

POSTERIOR MALLEOLAR FRACTURES

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Abstract—Posterior malleolus fractures are increasingly recognized as a key determinant of ankle stability and long-term functional outcomes. Traditional size-based indications for fixation have been challenged by advances in imaging and biomechanical understanding.

Objective: To provide a comprehensive and critical overview of current concepts in the diagnosis, classification, and treatment of posterior malleolus fractures.

Methods: A narrative review of contemporary literature was conducted, focusing on systematic reviews, biomechanical studies, and clinical outcome analyses.

Results: Evidence supports CT-based morphological assessment over fragment size alone. Direct posterior fixation offers improved articular reduction and syndesmotic stability in selected cases.

Conclusion: Management should be individualized based on fracture morphology, stability, and joint congruency. Anatomical reduction remains the cornerstone of optimal outcomes.

Keywords: posterior malleolus, ankle fracture, syndesmosis, classification, surgical fixation

1. INTRODUCTION

Ankle fractures are among the most common skeletal injuries, accounting for 4% to 9% of all fractures ^{1,2}.

Fractures of the posterior margin, also known as posterior tibial triangle fractures (PTTFs), represent a specific injury pattern occurring in up to 50% of all ankle joint fractures ³⁻⁷. They are also conventionally referred to as "posterior malleolar" fractures. Current consensus indicates that comminution of the posterior tibial rim in ankle fractures is associated with a poorer prognosis ^{1,3,8-12}.

1.1. HISTORICAL BACKGROUND

In 1828, Earle described a fracture of the posterior rim of the distal tibia associated with an ankle fracture-dislocation ^{13,14}.

In contemporary English- and German-language literature, this tibial fragment is also termed as "Volkmann's triangle", although von Volkmann^{15,16} originally described an anterolateral fracture of the distal tibia¹⁷.

Adams described a bimalleolar fracture configuration in 1836¹⁸, followed by Henderson, who introduced the term "trimalleolar fracture" in 1932¹⁹.

The earliest reports of the surgical reconstruction of PTTFs date back to the 1930s^{20,21}.

1.2. ANATOMY, BIOMECHANICS, AND PATHOPHYSIOLOGY OF THE POSTERIOR TIBIAL TRIANGLE

The posterior malleolus of the tibia is a vital structural component of the ankle joint and comprises part of the articular surface of the tibial plafond. This fragment serves as a critical stabilizer of the distal tibiofibular syndesmosis, primarily via the attachment of the posterior inferior tibiofibular ligament (PITFL)²².

The distal end of the tibia (tibial pilon/plafond) features a concave articular surface that transmits axial compressive forces^{23,24}.

The posterior tibial rim is positioned more distally than the anterior rim of the tibia²⁵.

The medial aspect of the posterior malleolus is separated from the medial malleolus by the retromalleolar groove, which accommodates the posterior tibial tendon.

The lateral aspect of the posterior malleolus forms the posterior tibial tubercle and the posterior section of the fibular notch (*incisura fibularis tibiae*). The PITFL consists of a superior oblique component and an inferior transverse component²³. It provides approximately 42% of the overall strength of the tibiofibular syndesmosis²⁶.

Posterior malleolar injuries frequently result from rotational trauma, falls, or sports-related incidents. They commonly accompany fractures of the medial and lateral malleoli, constituting trimalleolar fracture patterns.

Biomechanical investigations demonstrate that even small posterior fragments can significantly compromise joint stability when concurrent ligamentous disruptions are present. Loss of the posterior buttress can precipitate posterior subluxation of the talus and alter load distribution, thereby predisposing the joint to early post-traumatic osteoarthritis.

Most posterior malleolus fractures occur as components of rotational ankle injuries, particularly through supination-external rotation (SER) and pronation-external rotation (PER) mechanisms.

Axial loading combined with rotational forces contributes to:

- posterior shear fractures;
- posterolateral impaction;
- multi-fragmentary involvement of the tibial plafond.

A thorough understanding of the injury mechanism is essential for predicting fracture morphology and identifying associated structural lesions.

1.3. CLINICAL PRESENTATION AND DIAGNOSTIC METHODS

The primary clinical symptoms of PTTFs include pain and swelling localized to the posterior aspect of the ankle, accompanied by an inability to bear weight and, in severe cases, gross joint deformity.

Diagnostic imaging modalities for PTTFs include:

- **Plain radiography:** Used as the initial diagnostic modality. However, standard radiographs are widely recognized to underestimate the actual size and structural complexity of posterior malleolar fractures.
- **Computed tomography (CT):** The gold standard for evaluating fracture size, morphology, and fragmentation. It facilitates precise quantification of fragment displacement, identification of impacted zones, and comprehensive morphological analysis²⁷.
- **Magnetic resonance imaging (MRI):** Recommended when concomitant soft-tissue injuries or related structural damage are suspected.

2. CLASSIFICATION OF PTTFs

An optimal classification system should assist the surgeon in identifying and characterizing the injury pattern, establishing a potential prognosis, and guiding the selection of an appropriate treatment method. Achieving optimal therapeutic outcomes requires the most thorough understanding possible of the fracture morphology²⁷.

Currently, there is no universally accepted international standard for the classification of PTTFs.

Earlier classification paradigms for PTTFs relied primarily on fragment size as the definitive criterion for surgical intervention. However, recent advancements in cross-sectional fracture imaging and modern surgical techniques have shifted the focus toward fracture morphology and the preservation of syndesmotic integrity. Current evidence suggests that fragment morphology best reflects the true nature of the injury and should serve as the foundation for classifying these fractures^{28–31}. Most contemporary PTTF classifications aim to correlate morphological characteristics with specific therapeutic approaches to establish clinical algorithms and prognostic metrics.

In clinical practice, the decision to perform surgical fixation is still frequently based on fracture size evaluated via plain radiographs, which possess insufficient diagnostic value and can lead to misleading clinical decisions^{28,32–37}.

Driven by an improved understanding of PTTF morphology, several CT-based classification systems have been developed in recent years^{28,38,39}.

A recent systematic review analyzing 110 clinical trials involving a total of 12,614 patients with PTTFs demonstrated that four classification systems are most frequently used: fragment-size-based classification ($n = 66$), the Haraguchi classification ($n = 44$), the Bartoníček/Rammelt classification ($n = 21$), and the Mason classification ($n = 12$)²⁷.

The results of this analysis indicated that none of these classification systems had demonstrated clear superiority or achieved universal adoption.

The most widely utilized PTTF classification systems are detailed below:

2.1. AO Classification

The classification system originally published in 1987 by Müller/AO is a universal framework describing all skeletal trauma. It is a time-tested international system that remains relevant and was a staple of clinical practice for decades⁴⁰.

However, with the routine integration of CT scans for the reliable diagnosis and classification of trimalleolar fractures¹⁰, evidence has shown that virtually all these fractures involve the articular surface of the distal tibia^{28,38,41}.

This finding directly contradicts the AO classification according to Heim, which segregates posterior malleolar fractures into extra- and intra-articular variants⁴².

Consequently, the radiograph-based AO classification is poorly suited to evaluating the morphology and severity of posterior malleolar fractures and does not address specific therapeutic strategies for PTTF management^{43,44}.

2.2. Fragment-Size-Based Classification

The fragment-size-based classification of PTTFs is based on the ratio of fragment size to the total articular surface. The historical clinical guideline recommending surgical fixation for fragments exceeding 30% of the joint surface has recently been superseded by recommendations from modern classification systems that prioritize CT-evaluated fragment morphology^{8,27,43,45–50}.

2.3. Haraguchi Classification

Haraguchi et al. developed the first CT-based classification system for PTTFs by analyzing imaging data from 57 patients with posterior triangle fractures²⁸.

This system is based on the principle that fracture pathoanatomy must guide the therapeutic strategy.

According to this framework, PTTFs are divided into three distinct types:

- **Type I:** An oblique posterolateral wedge fragment involving the posterolateral corner of the tibial plafond.
- **Type II:** A fracture line demonstrating medial propagation from the fibular notch to the medial malleolus.
- **Type III:** A small, shell-like fragment involving the posterior rim of the tibial plafond.

Several modifications of the Haraguchi classification have been proposed in the literature. Kumar et al. subdivided Haraguchi Type II into two subtypes: Subtype A (a solitary fracture line extending from the fibular notch of the tibia to the medial malleolus) and Subtype B (a posterior fracture line forming two independent fragments)⁵¹.

Wang et al. proposed an alternative modification of Haraguchi Type II, subdividing the fracture pattern into an anterolateral oblique line (Subtype I) and a small avulsion (Subtype II)⁵².

Palmanovich et al. published a further modification that divides the posterior segment using a midline perpendicular to the bimalleolar line into medial and lateral sub-segments, creating a 4-quadrant grid⁵³. Based on fragment localization, each posterior malleolar fracture is designated as "posterolateral", "posteromedial", or "posterocentral".

Haraguchi Type II PTTFs are clinically associated with the poorest prognosis^{29,54,55}, an elevated risk of developing secondary osteoarthritis⁵⁵, and a relatively greater need for the placement of two syndesmotic screws^{56,57}.

However, several limitations of the Haraguchi classification became apparent following its widespread clinical implementation. Notably, it is not stratified by fracture severity and therefore fails to predict functional outcomes⁵⁸.

Furthermore, because the classification relies entirely on axial CT slices, fractures are evaluated in a single plane; vertical fracture propagation, medial fractures, and the degree of tibial incisura involvement are not assessed, which can lead to misleading conclusions^{27,59}.

Additionally, the majority of multi-fragmentary fractures cannot be adequately defined using the Haraguchi system⁶⁰.

Despite various modification attempts, some authors argue that it lacks the comprehensiveness required to reflect the full spectrum of PTTFs²⁷.

2.4. Bartoníček/Rammelt Classification

Bartoníček and Rammelt introduced an alternative CT-based classification for PTTFs in 2015³⁸. Its development was motivated by the inability of conventional radiographs to accurately evaluate the shape and size of the posterior malleolar fragment or its involvement with the fibular notch and medial malleolus. The protocol requires CT evaluation in the transverse, sagittal, and frontal planes, complemented by 3D reconstructions.

The Bartoníček/Rammelt classification distinguishes five fracture types (illustrated in Figure 1):

- **Type 1:** An extra-incisural fragment with an intact fibular notch.
- **Type 2:** A posterolateral fragment that includes the fibular notch.
- **Type 3:** A posteromedial two-part fragment extending to the medial malleolus.
- **Type 4:** A large posterolateral fragment involving more than one-third of the fibular notch.
- **Type 5:** An irregular osteoporotic fragment.

The Bartoníček/Rammelt classification has distinct advantages over the Haraguchi classification because it accurately reflects fracture severity and provides a direct therapeutic algorithm^{38,57}.

Conversely, limitations of the Bartoníček/Rammelt system include an insufficient definition of Type 5 fractures, which essentially serves as a category of exclusion for patterns that do not fit the four well-defined types. Some authors also note difficulty in distinguishing Type 2 from Type 4 fractures because of the subjective nature of quantifying exactly one-third of the tibial incisura⁵⁹.

According to the systematic review by Terstegen et al., the Bartoníček/Rammelt classification has the greatest potential for standardized adoption in both clinical practice and academic research. This is due to its associated therapeutic algorithm, high reproducibility, and accurate reflection of posterior triangle fracture severity, which increases progressively with the classification number²⁷.

They recommend its routine application in clinical trials investigating the surgical management of PTTFs.

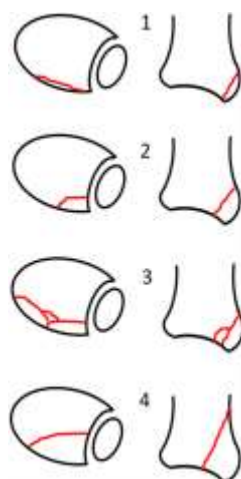


Figure 1. Graphical representation of the CT-based Bartoníček/Rammelt classification—Types 1–4. Type 5 comprises an irregularly shaped osteoporotic fragment that does not fit into any of the preceding categories⁵⁷.

2.5. Mason Classification

In 2017, Mason et al. developed a CT-based PTTF classification that stratifies fracture severity from least to most severe⁴¹.

The authors defined Type 1 as an extra-articular avulsion fracture resulting from rotational forces applied to the foot while the ankle is in plantarflexion and the talus is unweighted. Mason Type 2a fractures result from rotational forces acting on a weight-bearing foot and are characterized by the formation of a primary triangular posterolateral fragment. Type 2b fractures feature a secondary posteromedial fragment, typically oriented at 45 degrees relative to the primary fragment; these occur as the talus continues to rotate within the mortise. Type 3 fractures are characterized by a coronal fracture line spanning the entire posterior plafond and result from axial loading of the talus during plantarflexion (Figure 2).

A modification of the Mason Type 2B fracture has been described by Vosoughi et al., who subdivided it into a large intra-articular plafond fragment and a small extra-articular fragment⁶¹.

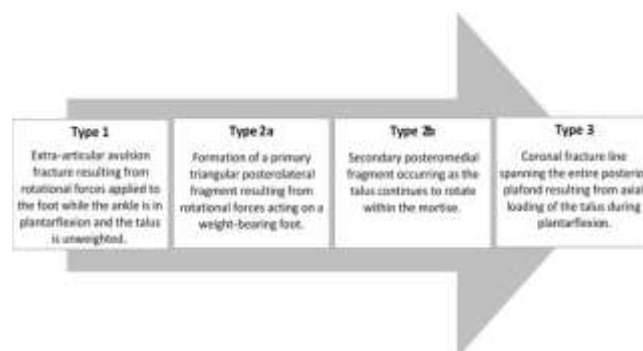


Figure 2. Progression of PTTF severity according to the Mason classification.

2.6. Mason-Molloy Classification

This system categorizes PTTFs into three variants based on distinct fracture characteristics and treatment implications (Table 1)⁶².

Table 1. The Mason-Molloy Classification of PTTFs⁶².

TYPE	DESCRIPTION AND TREATMENT IMPLICATIONS
Type 1	Extra-articular fractures that typically require syndesmotic fixation.
Type 2A	Posterolateral fractures amenable to open reduction and internal fixation (ORIF) via a posterolateral approach.
Type 2B	More complex fractures requiring ORIF via a posteromedial approach or a combination of surgical approaches.
Type 3	Fractures associated with poorer clinical outcomes, requiring ORIF via a posteromedial approach.

2.7. Yearson Classification

Yearson et al. proposed a PTTF classification directly linked to a treatment algorithm tailored to each fracture morphology. The authors assert that this direct correlation with the therapeutic approach facilitates accurate clinical interpretation and decision-making regarding the need for a posterior surgical approach. It prioritizes anatomical reduction of the articular fragment and resolution of syndesmotic instability using the simplest and most effective method. Each bone fracture configuration, shape, and direction is linked to a designated surgical approach, an optimal mode of osteosynthesis, and a reproducible model for stabilizing syndesmotic instability⁶³ (Figure 3).

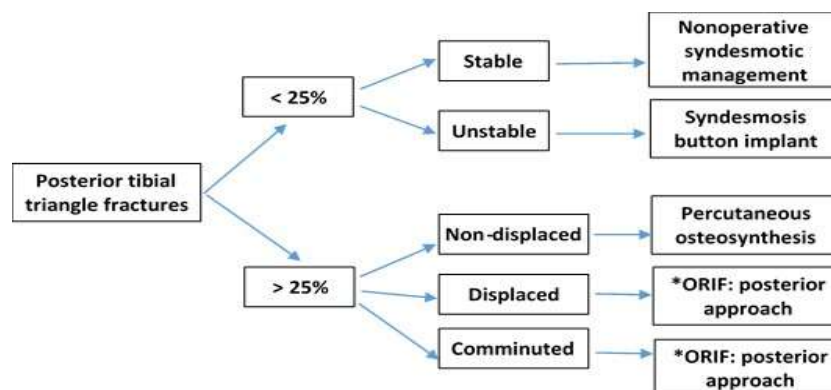


Figure 3. The Yearson classification of PTTFs (adapted)⁶³. *ORIF – Open Reduction and Internal Fixation

3. THERAPEUTIC APPROACH

Epidemiological data indicate that posterior malleolar fractures are present in 7% to 44% of all ankle fracture cases and are commonly associated with a poorer prognosis³.

Historically, underestimation of the relationship between these two fracture entities delayed the rigorous study, classification, and systematic evaluation of PTTF outcomes.

However, the therapeutic paradigm for PTTFs has undergone substantial evolution over the past decade.

Initially, PTTFs were underappreciated, and surgical intervention was rarely pursued¹³. Currently, it is accepted that nondisplaced or small fragments can be managed conservatively with immobilization followed by rehabilitation. Conversely, when unstable concurrent fractures and syndesmotic instability are present, the prognosis is significantly worse without surgical intervention⁴⁶.

The earliest invasive approach introduced into clinical practice was anterior-to-posterior compressive lag-screw osteosynthesis⁶⁴, which used indirect reduction without exposing the fracture site. Only within the last decade has surgical practice shifted toward direct posterior visualization, establishing open reduction and internal fixation as the preferred technique. The favorable initial outcomes associated with this approach led to the widespread adoption of posterior reduction for virtually all posterior malleolar fractures, occasionally without objective parameters to individualize the intervention. Ultimately, placing patients in the prone position and using an additional surgical exposure must be clinically justified to ensure a tangible benefit rather than introduce additional surgical trauma⁶³.

Initial radiographic evaluation must include anteroposterior (AP), mortise (20° internal rotation), and lateral projections of the injured ankle. Posterior malleolar fractures are generally best visualized on the lateral view. On the AP view, a double contour of the medial malleolus (the "wagtail fragment" or "spur sign") indicates a posterior malleolar fracture with medial extension^{65,66}.

Multiple studies have demonstrated that the true size and three-dimensional morphology of posterior malleolar fragments cannot be reliably quantified via plain radiographs alone^{28,35–39,67}.

To obtain clinically relevant data for treatment selection, a CT scan is mandatory whenever a posterior malleolar fracture is suspected^{41,68,69}.

Following documented poor outcomes from the nonoperative management of large posterior malleolar fractures^{70,71}, the threshold for surgical fixation remained set at 25% to 33% of the articular surface, coupled with displacement of ≥ 2 mm on lateral radiographs, for several decades^{71–75}.

With modern investigations into three-dimensional morphology, parameters beyond size and displacement—specifically incisural involvement, intercalary fragments, tibial plafond impaction, and syndesmotic instability—have increasingly guided therapeutic decision-making^{28,38,39,41,68,76–79}.

Consequently, the definitive goals of surgical fixation can be refined and summarized as follows^{28,61,65,77,80}.

1. Restoration of articular congruity across the posterior tibial plafond and posterior talar surface.
2. Bone-to-bone restoration of the PITFL to re-establish syndesmotic stability³ and restoration of the native anatomy and integrity of the fibular notch to facilitate accurate reduction of the distal fibula.

Based on these biomechanical tenets and CT-derived 3D characteristics, established treatment recommendations are summarized in Table 2^{28,38,39,41,67,77,80}.

Table 2. Treatment recommendations for PTTF management.

CLASSIFICATION SYSTEM	SUBTYPES / STRATIFICATION	THERAPEUTIC APPROACH
Haraguchi	Stratified by size and displacement	Dependent on specific fracture characteristics
Bartoniček/Rammelt	Types 1–5 based on fragment characteristics	Surgical modality selected based on type
Mason and Molloy	Type 1, Type 2A, Type 2B, Type 3	Ranges from isolated syndesmotic fixation to formal ORIF
Yearson	Type 1 (with subtypes), Type 2	Operative vs. nonoperative based on fragment size

Nonoperative treatment is indicated for Bartoniček/Rammelt Type 1 (extra-incisural) fractures and nondisplaced Type 2 and Type 3 fractures. Open reduction and direct internal fixation are the treatments of choice for displaced Type 2 and Type 3 fractures, particularly those featuring intercalary fragments or partial articular impaction. All Type 4 fractures (large triangular variants) routinely warrant open reduction with direct or indirect internal fixation to restore overall ankle stability. Even in the absence of initial displacement, primary ("joint first") fixation should be performed in the presence of concurrent spiral distal tibial shaft fractures to prevent secondary displacement during subsequent intramedullary nailing^{81–84}.

As a general rule, isolated, nondisplaced posterior malleolar fractures are managed nonoperatively, provided that occult syndesmotic instability has been definitively ruled out^{13,61,85,86}.

Beyond the specific pathoanatomy of the posterior malleolus fracture, individual treatment selection depends on the global ankle injury pattern—namely, the morphology of the fibular fracture, concomitant damage to anterior and medial structures, and the patient's overall physiological status^{23,87}.

4. SURGICAL TECHNIQUES

4.1. Posterior Approaches

Data indicate that a direct posterior approach (either posterolateral or posteromedial) optimizes fracture visualization, facilitates anatomical reduction, and ensures stable fixation with screws or buttress plates.

4.2. Indirect Fixation

Anterior-to-posterior screw fixation remains an acceptable alternative technique but carries distinct limitations, which include:

- Reduced intraoperative control over the quality of reduction.
- An inherent risk of incomplete or malaligned reduction.

4.3. Syndesmotic Stabilization

Rigid fixation of the posterior malleolar fragment frequently restores syndesmotic stability, potentially rendering trans-syndesmotic screws unnecessary.

5. COMPLICATIONS AND PROGNOSIS

Overall functional outcomes for ankle fractures involving the posterior malleolus are historically inferior to those of uni- or bimalleolar injuries, primarily due to compromised articular congruity and persistent instability.

Failure to achieve anatomical reduction leads to common complications, including:

- Post-traumatic osteoarthritis.
- Restricted mobility and diminished range of motion (ROM).
- Chronic pain and mechanical instability.

Properly performed surgical fixation combined with structured rehabilitation significantly improves long-term outcomes, particularly in the presence of large or displaced fragments⁸⁸.

Clinical success is heavily dependent on the precision of reduction, successful restoration of articular congruity, and stability of the final fixation construct.

Evidence confirms that inadequate reduction of the posterior fragment directly correlates with inferior long-term functional outcomes^{23,27,41}.

6. CONCLUSION

Posterior malleolus fractures represent a critical component of complex ankle injuries and must not be underestimated. They frequently occur in combination with other ankle injuries and require precise CT diagnosis, individualized treatment strategies, and tailored rehabilitation. Anatomical reduction and stable surgical fixation can result in improved functional outcomes and a lower risk of post-traumatic complications.

Contemporary clinical management requires:

- Routine utilization of preoperative computed tomography.
- Classification frameworks based on fracture morphology.
- An individualized surgical strategy.

Currently, the selection of the surgical approach is individualized and based on CT fracture morphology. Achieving anatomical reduction and stable fixation remains the cornerstone of long-term therapeutic success.

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