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Review Article

Posterior Malleolar Fractures: Reappraising Fixation Thresholds and Functional Outcomes- A Narrative Review

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Abstract

Posterior malleolar fractures have been regarded as secondary parts of rotational ankle injuries and treatment decisions have been based mainly on the size of the posterior tibial fragment. Fixation was recommended for many years as only indicated when more than 25-30% of the tibial plafond was involved. This threshold is commonly used, but it was derived from early radiographic studies and was set before computed tomography (CT) became a routine tool. More recent evidence has challenged this traditional paradigm, showing that fragment morphology, syndesmotic integrity, articular congruity and fracture stability may be more clinically relevant than fragment size alone. Classification systems based on CT have improved the understanding of posterior malleolar fracture patterns and have facilitated more individualised surgical decision making. Furthermore, biomechanical and clinical studies have demonstrated the key role of the posterior malleolus in syndesmotic stability. Anatomical reduction and stable fixation may restore ankle biomechanics more effectively in some patients than isolated fixation with syndesmotic screws. This narrative review critically assesses the evolution of posterior malleolar fracture management, focusing on fixation thresholds, fracture morphology, operative techniques and functional outcomes. The review also deals with the current evidence on surgical approaches, fixation techniques, postoperative outcomes and the remaining controversies. The review merges anatomical principles and modern clinical evidence to suggest a shift in indications from fragment size to morphology-driven and stability-oriented treatment algorithms.

Keywords: *Posterior malleolus; Ankle fracture; Syndesmosis; Computed tomography; Internal fixation; Functional outcome.*

Introduction

Ankle fractures are one of the most common injuries in orthopaedic trauma practice and remain a significant source of disability in all age groups. Injuries to the posterior malleolus are drawing more attention because of their impact on ankle stability, syndesmotic competence and long-term joint function, though the medial and lateral malleoli have traditionally received more attention [1,2].

The posterior malleolus constitutes the posterior border of the distal tibia and is a major part of the tibiotalar joint. In addition to contributing to the articular surface, it also provides the attachment site for the posterior inferior tibiofibular ligament (PITFL), one of the strongest stabilisers of the distal tibiofibular syndesmosis. Therefore, fractures involving this region affect not only the congruency of the ankle joint, but also the stability of the syndesmotic complex and their management is much more complex than previously appreciated [4,7].

Previously, the treatment recommendations were quite clear-cut. Since the late 1980s, fixation of the posterior malleolus has generally been reserved for fractures involving greater than one quarter to one third of the tibial plafond [1,2]. This recommendation became firmly entrenched in orthopaedic teaching and remained so for several decades. However, these early studies were based almost exclusively on plain radiographs which are now known to underestimate both fracture size and fracture morphology. More importantly, they could not properly evaluate the associated injuries to incisura, fibular notch or syndesmotic complex [2,5].

The understanding of posterior malleolar fractures has been revolutionised by the widespread use of computed tomography. Haraguchi et al. showed that these fractures have unique morphological patterns, and are not simple posterior rim avulsions [5]. Then Bartoníček and co-workers expanded this concept by developing a CT-based classification system that included fracture morphology, involvement of the fibular notch and the planned surgical approach [12,13]. These advances underscored that fragment configuration, fracture orientation and syndesmotic involvement frequently have a greater impact on ankle biomechanics than fragment size alone.

At the same time, progress in biomechanics challenged the traditional fixation threshold. Experimental studies have shown that in selected fracture patterns, anatomical fixation of the posterior malleolus restores syndesmotic stability better than trans-syndesmotic screw fixation [4,7]. Similarly, clinical studies have demonstrated improved reduction quality and lower rates of syndesmotic malreduction and improved functional outcome after direct posterior fixation, even when the posterior fragment was less than 25% of the articular surface [7,14,17]. These findings have slowly changed contemporary practice to a morphology based decision making rather than an arbitrary percentage of articular involvement.

These advances do not end important controversies. There is still controversy about the correct indications for fixation of small posterior fragments, the best surgical approach, the choice between direct buttress plating and anteroposterior screw fixation, and the relationship between anatomic reduction and long-term functional outcome. In addition, considerable heterogeneity has been reported among published studies [14,17] due to differences in fracture classification, outcome measures and follow-up periods.

There is a need to challenge the available evidence in the light of modern imaging, better understanding of ankle biomechanics and modern surgical techniques rather than accept historical treatment algorithms at face value. This appraisal is particularly relevant as mal-reduction of the syndesmosis can lead to persistent syndesmotic instability, post-traumatic arthritis and suboptimal functional outcome despite satisfactory fracture healing.

Thus, the aim of this narrative review is to critically appraise the evolution in the management of posterior malleolar fractures, to review the evidence for current thresholds for fixation and to discuss their effect on functional outcome. Importantly, the transition from size-based indications to CT-guided, morphology-based surgical decision-making more accurately reflects contemporary orthopaedic practice.

Materials and Methods

This narrative review was conducted using the Scale for the Assessment of Narrative Review Articles (SANRA) to ensure methodological rigour, transparency and critical interpretation of the evidence available. The goal of this review was not a quantitative synthesis as in systematic reviews but a comprehensive appraisal of the evolving concepts on posterior malleolar fractures with a focus on fixation thresholds, fracture morphology and functional outcomes.

A structured literature search was performed in PubMed/MEDLINE, the primary database. The reference lists of key publications and recent review articles were also searched for additional relevant articles. The search strategy included Medical Subject Headings (MeSH) and free-text key words including: posterior malleolar fracture, posterior tibial fragment, ankle fracture, syndesmotic injury, posterior malleolus fixation, computed tomography, functional outcome, posterolateral approach and ankle biomechanics. Initially, we searched for articles published between 1989-2023 that describe the transition from classical treatment algorithms based on fragment size to present CT-guided management approaches.

Preference was given to original clinical studies, biomechanical investigations, anatomical studies, systematic reviews and critical reviews published in peer-reviewed, PubMed-indexed journals.

For historic context, the traditional fixation thresholds were determined in Classical studies, and more recent investigations were chosen to illustrate the trend to treatment principles based on morphology. We excluded articles in languages other than English, conference abstracts lacking full manuscripts, expert opinion without supporting evidence and duplicate publications.

Finally, 20 key publications were selected based on scientific quality, historical significance and relevance to the objectives of this review. Particular attention was paid to studies evaluating fracture morphology, CT-based classification systems, syndesmotic stability, indications for surgery, fixation techniques, and postoperative functional outcome. Instead of a chronological account of the available evidence, the literature was critically synthesised for areas of consensus, evolving concepts and persistent controversies within contemporary orthopaedic practice.

Evolution of Posterior Malleolar Fracture Management

One of the major paradigm shifts in modern foot and ankle surgery has been the management of posterior malleolar fractures. Few fracture patterns have seen such a dramatic shift from simple radiographic measurements to complex morphology-driven surgical decision making. Today's surgeons rely much more on CT imaging and knowledge of ankle biomechanics. This, however, has been an evolution with better imaging, anatomic understanding and clinical outcome research.

The posteromalleolar region has been relatively neglected in the past. The treatment concepts were aimed mainly at restoring the length of the fibula and stabilising the medial malleolus. The posterior fragment was generally considered a minor injury and was only fixed if it constituted a significant part of the tibial plafond. This philosophy was largely based on the work of Jaskulka et al. who postulated that larger posterior fragments were associated with poorer functional outcomes and therefore required surgical stabilisation [1]. While a major advance at the time, the assessment of fractures was almost entirely based on plain radiographs that were unable to accurately define the fracture morphology or syndesmotic involvement.

Further clinical investigations in the 1990s and early 2000s provided more support for the idea that treatment was determined by fragment size. Langenhuijsen et al. reported better results after anatomical reduction of large posterior fragments, and De Vries et al. reported the correlation of residual displacement with the development of post-traumatic arthritis [2,3]. These studies also helped establish the current rule of 25-30% articular involvement that was subsequently incorporated into orthopaedic texts and teaching of surgery. Although commonly accepted, the threshold was based on relatively limited radiographic evidence, and did not take into consideration fracture configuration, ligamentous attachments, or syndesmotic stability.

The introduction of computerised tomography was a fundamental change to this view. CT showed considerable variation in fracture morphology, fragment orientation and involvement of the fibular incisura rather than simple posterior rim fractures. Haraguchi et al. showed three reproducible fracture patterns and demonstrated that many posterior malleolar fractures extended beyond the posterior articular margin, challenging the simplistic concept of fragment size alone [5]. This observation was a game changer because it suggested that fractures with similar percentages of articular involvement could behave very differently biomechanically and could have very different surgical needs.

These observations led Bartoníček et al. to propose a CT classification that incorporates fracture morphology, the presence of a fibular notch, and the intended surgical approach [12,13]. Their work changed the direction from estimation of fragment size on lateral radiographs to understanding of the anatomical features of individual fracture patterns . Importantly, this classification also recognised that fibular incisura fractures could significantly compromise syndesmotic stability, even when the posterior fragment appeared relatively small.

Around the same time biomechanical studies gave further evidence that was against the standard treatment algorithms. Gardner et al. [4] demonstrated in cadaver models that anatomic fixation of the posterior malleolus resulted in better restoration of syndesmotic stability as compared to isolated syndesmotic screw fixation. Subsequently, Miller et al. reported similar findings, demonstrating that fixation of the posterior fragment could provide stability comparable to trans-syndesmotic screw fixation and restore the native ligamentous attachments [7]. These studies turned the attention from the osseous fragment per se to the functional role of the distal tibiofibular complex.

Advances in CT imaging, biomechanical understanding and clinical outcome research have changed the face of modern surgical practice. The emphasis has changed from an arbitrary percentage of articular involvement to achieving articular congruity, preserving the integrity of the fibular incisura and maintaining syndesmotic stability. Thus, many surgeons now recommend fixation of selected posterior fragments <25% of the articular surface when CT shows instability, displacement, or involvement of critical anatomic structures [13,17].

Table 1 presents the evolution of treatment concepts over the last 4 decades. The table shows the shift from radiograph-based fragment size assessment to the current CT-guided, morphology-driven management strategies.

Table 1. Evolution of posterior malleolar fracture management.

Period	Predominant concept	Imaging modality	Primary indication for fixation	Major limitations
1980s	Large fragments associated with poorer outcomes	Plain radiographs	Fragment >25-30% of tibial plafond	Underestimation of fracture morphology
1990s-Early 2000s	Articular reduction emphasised	Plain radiographs	Fragment size and displacement	Syndesmotic injury poorly appreciated
2006-2014	CT reveals distinct fracture patterns	CT scan	Morphology increasingly recognised	No universal classification
2015-Present	CT morphology and biomechanics guide treatment	CT ± 3D reconstruction	Syndesmotic stability, incisura involvement, articular congruity and fracture configuration	Optimal fixation indications for small fragments remain debated

Anatomy and Biomechanics of the Posterior Malleolus

The posterior distal tibia has a unique anatomic and biomechanical role and without an appreciation of this role, one cannot fully appreciate the management of posterior malleolar fractures. The posterior malleolus was historically considered to be the posterior lip of the tibial plafond. Current anatomical and biomechanical research, however, has shown that it is an important stabilising structure contributing to articular congruity, syndesmotic integrity and normal ankle kinematics. This indicates that injury to the posterior malleolus has a far greater impact than merely the articular surface [4,5,12].

The posterior malleolus is the posterior lip of the distal tibia and constitutes approximately one third of the tibial plafond. While the exact measurements vary from individual to individual, it is important not only for its contribution to the weight bearing articular surface but also as the point of attachment for several important ligamentous structures. The posterior inferior tibiofibular ligament (PITFL) is one of the most important. This ligament attaches to the posterior distal tibia and inserts onto the posterior aspect of the fibula and is one of the strongest stabilising components of the distal tibiofibular syndesmosis [4,13].

Unlike the anterior syndesmotic ligaments, the PITFL is a significant contributor to resisting posterior translation and external rotational displacement of the fibula. Experimental studies have shown that the PITFL contributes approximately 50% of the syndesmotic stability with physiologic loading. Therefore, posterior malleolar avulsion often is a bony avulsion of the intact PITFL, rather than an isolated bony injury. This observation has major surgical implications as the anatomical reduction of the posterior fragment restores simultaneously the native attachment of the ligament without the need of a direct ligament repair [4,7].

Another important anatomic consideration is the fibular incisura, which is the distal tibiofibular articulation. Posterior malleolar fractures extending into the incisura, although involving only a relatively small proportion of the tibial plafond, can have a significant effect on syndesmotic congruity. As a result, such injuries may cause rotational instability in excess of the apparent size of the fragment on conventional radiographs. This explains the occurrence of persistent syndesmotic instability in some patients with fragments < 25% of the articular surface treated non-operatively [12,13].

The posterior malleolus also contributes to the congruity of the tibiotalar articulation. Small residual step-offs may alter the contact mechanics in the ankle joint. Biomechanical studies have demonstrated an increase in maximum contact pressures and a decrease in the effective contact area of the tibiotalar joint with displacement of the posterior fragment. These changes are thought to promote progressive cartilage degeneration and the development of post-traumatic osteoarthritis [3,10].

The mechanism of injury further influences the morphology and biomechanical behaviour of the fracture. In external rotation injuries, shear forces are generated along the posterior tibial plafond, and the PITFL is put under tension due to posterior talar displacement. Depending on the magnitude and direction of the applied force, failure may occur by ligament rupture, bony avulsion or a combination of both mechanisms. Posterior malleolar fractures have a wide range of fragment size, orientation and associated syndesmotic disruption. This explains why fractures with similar radiographic appearances can have markedly different patterns on CT imaging [5,11].

Biomechanically, the posterior malleolus has developed from a simple articular fragment to a functional stabiliser. Gardner et al demonstrated in a cadaveric model that fixation of the posterior fragment was superior to isolated syndesmotic screw fixation in restoring syndesmotic stability [4]. Later, similar results were reported by Miller et al, who found that the anatomical reduction of the posterior fragment restored the ligament tension by restoring the native PITFL insertion and achieved stability comparable with trans-syndesmotic screw fixation [7]. These observations challenged the standard treatment algorithms by demonstrating that fixation decisions should be made on the basis of ligamentous function in addition to fragment size.

These biomechanical observations are more and more confirmed by clinical studies. Anatomical restoration of the posterior fragment has been associated with better maintenance of the position of the fibula, more accurate reduction of the syndesmosis, and lower rates of postoperative malreduction. Conversely, an insufficient reduction of the posterior malleolus may result in a persistent incongruity of the fibular incisura, even if the fibula and medial malleolus have been fixed in a satisfactory manner. Such residual malalignment has been associated with chronic pain, restricted ankle motion, and early degenerative change [13,16].

Also, the role of posterior malleolus in load transmission has gained more and more attention. In normal gait, forces through the ankle are evenly distributed across the tibial plafond. Loss of posterior articular support can shift these forces anteriorly resulting in focal increases in cartilage stress The size of the fragment is undoubtedly a factor in this phenomenon. However, recent evidence has shown that the quality of the anatomic reduction is more important than the fragment size alone . The restoration of joint congruity appears to be more important to the long-term functional outcome than the percentage of articular involvement [3,14].

The main anatomical structures attached to the posterior malleolus and their biomechanical importance are listed in Table 2. Understanding these relationships explains the rationale for the recent evolution of fixation strategies toward syndesmotic anatomical reduction rather than the sole use of fragment size.

Table 2. Anatomical structures attached to the posterior malleolus and their biomechanical significance.

Structure	Anatomical attachment	Biomechanical function	Clinical relevance
Posterior inferior tibiofibular ligament (PITFL)	Posterior distal tibia to posterior fibula	Primary stabiliser of the distal tibiofibular syndesmosis; resists posterior translation and external rotation of the fibula	Anatomical reduction of the posterior fragment restores native ligament tension and syndesmotic stability [4,7]

Table 2. Continued...

Fibular incisura	Posterolateral distal tibia	Maintains congruent articulation between tibia and fibula	Involvement may lead to syndesmotic malreduction even with small fracture fragments [12,13]
Posterior tibial plafond	Posterior one-third of distal tibial articular surface	Contributes to tibiotalar load transmission and joint congruity	Residual step-off increases contact pressure and predisposes to post-traumatic osteoarthritis [3,10]
Posterior ankle capsule	Posterior distal tibia	Secondary restraint to posterior talar translation	Capsular injury may contribute to postoperative stiffness and instability
Posterior malleolar fragment	Bony insertion of the PITFL and posterior plafond	Restores articular congruity and ligamentous stability when anatomically reduced	Fixation influences both joint mechanics and syndesmotic reduction [4,13,17]

CT-Based Classification Systems of Posterior Malleolar Fractures

One of the most important advances in the management of posterior malleolar fractures has been the widespread use of computed tomography (CT). Conventional radiographs are still the first step in the assessment of ankle fractures, but often underestimate the size, orientation and complexity of posterior tibial fragments. Plain radiographs also give little information about involvement of the fibular incisura, articular comminution and associated osteochondral injury. These limitations played a significant role in the historical reliance on fragment-size thresholds, as treatment decisions were made based on incomplete visualisation of the fracture anatomy [2,5].

CT imaging has revolutionised this understanding. CT allows multiplanar visualisation of the distal tibia and accurate assessment of fragment morphology, displacement, comminution and syndesmotic involvement. More importantly, CT has shown that posterior malleolar fractures are not a homogeneous group of injuries but rather a spectrum of different fracture configurations with different biomechanical implications and surgical requirements [5,12].

Posterior malleolar fractures were first systematically classified by CT imaging by Haraguchi et al. In their seminal study, they defined three reproducible fracture patterns based on the orientation and location of the posterior fragment [5]. Type I fractures with posterolateral oblique fragment are the most common pattern of injury. The attachment of the posterior inferior tibiofibular ligament is often involved in these fractures and they are frequently seen with rotational ankle injuries. Type II fractures extend medially and involve more of the posterior plafond. Type III fractures are made up of small shell-like avulsion fragments from the posterior lip of the tibia. This classification showed that fractures that looked similar on radiographic appearance could show large differences in morphology and mechanism of injury.

The Haraguchi classification was an important conceptual advance but was not a guide to operative management. The classification was based mainly on the fracture morphology and not on the degree of articular involvement, extension into the fibular notch or the expected fixation strategy. Anatomical knowledge was increasing, but this had little direct bearing on the planning of surgery.

Understanding these limitations, Bartoníček et al. developed a more comprehensive classification system based on CT, which integrated anatomical morphology with clinical decision making [12,13]. Their classification divides posterior malleolar fractures into five major types according to the degree of posterior tibial involvement, involvement of the fibular incisura, and complexity of the fracture pattern.

Type I injuries are small extraincisural avulsion fragments that usually preserve syndesmotic congruity and rarely need direct fixation. Type II fractures involve the fibular incisura and therefore have more implications for syndesmotic stability despite relatively small fragment size. Type III fractures are characterised by medial tibial plafond involvement and greater tibial plafond involvement and Type IV fractures are characterised by significant posteromedial comminution. Type V injuries are irregular fracture patterns that do not fit into the above types. The Bartoníček system, unlike the previous classifications, gives practical advice for surgical exposure and fixation strategy, which is especially useful in current clinical practice [12].

The point of the Bartoníček classification is that it acknowledges that location is often more important than size. A smaller fragment involving the fibular incisura might result in more significant syndesmotic instability than a larger fragment limited to the posterior articular surface. That is why today surgeons tend to decide the treatment based on the fracture morphology and not the old 25–30% rule. The classification is thus a transition from descriptive anatomy to a functional analysis of ankle stability.

Further studies have demonstrated that CT is superior to conventional radiographs in characterising posterior malleolar fracture patterns. Switaj et al. [11] showed that CT often reveals posterior pilon variants and occult fracture extensions that are not visible on standard radiographs. Mason et al. also demonstrated that posterior malleolar fractures are frequently associated with other osteochondral lesions and syndesmotic injury, emphasising the need for thorough preoperative imaging [16]. Taken together these studies support the view that treatment based on lateral radiographs alone may underestimate the complexity of the injury.

But, like any classification system, there are disadvantages. The Haraguchi classification is simple and reproducible but provides little information on operative strategy. On the other hand, the Bartoníček classification is more clinically useful, but requires knowledge of CT anatomy and has not been universally accepted. Moreover, neither classification fully accounts for ligamentous injury, cartilage damage or patient-specific factors such as bone quality that may influence surgical decision-making.

More recently, several investigators have proposed additional subclassifications and three-dimensional CT reconstructions to better understand the fracture morphology. While these techniques improve preoperative planning, they have not been clearly shown to be superior to established CT-based classifications in predicting clinical outcomes. Thus, the systems of Haraguchi and Bartoníček still remain the most accepted classifications in modern orthopaedic practice [12,13].

The major CT-based classification systems and clinical applications are presented in Table 3 . This comparison illustrates the shift from purely descriptive fracture morphology to classifications that are directly useful in planning the surgical approach and fixation strategy.

Table 3. Comparison of major CT-based classification systems for posterior malleolar fractures.

Classification	Year	Basis of classification	Advantages	Limitations	Surgical relevance
Haraguchi et al. [5]	2006	Three fracture patterns based on CT morphology (posterolateral oblique, medial extension, shell fragment)	First CT-based classification; simple; highly reproducible; improved understanding of fracture morphology	Does not consider fibular incisura involvement, fragment stability or fixation strategy	Useful for recognising fracture configuration but limited guidance for operative planning

Table 3. Continued...

Bartoníček et al. [12]	2015	Five fracture types based on morphology, fibular incisura involvement and posterior plafond extension	Correlates anatomy with surgical planning; emphasises syndesmotic stability; facilitates operative decision-making	Requires detailed CT interpretation; less familiar to some surgeons	Highly useful in selecting surgical approach and fixation method
Posterior pilon concept (Switaj et al.) [11]	2014	Identifies posterior plafond impaction and comminution	Recognises high-energy variants requiring anatomical reduction	Not a formal classification; limited reproducibility	Highlights fractures requiring direct posterior exposure and buttress fixation

Is Fragment Size Still Relevant?

The size of the posterior fragment in relation to the tibial plafond has dictated fixation of a posterior malleolar fracture for more than three decades. The concept of repairing fragments involving more than 25–30% of the articular surface has become well entrenched in orthopaedic education and still guides surgical practice worldwide [1–3]. However, this threshold was established in an era of predominantly plain radiograph-based fracture assessment, despite its longevity. Current imaging, biomechanical research, and analysis of clinical outcomes have cast doubt on the validity of this traditional concept and have resulted in a fundamental reappraisal of the indications for fixation.

The 25-30% rule was first reported by Jaskulka et al. and subsequently by Langenhuijsen et al., who observed that larger posterior fragments were associated with poorer radiographic and functional outcomes [1,2]. Their recommendation was obvious. The larger fragments were assumed to imply greater loss of the weight-bearing articular surface, more instability, and a higher likelihood of post-traumatic arthritis. An anatomic reconstruction of these fragments seemed logical. However, such studies were performed prior to the advent of routine CT imaging, and as such estimated the size of fragments from lateral radiographs, which are now known to underestimate both the size of the fracture and the complexity of the fracture [5,12].

Further studies emphasised the need for restoration of articular congruency. Persistent displacement of the posterior fragment was associated with inferior long-term outcome and increased incidence of degenerative changes as shown by De Vries et al. [3]. These findings shifted the emphasis from the size of fragment per se to the quality of reduction. However, the percentage cut-off was largely unchanged because there was no alternative way to stratify fracture severity.

The arrival of CT imaging exposed several weaknesses in this traditional approach. Despite similar fragment sizes on radiographs, a large variation in the morphology of posterior malleolar fractures was demonstrated by Haraguchi et al. [5]. A few small fragments involved the fibular incisura and included the attachment of the posterior inferior tibiofibular ligament, whereas others were isolated posterior rim fractures with minimal effect on syndesmotic stability. Hence, fractures with the same proportion of the articular surface may have very different biomechanical consequences.

This finding was also further supported by the CT-based classification proposed by Bartoníček et al. which emphasised the importance of fracture morphology and involvement of the fibular notch [12,13]. Their work indicated that the size of the fragment might be less clinically relevant than its location. A relatively small fragment extending into the fibular incisura may destabilise the syndesmosis more than a considerably larger fragment confined to the posterior plafond. These findings directly challenged the rationale for using a single numerical threshold to define fixation.

Additional evidence against reliance on fragment size alone has come from biomechanical studies. Gardner et al. demonstrated that fixation of the posterior fragment was more effective for restoring syndesmotic stability than syndesmotic screw fixation alone, regardless of fragment size [4]. Similarly, Miller et al. showed that anatomic reduction of the posterior malleolus restored the native tension of the posterior inferior tibiofibular ligament and provided stability comparable to trans-syndesmotic screw fixation [7]. These studies shifted the focus of attention from the osseous fragment itself to the functional integrity of the syndesmotic complex.

Similar observations have been reported in clinical outcome studies. Xu et al. reported that patients with anatomical fixation of the posterior fragment had improved quality of reduction and satisfactory functional outcomes even though the size of the fragment alone would not have met traditional criteria for fixation [10]. In their systematic review, Verhage et al. concluded that the available evidence no longer supports fragment size as the only factor influencing operative treatment and proposed consideration of fracture morphology, displacement, syndesmotic instability and joint congruity when selecting patients for fixation [17]. Odak et al. found similar results and reported that the historical fragment-size threshold is not scientifically well supported and should be interpreted with caution [15].

Another important consideration is quality of reduction vs decision to fix alone. Anatomical reduction has been shown by several studies to be associated with better radiographic results and less post-traumatic arthritis regardless of the size of the fragment [3,14]. Inadequate reduction, however, may result in persistent incongruity of the tibial plafond and malalignment of the fibular incisura despite technically successful fixation. This emphasises that the reduction of the fragment may be more important than the fragment exceeding a predetermined percentage of the articular surface.

The widespread use of CT has also improved our understanding of fracture displacement. Small fragments with minimal displacement on lateral radiographs are frequently seen with rotational malalignment, depression or extension into the incisura on multiplanar CT reconstruction [11,16]. These findings explain why some patients treated according to the traditional 25–30% rule develop persistent instability or unsatisfactory functional recovery. The problem, then, is not the numerical threshold itself, but the assumption that fragment size is an adequate surrogate for injury severity.

But it is also important not to entirely abandon fragment size. Larger fragments often suggest greater disruption of the tibial plafond and typically require anatomical reduction to restore joint congruity. Thus, the size of the fragment remains an important parameter, but should be considered only as part of a comprehensive assessment, and not as the main determinant of treatment. Contemporary surgical decision-making is an interplay of the fragment size and the CT morphology, syndesmotic stability, fracture displacement, articular step-off, involvement of the fibular incisura and patient-specific factors like functional demands and bone quality.

In a practical point of view, modern fixation algorithms turned into an individualised approach. Fragments involving > 25-30% of the articular surface should be carefully considered for fixation. Smaller fragments may also require operative stabilisation if CT demonstrates involvement of the fibular incisura, persistent syndesmotic instability, significant articular incongruity or rotational displacement. In contrast, relatively large fragments that are anatomically reduced and stable after fixation of the fibula may not require direct fixation. This approach is in line with the growing awareness that fracture morphology and ankle stability are more critical than fragment size alone.

Surgical Fixation Strategies and Operative Decision-Making

Operative management of posterior malleolar fractures has changed considerably over the past 20 years. The prior management strategy was to restore articular surface of a posterior fragment of size larger than a predetermined size. However, the current trend in surgery is to achieve a more complete restoration of ankle biomechanics, by addressing syndesmotic stability, fibular incisura congruity and anatomical reduction of the posterior tibial plafond . Therefore, the posterior malleolus should no longer be considered as an isolated procedure, but rather as a component of complete ankle reconstruction [4,7,13].

Successful management is based on meticulous preoperative planning. Standard anteroposterior, mortise and lateral x-rays remain the initial imaging modality, but CT has become invaluable for operative decision-making. CT precisely determines the size of the fragments and also shows the direction of the fracture, the comminution, the extension into the fibular incisura and associated posterior plafond impaction. The relative percentage of articular involvement is more often influential to the surgical approach and fixation construct than the absolute percentage of articular involvement [5,11-13].

Indications for surgical fixation

But the most important change in modern practice is the move away from size-based indications to indications based on stability. Historically, fragments > 25–30% of the tibial plafond were routinely fixed while smaller fragments were often ignored [1–3]. Current evidence suggests that this is a gross oversimplification of a complex injury pattern.

Contemporary indications for fixation include:

1. Continued displacement of the posterior fragment (>2 mm articular step-off)
2. Fibular incisura involvement
3. Fibular fixation and instability of the syndesmosis
4. Posterior talus subluxation
5. Posterior impaction of Plafond
6. Rotational malalignment (CT evidence)
7. Bartonicek Type II–IV fractures
8. Variants of posterior pilon

On the other hand, very small avulsion fragments that are anatomically reduced and do not result in syndesmotic instability can be managed without direct fixation [12, 13, 17].

Importantly, fixation should not be considered an end in itself. The goal is restoration of stable ankle mechanics, not fixation of every posterior fragment seen on CT scan.

Surgical Techniques

The choice of surgical approach is largely determined by fracture morphology, associated injuries, and surgeon familiarity. Indirect reduction with ligamentotaxis was previously a common technique, but direct posterior exposure is now more widely accepted as it allows visualisation of the fracture surface, removal of interposed tissue and anatomical reduction.

Posterolateral approach

The posterolateral approach has become the workhorse exposure for the majority of posterior malleolar fractures. It lies between the peroneal tendons and the flexor hallucis longus and gives an excellent view of the posterolateral tibia and allows fixation of the fibula at the same time through the same incision [6,16].

Advantages include:

View of the fracture

Anatomic reduction under direct vision

Application of buttress plate

Concurrent fibular fixation

Decreased reliance on fluoroscopic estimation

Potential disadvantages are proximity to the sural nerve and the need for careful soft-tissue management. However, a number of series report acceptable rates of union with few wound complications when careful surgical technique is employed [6,16].

Posteromedial Approach

The posteromedial approach is indicated for medially extending fractures, especially Bartoníček Type III and IV injuries. It provides an excellent view of the posteromedial plafond but minimal access to the fibula. This may necessitate separate lateral fixation.

Less common than the posterolateral approach, it is useful with significant medial extension of the fracture or posterior collicular involvement [12].

Combined Posterior Methods

Complex fracture patterns may need combined posterolateral and posteromedial exposures. These methods should be reserved for large posterior plafond injuries or posterior pilon variants where accurate reduction requires complete visualisation.

Combined approaches may add to the operative time and soft-tissue dissection but may allow for better reduction in select cases.

Indirection Reduction

Indirect reduction with anteroposterior screws after fibular fixation is an accepted technique in minimally displaced fragments. Reduction is achieved by restoring fibular length and tensioning the intact posterior inferior tibiofibular ligament.

The indirect reduction is technically simple, less invasive, but is mainly dependent on ligamentotaxis, not allowing direct assessment of articular congruity. Thus its role has gradually diminished for displaced fractures, where anatomical reduction is considered to be essential [4,17].

Figure 1 summarises the main characteristics, advantages and limitations of the most commonly used surgical approaches and depicts the decision-making process based on fracture morphology and computed tomography (CT) findings.

Methods of Fixation

The method of fixation should be individualised to fracture morphology, bone quality and anticipated loading. There is no one construct that has shown universal superiority and the choice often is a reflection of both fracture configuration and surgeon experience.

Screw Fixation Anteroposterior

Anteroposterior screws remain appealing due to their placement through a standard anterior incision without the need for additional posterior dissection. They are technically simple and reduce the operative time

However, AP screws are dependent on indirect reduction and may not be adequate for compression of oblique fracture planes. In addition, screw placement is done without direct visualisation of the posterior fragment, increasing the risk of residual articular incongruity.

Posteroanterior Screw Fixation

Posteroanterior screw placement from a posterior approach permits direct visualisation of the reduction and better compression perpendicular to the fracture plane. This technique has become popular for simple posterior fragments with minimal comminution.

Buttress Plate Fixation

Among the current fixation methods, buttress plating has attracted increasing attention. Posterior buttress plates are superior to isolated lag screws for resisting posterior shear forces and provide stable fixation in larger or comminuted fragments.

Clinical studies have reported excellent maintenance of reduction for buttress constructions especially in posterior pilon variants and fractures involving fibular incisura [11,16]. The main disadvantage continues to be the need for posterior exposure and more soft-tissue dissection.

Fixation with mini fragments

Low profile mini fragment systems have expanded options for the fixation of small posterior fragments. These implants are less prominent and give adequate stability for early mobilisation. There have been encouraging early results, but there is little comparative evidence on the long term.

Table 4. Surgical fixation strategies for posterior malleolar fractures.

Fixation strategy	Preferred indications	Principal advantages	Limitations and precautions
Indirect reduction with anteroposterior screws	Small or moderately sized, minimally displaced fragments that reduce adequately after fibular fixation	Less soft-tissue dissection; familiar technique; shorter operative time	Reduction cannot be directly visualised; residual step-off or rotational malreduction may be missed; less suitable for comminution or incisural involvement [4,17]
Direct posteroanterior lag screw fixation	Simple posterior fragments with a clear fracture plane and adequate bone stock	Direct visualisation; compression perpendicular to the fracture plane; improved control of reduction	Limited stability in comminuted fragments; screw trajectory must avoid joint penetration and neurovascular structures [6,16]
Posterior buttress plate fixation	Large, displaced or comminuted fragments; posterior shear patterns; posterior pilon variants; fractures involving the fibular incisura	Resists posterior shear; maintains reduction; permits anatomical restoration of the posterior plafond and incisura	Requires posterior exposure; greater soft-tissue dissection; risk of implant prominence or wound complications [11-13,16]
Mini-fragment or low-profile fixation	Small fragments, thin fragments or osteoporotic bone where conventional implants may be prominent	Allows fragment-specific fixation; lower implant prominence; useful for complex morphology	Limited long-term comparative evidence; fixation strength depends on fragment size and bone quality [12,16]
Posterior fragment fixation before fibular fixation	Displaced fractures with incisural involvement or where direct posterior reduction is planned	Restores the fibular incisura first; facilitates fibular and syndesmotic reduction; may reduce the need for trans-syndesmotic fixation	Sequence must be individualised; may be difficult in severe fibular comminution or compromised soft tissues [7,12,13]
Fibular fixation followed by posterior assessment	Fractures expected to reduce through ligamentotaxis or when indirect posterior fixation is planned	Restores fibular length and may indirectly reduce the posterior fragment	Inadequate for impacted, rotated or comminuted posterior fragments; syndesmotic congruity must be reassessed after fixation [4,7,17]

AP, anteroposterior; PA, posteroanterior.

Sequence of Fixation

The best order of fixation is still a topic of discussion.

The conventional approach was to restore the fibular length first, followed by the medial malleolus fixation and finally assessment of the posterior fragment. Ligamentotaxis was used to indirectly reduce the posterior fragment in the sequence.

More recently, many surgeons advocate fixation of the posterior malleolus prior to definitive fibular fixation when direct posterior exposure is planned. Anatomical reduction of the posterior fragment recreates the fibular incisura, enabling subsequent reduction of the fibula and syndesmosis. The advantage of this technique is particularly clear in Bartoníček Type II and III fractures where incisural anatomy is an important factor of ankle stability [7,12,13].

The evidence at present does not favour a single sequence for all fracture patterns. The order of fixation should rather be individualised according to the morphology of the fracture and the surgical approach chosen. Figure 1 depicts an algorithm for management of posterior malleolar fractures.

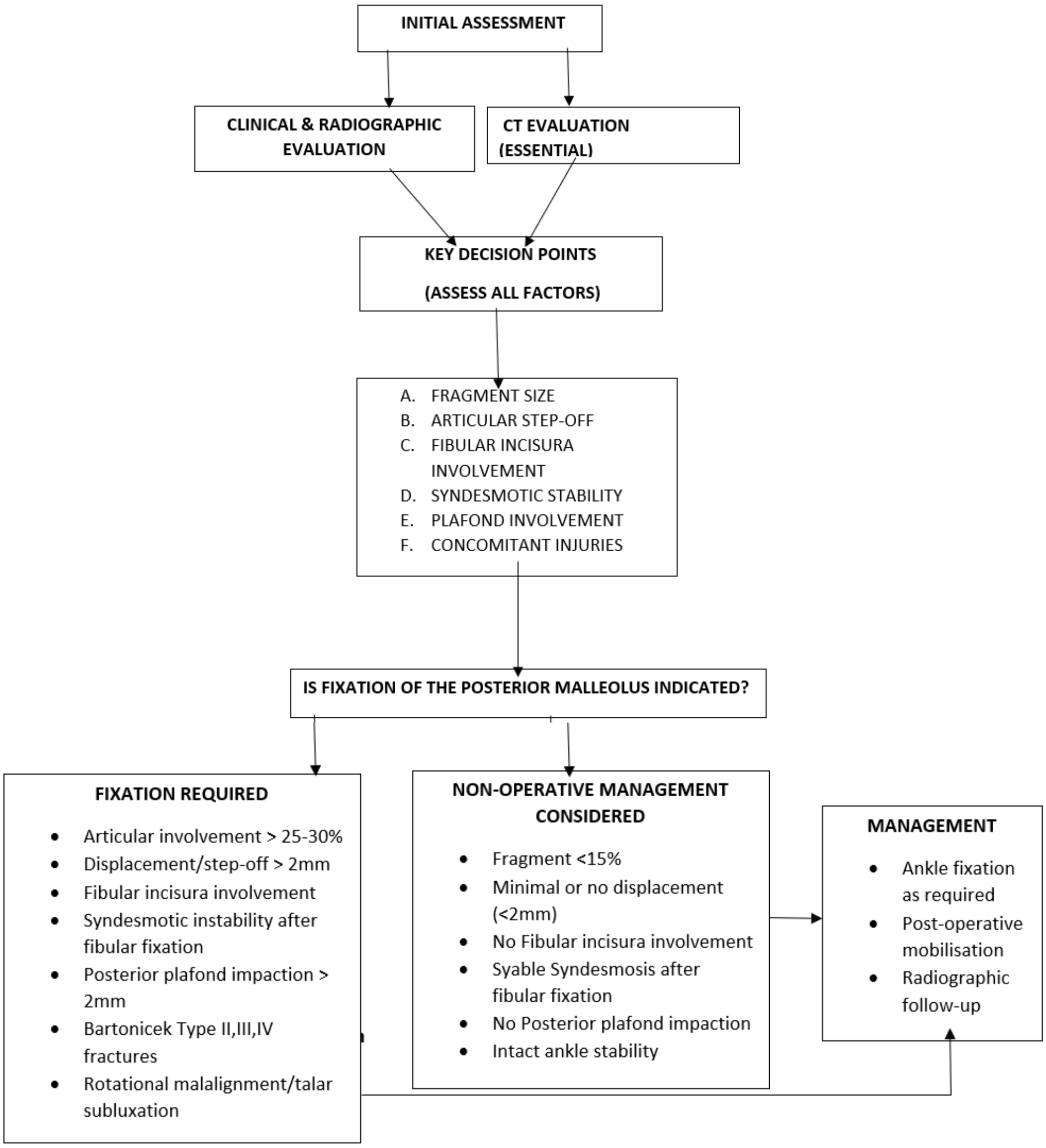

Figure 1. Clinical Decision-Making Algorithm for Management of Posterior Malleolar Fractures.

Pitfalls

Success of posterior malleolar fixation is as much dependent on surgical technique as the implant selection.

The literature consistently revealed several technical principles:

- All three planes of the CT scan should be reviewed before incision.
- Where good reduction cannot be confidently achieved indirectly, direct visualisation should be preferred.
- Before assessment of syndesmosis stability, the fibular incisura needs to be restored anatomically.
- Intraoperative fluoroscopy should be used to obtain true lateral and mortise views to document reduction.
- After posterior fixation, syndesmotic stability should be re-evaluated, as anatomic reduction often negates the need for trans-syndesmotic screw fixation [4,7].

Failure to recognise posterior plafond impaction, rotational malreduction or residual fibular notch incongruity may jeopardise long-term outcomes even with apparently satisfactory fixation.

Current Controversies and Future Directions

Despite great advances in knowledge about posterior malleolar fractures, some aspects of their management remain controversial. Advances in imaging, biomechanics, and fixation techniques have improved surgical decision making, but consensus on the best treatment has not been reached. The challenge now is not to recognise the importance of the posterior malleolus but to identify which patients benefit most from operative intervention and how best to fix it.

One of the most debated issues is whether all posterior malleolar fractures need fixation. Modern evidence clearly shows that the size of the fragment should not be the basis for treatment. But the converse assumption, that all posterior fragments should be fixed, may be equally inappropriate. Small avulsion fragments without displacement, syndesmotic instability or fibular incisura involvement may remain clinically insignificant, and can often be managed successfully without direct fixation . Future studies should thus aim at finding reliable predictors of instability, rather than at arbitrary anatomical thresholds.

Another ongoing controversy is the use of CT scans as a routine procedure. Many surgeons consider CT essential in preoperative planning, especially in trimalleolar fractures. CT accurately delineates the fracture morphology, occult posterior plafond impaction, and involvement of the fibular incisura that may not be detected on standard radiographs [5,11,12]. The routine use of CT for all ankle fractures, however, remains controversial because of concerns regarding cost, radiation exposure and availability of resources. Future studies evaluating the cost effectiveness of selective versus routine CT protocols are needed, particularly in resource-limited health care settings.

Also, there is a discussion about the choice of the surgical approach. Direct posterior approaches allow anatomical reduction under visual control and buttress plating. Indirect reduction through anterior screw fixation is a less invasive alternative. Current evidence is increasingly in favour of direct reduction for displaced fractures as this allows accurate restoration of the articular surface and syndesmotic anatomy. However, no single method can be applied universally and treatment should continue to be individualised according to fracture morphology, soft tissue condition and surgeon expertise.

Implant selection also has not been standardised yet. Buttress plating provides greater resistance to posterior shear forces and is particularly useful in comminuted or posterior pilon-type fractures. Conversely, posteroanterior lag screws offer excellent compression in simple fracture patterns with less implant prominence. There is currently insufficient comparative evidence to suggest that one construct is better than another. Hence, large prospective, multi-center studies comparing fixation techniques would be valuable to guide clinical practice.

Preoperative planning is further improved with the increasing availability of three-dimensional CT reconstruction, which improves the appreciation of fracture morphology and spatial orientation. In addition to conventional imaging, patient-specific three-dimensional (3D) printed models have been used in certain centres to assist with implant contouring, define screw trajectories and improve surgical simulation for complex fractures.

Although these technologies are still largely confined to specialist institutions, they are an important direction for the future of orthopaedic trauma surgery.

Emerging developments in artificial intelligence (AI) and machine learning also show promise. Automated fracture recognition, CT based fracture classification and computer assisted preoperative planning may improve diagnostic accuracy and reduce observer variability. AI based image segmentation is a potential tool to quantify fragment morphology, predict syndesmotic instability and guide surgeons in choosing the most appropriate fixation strategy. But these technologies are still investigational and will require rigorous clinical validation before they can be widely deployed.

Arthroscopy-assisted fixation is another area that will influence future management. The arthroscopy allows the direct assessment of articular reduction, detection of osteochondral injuries and removal of loose bodies with minimisation of further soft-tissue dissection. Initial reports have been encouraging but there is insufficient current evidence to support routine arthroscopic assistance in all posterior malleolar fractures. Well designed comparative studies are required to assess if arthroscopy improves long term functional outcomes compared to conventional open reduction techniques.

Finally, perhaps the greatest unmet need is the availability of high quality prospective randomised trials. Much of the currently available evidence is based on retrospective case series with heterogeneous fracture patterns, variable fixation methods and inconsistent rehabilitation protocols. Standardisation of outcome measures, inclusion of CT based classifications and longer follow up periods will be essential in the development of universally accepted treatment algorithms. Future studies should also incorporate patient-reported outcome measures, return to sport rates, and health economic implications to more fully evaluate treatment success.

Conclusion

Treatment of posterior malleolar fractures is now based on fracture morphology, syndesmotic stability and ankle biomechanics. CT imaging demonstrates that posterior fragment location and configuration have a tendency to influence treatment decisions more than size. Current evidence supports anatomical reduction in select fractures to restore tibial plafond, fibular incisura and syndesmotic stability to improve ankle mechanics and minimise long term problems. Fragment size is important, but this needs to be assessed in the context of fracture displacement, articular congruity and ankle stability prior to fixation. Imaging and fixation have improved but most of the evidence is retrospective and there is a need for well-designed prospective trials to standardise the treatment methods. Until stronger evidence is available, management should be individualised according to CT findings, fracture morphology and surgical judgement. The most important development in the management of posterior malleolar fracture is a change from a numeric cut-off to morphology and stability.

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