative options include oral pain relief, shock-absorbing footwear, joint-offloading supports, weight loss, physical therapy, and hydrotherapy. Based on the patient's condition, operational options typically comprise total knee replacement (TKR), unicompartmental knee replacement (UKR), or HTO. The criteria for UKR and HTO are still under discussion. Recent reviews stress that planning should adapt to patients' anatomy and disease severity (15). Recently, joint distraction has emerged as a technique to relieve pressure from the medial compartment, potentially aiding cartilage regeneration (16).

The most important indication for HTO is knee varus with OA in the medial compartment of the knee. In 2005, the International Society of Arthroscopy, Knee Surgery, and Orthopedic Sports Medicine (ISAKOS) established a widely recognized protocol outlining the criteria for ideal, possible, and unsuitable candidates for osteotomy. These criteria consider factors such as age, activity level, and other knee conditions (10) (Table 1).

HTO is generally not recommended for patients over 65 years of age or those with severe medial compartment OA (Ahlback grade III or above), tri-compartmental OA, significant patellofemoral OA, knee flexion less than 90° or flexion contracture greater than 10°, joint instability, lateral tibial thrust of 1 cm or more, or malalignment of 20° or greater (14, 17).

Other relative contraindications include inflammatory arthritis, extensive bipolar full-thickness cartilage loss on the tibial and femoral articular surfaces, and heavy smoking (18-21).

Aiming for the weight-bearing line at approximately 62% lateral (≈3°–5° valgus) optimizes the load shift, thereby reducing pain and correcting malalignment (22).

Step 5. Choice of HTO Technique: MOWHTO vs. LCWHTO

Limited information exists on the long-term results of MOWHTO compared to LCWHTO (23), as shown in figure 2. In patients who do not convert to TKA, there has been no significant difference between MOWHTO and LCWHTO regarding clinical outcomes or radiographic alignment (24-26).

Table 1. Guidelines for the selection of candidates for high tibial osteotomy (HTO) according to the International Society of Arthroscopy, Knee Surgery, and Orthopedic Sports Medicine (ISAKOS)

Ideal	Possible	Not suited
Isolated medial joint pain	Age < 40 or 60-70 years	Obese patients
Age: 40-60 years	Desire to return to all sports	Fixed flexion contracture > 25°
BMI < 30 kg/m2	Flexion contracture < 15°	Bi-compartmental arthritis (medial and lateral), previous lateral meniscectomy
High-demand activity but no running or jumping	Moderate patellofemoral arthritis	
Malalignment < 15°	Anterior cruciate, posterior cruciate, posterolateral corner insufficiency	
Tibial bone varus angle > 5°	Previous infection	
Full range of movement		
Regular lateral and patellofemoral compartments		
IKDC (A), Ahlback I-IV		
Normal ligament balance		
Non-smoker		
Some level of pain tolerance		

BMI: Body mass index; IKDC: International Knee Documentation Committee

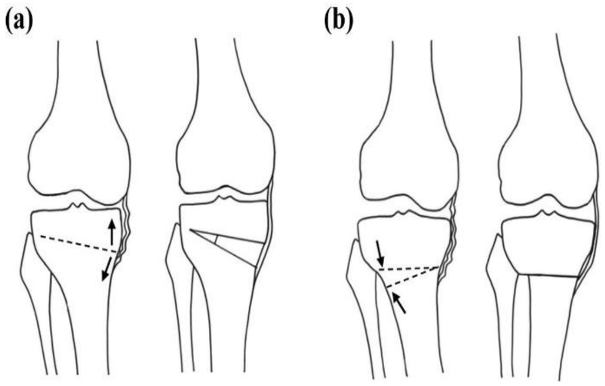

Figure 2. Schematic illustration of (a) medial opening wedge high tibial osteotomy (MOWHTO) and (b) lateral closing wedge high tibial osteotomy (LCWHTO) in a varus knee. Adapted from Liu et al. (27).

MOWHTO was associated with more complications, while LCWHTO had a greater tendency toward early TKA conversion (25, 27) (Table 2).

Table 2. Comparison of the clinical results between medial opening wedge high tibial osteotomy (MOWHTO) and lateral closing wedge high tibial osteotomy (LCWHTO)

MOWHTO	LCWHTO
More complications	More early conversions to total knee arthroplasty within six years
Patella baja associated with patellofemoral pain and poor clinical outcomes	Better satisfaction and score
Reduced knee varus moment and lateral thrust	Little effect on reducing lateral thrust
Higher survival rate	—
Increased posterior slope angle and limb length, decreased patellar height, higher accuracy of correction	Higher incidence of opposite cortical fracture
Increased range of motion, increased posterior tibial slope angle, and decreased patellar height	No significant difference in HKA angle and mean angle of correction
Increased leg length correlated with degree of correction	Negligible decrease in leg length

MOWHTO: Medial opening wedge high tibial osteotomy; LCWHTO: Lateral closing wedge high tibial osteotomy; HKA: Hip-knee-ankle

Retrospective studies of MOWHTO have indicated survival rates (the percentage of procedures not converted to TKA) ranging from 51% to 97.6% after a ten-year follow-up (19, 23, 28-31).

No single technique demonstrates clear superiority; rather, the decision ultimately rests on the individual preferences and experience of the surgeon performing the procedure (7).

Step 6. Uniplanar vs. Biplanar Osteotomy

Choosing between uniplanar and biplanar MOWHTO remains challenging for surgeons, as shown in figure 3.

Existing research fails to provide definitive evidence on the differences in clinical outcomes between the two techniques (32).

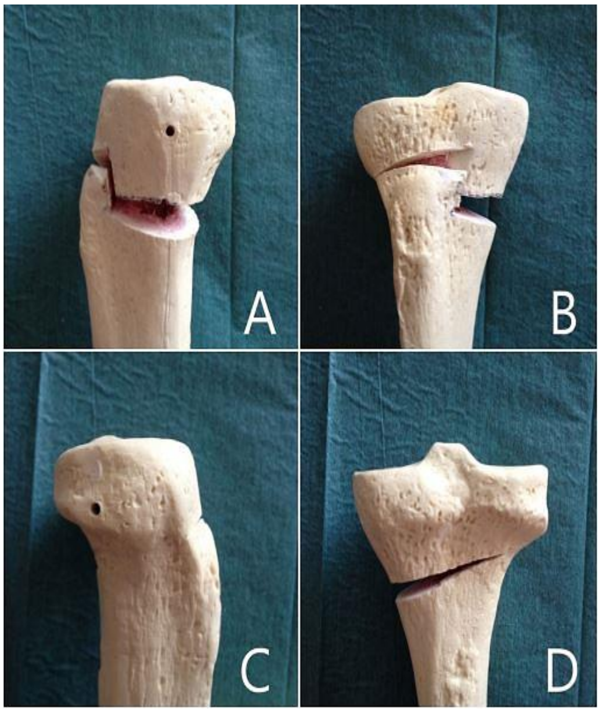

Figure 3. A, B) Uniplane medial opening wedge high tibial osteotomy (MOWHTO); C, D) Biplane MOWHTO. Adapted from Suh et al. (31).

Both biplanar retro-tubercular MOWHTO and uniplanar MOWHTO are clinically effective in treating varus knees. Notably, retro-tubercle osteotomy also demonstrates radiological benefits by preventing patella baja and changes in the tibial slope (33). Biomechanical studies suggest that biplanar MOWHTO offers significant advantages in axial stiffness, particularly under cyclic loading and in terms of increased fracture resistance (34). However, uniplanar MOWHTO exhibits a lesser PTS increase than its biplanar counterpart. Given the potential implications of increased PTS, uniplanar osteotomy is often recommended as it has a lower incidence of lateral hinge fractures than biplanar MOWHTO (32).

Step 7. Tourniquet Use

During HTO, tourniquets are typically used to minimize intraoperative bleeding, improve the surgical field, and potentially reduce blood transfusions. However, their use can lead to ischemia-reperfusion injury, increased oxidative stress, and complications such as nerve palsies, thigh pain, and decreased quadriceps strength (35). In modern MOWHTO, avoiding a tourniquet does not increase total blood loss or complication risks and may enhance postoperative recovery by reducing pain and improving mobility (35-37).

However, other studies show that avoiding a tourniquet does not increase total blood loss and yields less early pain and inflammation (35, 38). Wang et al. found no difference in total blood loss between tourniquet and non-tourniquet HTO, but immediate pain was higher with tourniquet (35). Similarly, Li et al. reported lower postoperative pain scores without a tourniquet (36).

Step 8. Degrees of Correction and Preoperative Planning

An individualized approach to surgical correction has been advocated, adjusting the desired correction point towards a neutral alignment based on the severity of OA at baseline. For individuals with early-stage OA, it is advised to aim for a correction near neutral alignment. Conversely, those with advanced OA might need a correction that leans more towards the lateral compartment, underscoring the necessity for personalized treatment plans (39).

Once the desired correction point is established, the necessary opening gap for this correction can be calculated. Miniaci et al. (39) and Dugdale et al. (11) introduced two techniques for determining the necessary opening wedge which have gained popularity, as shown in figure 4.

Figure 4. Preoperative planning methods for medial opening wedge high tibial osteotomy (MOWHTO): A) Miniaci method; B) Dugdale method. Adapted from Aygün et al. (40) under the Creative Commons Attribution 4.0 International License (CC BY 4.0).

Various user-friendly proprietary software packages incorporate these measurement algorithms, showcasing exceptional inter- and intra-observer reliability. These tools can simulate the osteotomy and the resulting mechanical angles, allowing for the identification of any potential unwanted deformities, such as a medial proximal tibial angle (MPTA) greater than 93°. This foresight enables adjustments to the surgical plan (41).

The joint line congruence angle (JLCA) can also be calculated, and intra-articular corrections can be simulated to prevent overcorrection. Once the opening gap is determined, a gap of 0.7 to 1 mm is necessary. A type I fracture is defined to account for the thickness of the saw blade. Neglecting this adjustment can lead to consistent under-correction of the lower limb (15).

Step 9. Starting Point in MOWHTO

There are two standard starting point techniques for the osteotomy. In the first technique, a distance of 55 mm from the surface of the medial tibial joint is a starting point (42).

The second starting point is the upper border of the pes anserine tendon, which does not use the distance from the joint (29). A review of the literature yielded no randomized clinical trials (RCTs) comparing the clinical outcomes of these two methods; thus, technique selection relies on surgeon preference.

Step 10. Hinge Point in MOWHTO

Unlike LCWHTO, MOWHTO does not necessitate a fibular osteotomy, as the hinge point is ideally above the PTFJ (43). If the hinge is positioned below the PTFJ, the fibula may rotate, leading to a possible fracture and requiring a fibula osteotomy. Besides, if the osteotomy path goes below the PTFJ joint, a fracture of the lateral tibial cortex is possible. To open the proximal fragment without shortening the fibula, the hinge must stay above the PTFJ, which aids in preserving the stability of the MOWHTO procedure (15, 44).

Step 11. Direction of Osteotomy

First, a tangential view of the PTFJ is needed to orient the osteotomy correctly. Two Kirschner wires (K-wires) are inserted into the PTFJ from the specified entry point. The limb is then internally rotated by 50°, and an X-ray is performed to confirm the hinge position and PTFJ connection. The placement of the pins should be arranged so that connecting their intersection with the medial cortex is parallel to the joint surface in the sagittal plane. This ensures that the tibial slope remains unchanged. An osteotomy will be performed under the inserted K-wire (44). Additionally, the surgeon will move the osteotome forward up to 1 cm from the lateral cortex, as advancing further may result in a lateral hinge fracture. The direction of the saw and the osteotome should be angled 10° forward toward the head of the fibula; otherwise, there is a risk of vascular damage.

If the osteotomy is misdirected, three types of fractures may occur. Type I fractures extend from the osteotomy site, either proximal to or within the PTFJ; Type II fractures affect the distal part of the PTFJ; and type III fractures involve the lateral plateau (45).

Step 12. Direction of Biplanar Limb Osteotomy (Ascending vs. Descending)

Biplanar osteotomies of the MOWHTO can be categorized into two techniques: descending and ascending osteotomy, as shown in figure 5.

The choice between these approaches is primarily influenced by the direction of the coronal retro-tubercular cut made during the procedure. Each technique offers distinct advantages and disadvantages, which may impact surgical outcomes and recovery. However, the appropriate indications for choosing one method over the other continue to be a topic of debate among orthopedic specialists (29, 46, 47).

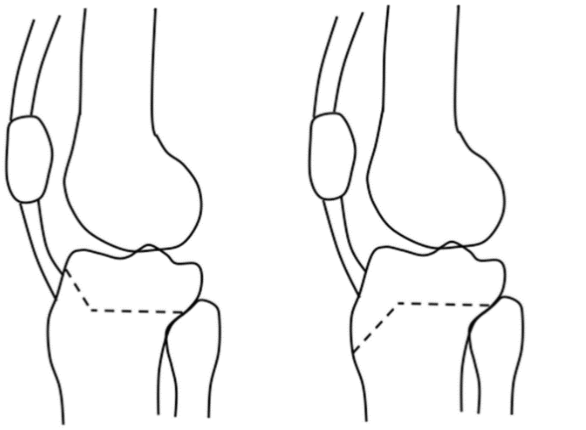

Figure 5. Ascending biplanar osteotomy and tibial tubercle-sparing osteotomy in medial opening wedge high tibial osteotomy (MOWHTO). Adapted from Hopwood et al. (46).

In a descending MOWHTO, the tuberosity remains attached to the proximal tibia. At the same time, in an ascending MOWHTO, it shifts distally and laterally, as it remains attached to the distal tibia at the osteotomy cut (47). The ascending biplanar MOWHTO results in a 2 mm increase in the tibial tubercle-trochlear groove (TT-TG) distance. However, notable reductions in patellar height were also noted, which are linked to the degree of axis correction (5). Using the descending method is better in cases with some patellofemoral maltracking. Descending MOWHTO maintains the postoperative patellar height and is therefore indicated for patients with severe patellofemoral OA (48, 49). In contrast, an ascending cut is needed to improve tracking.

Finally, in the descending method, the surgeon must insert a screw into the tibial tuberosity in an anterior-to-posterior direction to facilitate the active extension of the knee postoperatively (49).

Step 13. Selection of Device after MOWHTO

After a MOWHTO, various plate options are available for fixation, including I-shaped, T-shaped, Puddu, and Tomofix plates. Biomechanical studies indicate that the Tomofix plate outperforms the other three options (27, 50). Additionally, when the plate is positioned medially, it demonstrates better performance compared to when it is placed anteriorly (50). The sequence for placing the screws is indicated on the Tomofix plate (51). Compared to the plate alone, the additional opposite screw from inferolateral to posteromedial direction improves the implant and fixation stability under immediate weight-bearing without causing complications. Moreover, a faster return to sports and work, maintenance of posteromedial reduction, and shorter union time can be noted (52, 53).

Step 14. Bone Graft

There are several methods for augmenting an osteotomy defect, including autogenous bone grafting, allogeneic bone grafting, synthetic material filling, and leaving the defect without filling (54). If the osteotomy defect is less than 10 mm, there is no need for a graft to fill the defect, as there is no significant difference in union rates and subsequent rehabilitation outcomes (55). However, if the osteotomy defect exceeds 10 mm, it should be filled with a graft. Autografts have a higher morbidity rate and longer operation time but present a lower risk of infection and disease transmission. In contrast, allografts carry a higher risk of viral transmission and can irritate surrounding soft tissues (54). The use of synthetic grafts is not recommended, as they have a higher rate of reduction loss and a longer union time compared to autografts (56).

Step 15. Drain Placement

The placement of a drain during HTO is a standard procedure. Some trial studies have utilized drains (33), while others have not (5). A prospective RCT demonstrated that drainage reduces pain, leg swelling, and incidence of incision complications without increasing postoperative blood loss in HTO patients (57).

Conclusion

MOWHTO is a valuable surgical option for patients with varus knee deformities and medial compartment OA. Over the years, advances in surgical techniques and imaging have improved the outcomes of this procedure, enhancing the QoL for many patients. However, the choice of technique, whether MOWHTO or other variants like LCWHTO, depends largely on the surgeon's skill, patient anatomy, and specific correction goals. This review offers a detailed, step-by-step assessment of the procedure, covering key considerations such as patient selection, preoperative planning, and intraoperative decisions. Comparing different osteotomy types, the roles of biplanar versus uniplanar cuts, and managing postoperative complications highlight the complexity and variability involved in HTO. Additionally, techniques for fixation, bone grafting, and drain use are critically examined to achieve the best possible outcomes. Both MOWHTO and LCWHTO have demonstrated effectiveness, but the decision-making process remains individualized, emphasizing the importance of a tailored approach for each patient. As ongoing research advances, further improvements in technique and technology are expected to enhance the long-term success of HTO procedures, offering hope for even better results in the future.

Conflict of Interest

The authors declare no conflict of interest in this study.

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