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REVIEW ARTICLE

How to address the posterior malleolus in ankle fractures? A decision-making model based on the computerised tomography findings

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Abstract

Introduction The posterior malleolus (PM) is affected in around the 40% of ankle fractures. Anatomical reduction of the articular surface and fibular notch are essential for ankle stability and functional outcomes. These facts justify the increasing interest in the surgical treatment of PM in ankle fractures. Within this context, pre-operative computed tomography (CT) images and posterior approaches to the ankle play a crucial role. The aim of this paper is to make an accurate description of the literature and describe, according to authors' experience, the best surgical approach to the PM based on the CT findings while assessing their advantages and disadvantages.

Methods The fracture pattern of PM is classified according to Haraguchi or Bartoníček classification, both based on pre-operative CT scan images. The posterolateral (PLA) and posteromedial (PMA) approaches to the ankle and their corresponding modifications are described. We propose a decision-making algorithm for posterior malleolus fractures to facilitate treatment selection.

Results Posterolateral approach should be the election for Haraguchi I or III and Bartoníček 1, 2, or 4 fractures. Percutaneous PLA might be adequate in Haraguchi I and Bartoníček 1 to improve syndesmotic stability. In PL approaches, the fibula fracture may be addressed and fixed with a posterolateral plate or through a subcutaneous window that allows lateral reduction and fixation. Posteromedial approach should be the election for Haraguchi II and Bartoníček 3 fractures. A modified PMA might be the election to reduce and fix any fragment dependent on the anterior inferior tibiofibular ligament (AITFL). The modified PMA is performed in a supine position and allows us to check the articular reduction under direct vision. Both PMA are associated with a lateral fibular approach.

Conclusion To address the posterior malleolus when treating ankle fractures, surgeons should choose the most adequate approach based on the fracture pattern and their own experience. Anatomical reduction and stable fixation are critical to improve outcomes.

Keywords Ankle fracture · Posterior malleolus · Computed tomography · Surgical approaches

Highlights

1 Anatomical reduction and stable fixation of posterior malleolus in ankle fractures are critical to improve outcomes.

2 The posterior malleolus should be addressed via posterolateral or posteromedial approach based on pre-operative CT scan images.

3. Haraguchi I or III and Bartonicek 1, 2, or 4 fractures are suitable for a posterolateral approach.

4. Haraguchi II or Bartonicek 3 fractures are suitable for a posteromedial approach.

5. A careful study of the pre-operative CT scan images allows the surgeon to choose between the classical posterolateral and posteromedial approaches and their modifications as well as the best approach to the fibula.

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Introduction

Up to 40% of ankle fractures involve the posterior malleolus (PM) [1]. If affected, the posterior malleolar fragment disrupts the tibiotalar congruency and it is often related to poor outcomes and mid-to-long-term osteoarthritis development [2, 3]. However, the surgical management of these injuries remains controversial.

Traditionally, when treating an ankle fracture, the posterior malleolar fragment was ignored unless its size exceeded the 25–30% of the articular surface. Therefore, indirect reduction and fixation was indicated [2–4].

Nowadays, it is known that beyond the size of the posterior malleolus fragment, other variables as the shape of PM and the involvement of the fibular notch are crucial to establish the best treatment strategy [5, 6].

In recent years, two different classifications of the posterior malleolus fracture based on the computed tomography (CT) images have been developed by Haraguchi and Bartoníček (Table 1), due to the difficult assessment of the PM in plain radiographs [7, 8].

Most authors support the use of computed tomography (CT) as the imaging procedure of choice for ankle fractures, especially if the PM is involved, to set up the principles of surgical management [6, 9, 10].

The increasing interest in PM fractures is sustained on the fact that just a 1-mm misreduction of the 5% of the articular surface is related to a major risk of osteoarthritis and poor functional outcome [2].

The posterior approaches to the ankle joint, posterolateral (PLA), and posteromedial (PMA) and their modifications offer an excellent exposition of the PM allowing an anatomic reduction, stable fixation and restoring the tibiofibular mortise [11–13].

The treatment of the PM fracture still remains challenging for orthopaedic surgeons because of the absence of clear consensus [6]. The aim of this paper is to describe the best surgical approach to the PM based on the CT findings while assessing their advantages and disadvantages, according to the authors' own experience.

Posterolateral approaches

The posterolateral approach (PLA) has become a popular method to address the posterior malleolus, as it provides an excellent visualization of the posterolateral facet of posterior malleolus. In addition, the lateral malleolus may be fixed through this approach or its variants. Despite the PLA being well described previously [14], it has not received much attention until the increasing interest in improving the outcomes by fixing the posterior malleolus [15].

Based on CT images, the choice of posterolateral approach should be considered, especially in the following patterns: Haraguchi I and III and Bartoníček 1, 2, and 4 [7, 8, 16].

Classic posterolateral approach

The patient is placed in a prone, lateral or floppy position, depending on any other associated approaches. The knee is slightly flexed, the ankle could be placed on a towel bump to improve fluoroscopic X-rays, always allowing free dorsiflexion of the ankle, which could also help in reduction manoeuvres. A longitudinal skin incision is located in the interval between the posterior border of the fibula and the lateral border of the Achilles tendon (Fig. 1a). The lesser saphenous vein and sural nerve are identified and protected if possible, as there is a high variability in the distribution of sural nerve [17]. The superficial fascia will be opened (Fig. 1b), and blunt dissection is performed between the peroneal tendons and the *flexor hallucis longus* (FHL). The peroneal tendons are retracted anterolaterally, and the deep fascia over the FHL is incised (Fig. 1c). The FHL is detached from the posterior tibial border, interosseous membrane, and posterior surface of the tibia, being retracted medially and, thus, protecting the posterior tibialis neurovascular bundle (Fig. 2). This PL approach allows the exposure of approximately half the posterior plafond.

It is possible to reduce and fix the fibula through the same approach, retracting the peroneal tendons laterally, or developing a window subcutaneously just posterior to peroneal

Table 1 Two different classifications of the posterior malleolus fracture based on the CT images

Haraguchi et al. (2006). Based on the angle between the bimalleolar axis [7]	
I. Posterolateral-oblique fragment: wedge-shaped fragment involving the posterolateral corner	
II. Transverse-medial extension: fracture from the fibular notch to the medial malleolus	
III. Small-shell fragments: one or more fragments at the posterior lip of the tibial plafond	
Bartoníček et al. Based on the fibular notch injury [8]	
1. Extraincisural fragment: intact fibula notch	
2. Posterolateral fragment including fibula notch	
3. Posteromedial two-part fragment: from fibula notch to medial malleolus	
4. Large posterolateral fragment: more than one third of the notch	
5. Irregular, osteoporotic fragments	
Correlation between posterior malleolus fracture classifications	
Haraguchi et al.	Bartonicek et al.
III. Small-shell fragments	1. Extraincisural fragment
II. Transverse-medial extension	3. Posteromedial two-part fragment
I. Posterolateral-oblique fragment	2. Posterolateral fragment including fibula notch
	4. Large posterolateral

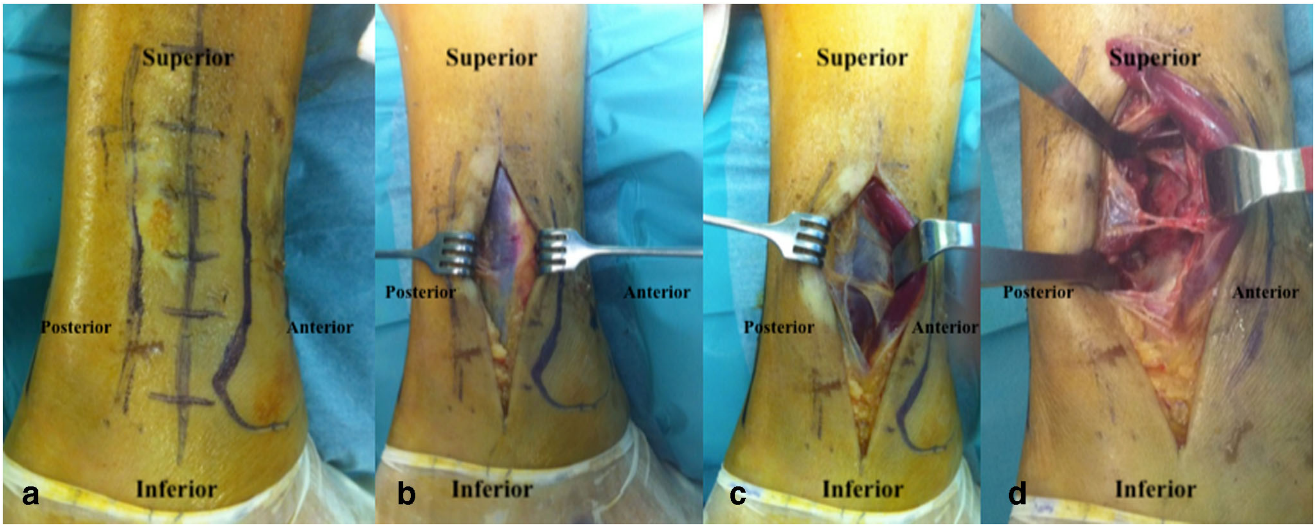


Fig. 1 Skin incision for PL approach (**a**), superficial fascia (**b**), deep fascia incision (**c**), and exposition of the posterior tibial plafond after retracting *FHL* belly (**d**)

tendons, and placing the screws and/or plates on the lateral surface of the fibula (Fig. 3). This strategy pretends to minimize friction between peroneal tendons and plate or screws.

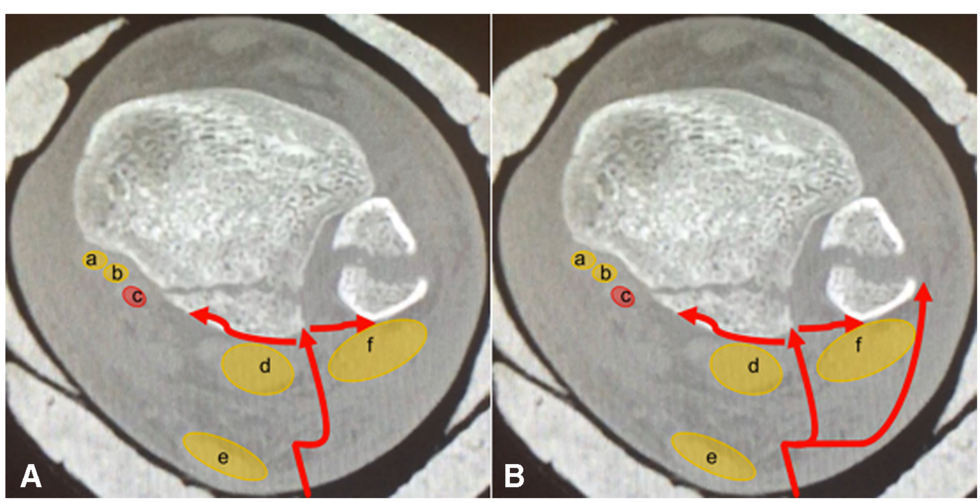
In addition to sural nerve and lesser saphenous vein, the damage of the peroneal artery and its branches (perforating and communicating arteries) should also be avoided, especially in open fractures and pilon fractures, where the incidence of anterior tibial artery injury could be as high as 40% [18]. In those cases, the peroneal artery could increase its diameter due to vascular hyperflux (Fig. 4a–c). We should remember that the peroneal artery may be a dominant artery supplying blood flow to the foot in 5% of patients, and its damage could also be devastating [19]. If CT scan demonstrates a PM fracture with a large fragment (Bartoníček 4), or dissection needs to be carried 40 mm proximal to the tibial joint line, the peroneal artery should be identified to avoid vascular injuries, as demonstrated in cadaveric studies [20].

There are some other variations described in the literature as the one described by Choi JY et al. [21], based on a single oblique posterolateral approach to better visualization of lateral malleolar fracture, minimizing the sural nerve injury because of the smaller and more oblique incision.

Percutaneous posterolateral approach

If the CT scan shows a small PM fragment (Haraguchi I, Bartoníček 1) and fixation of PM is recommended, it is possible to perform a limited percutaneous posterolateral approach following the steps of the open posterolateral approach. Blunt dissection should be made over the FHL tendon with a small clamp. From the authors' point of view, this strategy could be recommended in order to improve syndesmotic stability, as fixation of PM provides greater stability than syndesmotic screws [22].

Fig. 2 Posterolateral approach for prone position. Red lines represent skin incision and dissection ways: posterior reduction and posterolateral plating of the fibula (**a**) subcutaneous window for lateral reduction and plating of the fibula (**b**). *Posterior tibialis* tendon (a), *flexor digitorum longus* (b), neurovascular bundle (c), *flexor hallucis longus belly* (d), Achilles tendon (e), and peroneal muscles (f)



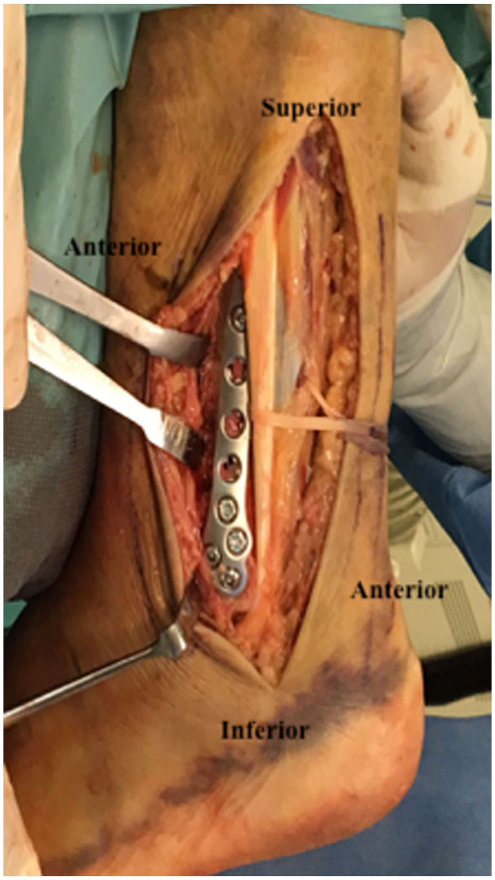


Fig. 3 Lateral fibula plate through a subcutaneous window posterior to the peroneal tendons in a PL approach

Direct lateral approach: transfibular approach

Described by Gatellier and Chastang in 1924 [23] and modified by other authors posteriorly, this approach is performed through a Weber type B lateral malleolar fracture, opening the fracture line gently with a lamina spreader [24]. The PM could be reduced with a pointed clamp and fixed with A-P screws, or P-A screws, as described by Kim et al. [25].

Posteromedial approaches

Although not as popular as the PLA, the posteromedial approach is indicated in fractures of PM with medial extension and two-part fractures, involving the medial malleolus (Haraguchi type II fracture or Bartoníček type 3) [7, 8]. The presence of displaced intercalary fragments and the double medial contour, known as the spur sign or flake fragment sign in plain radiographs and CT scan, could also suggest the choice of posteromedial approach (Fig. 5).

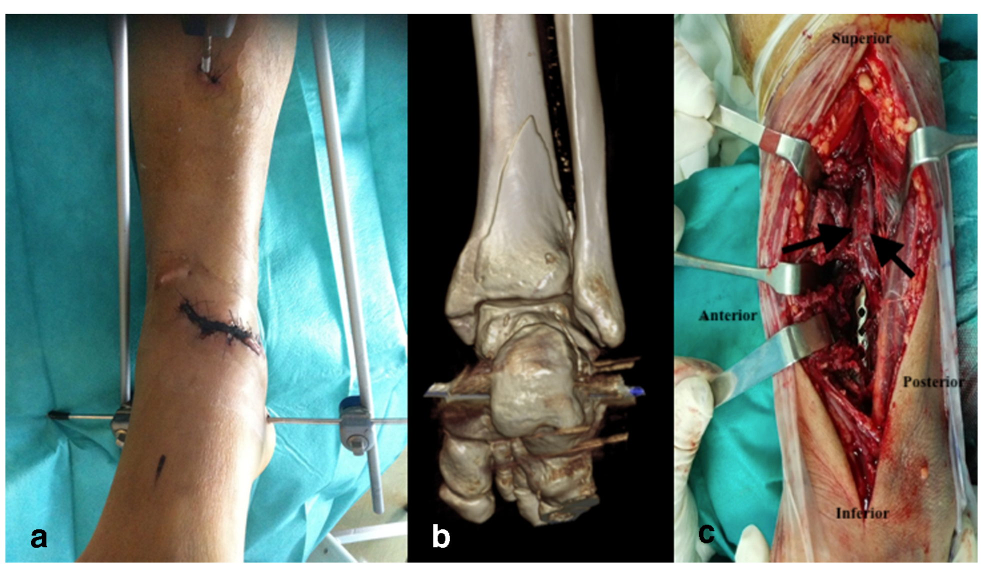
Probably, the use of PMA is less widespread because it was originally described for prone position. However, subsequent modifications allow to be performed in supine. Therefore, once the posteromedial approach has been chosen, we should still decide between the classical PMA and its modifications.

Pre-operative planning is mandatory to avoid the need to change the patient's position during surgery. When it is expected to repair fragments dependent on the anterior inferior tibiofibular ligament (AITFL—Chaput-Tillaux, Lefort-Wagstaffe), a lateral fibular approach associated with a posteromedial modification in the supine position is recommended. Otherwise, if the need to access the anterolateral region is not predictable, a lateral approach to the fibula and the classic posteromedial in prone is recommended, maintaining a cutaneous bridge of at least 6 cm between the skin incisions.

Classic posteromedial approach

The patient is placed in the prone position. Incision is made between the medial malleolus and the Achilles tendon. The

Fig. 4 Case of a 51-year-old male who sustained an open distal tibia fracture with an anterior tibial artery injury (**a**), the large PM fracture (**b**) was fixed with a long buttress plate. In the PL approach, an engorge peroneal artery was noticed due to hyperflux (**c**)



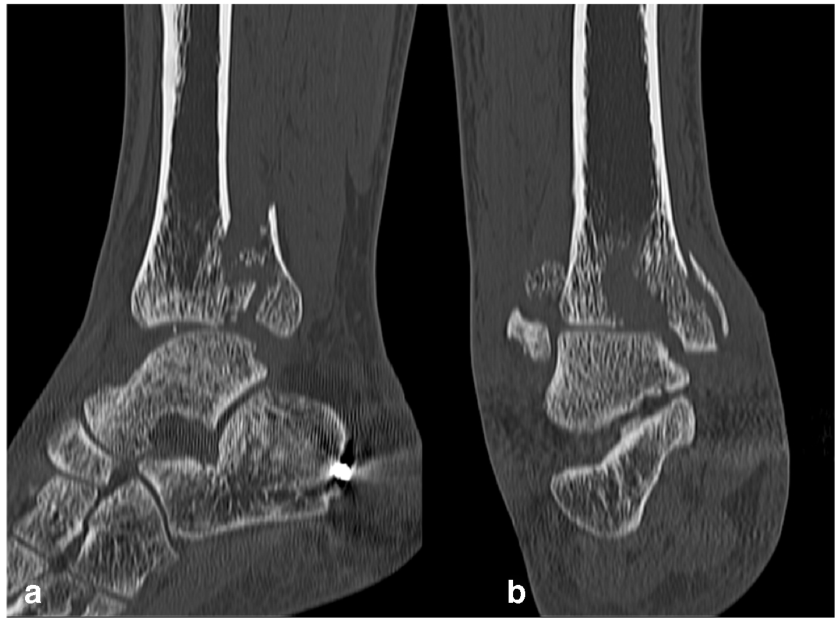


Fig. 5 Displaced intercalary articular fragment in CT sagittal reconstruction (**a**). Spur/flake fragment sign in CT coronal reconstruction (**b**)

fascia is dissected and the neurovascular bundle and flexor tendons are exposed. The posterior malleolus can be reached between the *posterior tibialis* tendon and the *flexor digitorum longus* [26] (Fig. 6a). The fragment is mobilized, provisionally reduced with Kirschner wires, and definitely fixed with screws or a buttress plate. When CT scan shows displaced intercalary and impacted articular fragments, a small cortical window may be required in large single fragments. Sometimes, the open-book technique is recommended to allow reduction and grafting through the vertical line that separates the posterolateral and posteromedial fragments (Fig. 7). Direct joint visualization is not possible with this approach so surgeons rely on cortical reduction and fluoroscopic assistance [27].

Modified posteromedial approach

Modifications to the posteromedial approach were developed to avoid the prone position and allow a better joint visualization. The modified PMA is based on the extension of the medial incision for osteosynthesis of the medial malleolus proximally over the medial tibial crest [28, 29]. The posterior malleolus can be reached between the neurovascular bundle and the *flexor hallucis longus*, mobilizing the *posterior tibialis* tendon or the *flexor digitorum longus* to lateral [26] (Fig. 6b). Always protecting the bundle, this approach allows access to the posterior malleolus with the advantage of the simultaneously medial and posterior malleolus reduction and fixation in supine position. The modified PMA gives the chance to check joint reduction through the fracture site of the medial malleolus (Fig. 8).

Authors' recommendation

We propose the following decision-making algorithm for posterior malleolus fractures to facilitate the best surgical choice (Fig. 9).

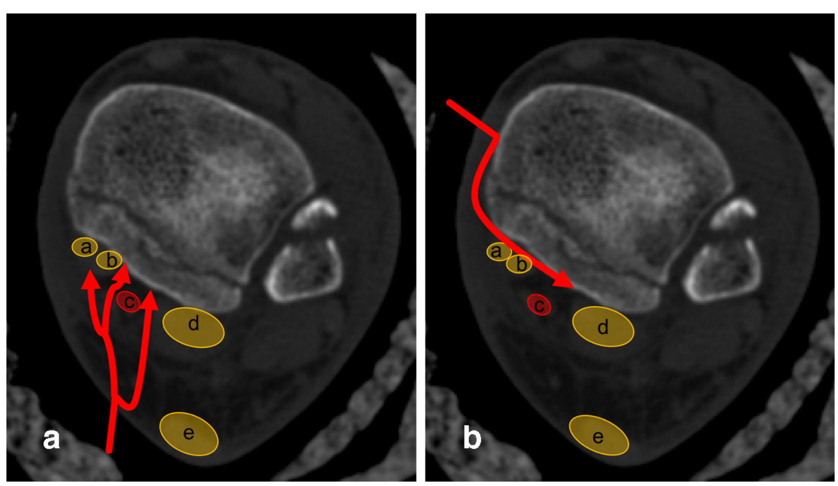


Fig. 6 Posteromedial approach for prone position (**a**). Modified posteromedial approach (**b**). Red lines represent skin incision and dissection ways. *Posterior tibialis* tendon (a), *flexor digitorum longus* (b), neurovascular bundle (c), *flexor hallucis longus belly* (d), and Achilles tendon (e)

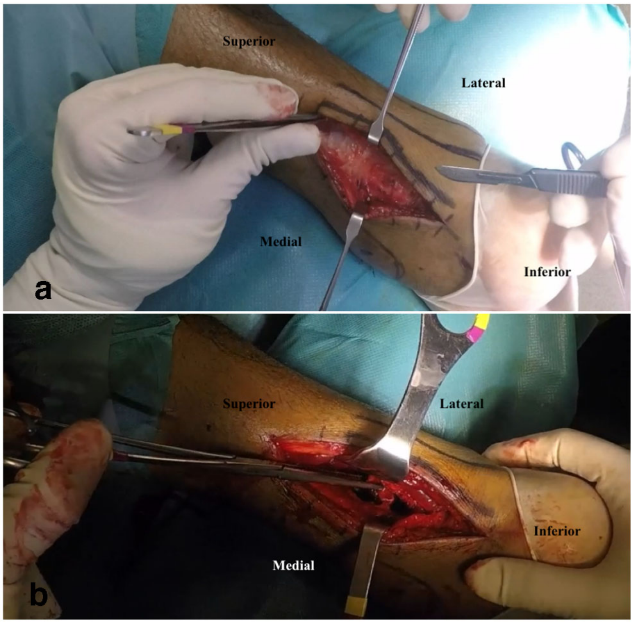


Fig. 7 Posteromedial approach of a right ankle in prone position (**a**). Same case with open-book technique for reduction of intercalary fragment (showed in Köcher clamp) (**b**)

Discussion

Traditionally, the syndesmotic instability in ankle fractures has been correlated with the level of fibular fracture, but up to 40% of supination and external rotation fractures—classically called Weber's type B—present affectation of syndesmosis [30]. The reduction criteria for the posterior malleolus have changed in recent years [24]. In different clinical and biomechanical studies, it has been proven that simple radiography studies are insufficient to correctly assess joint involvement of the posterior malleolus [8, 31, 32]. The fixation of the posterior malleolus greatly improves the stability of the ankle [6, 22]. Therefore, most authors advocate the use of CT when planning the approach for this type of fracture. It is necessary to know the advantages of each approach and its indications according to the fracture pattern of the posterior malleolus.

The fixation of the PM can be done in different ways and there is no clear consensus about the best approach. The elected approach should allow us adequate access to the posterior fragment, be as anatomical as possible, and avoid the maximum risk of damaging neurovascular structures, as well as to ensure the correct reduction of the fracture and syndesmosis. In addition, the approach should allow a stable fixation of the PM. The current trend is the use of buttress plates although the best implant selection exceeds the objective of this paper.

Several works advocate the use of PLA or PMA but, up to our knowledge, there are no published works that help us to make the decision of the best approach for each fracture pattern. Most surgeons prefer to use the PL approach for the fixation of a single posterior malleolar fragment [12].

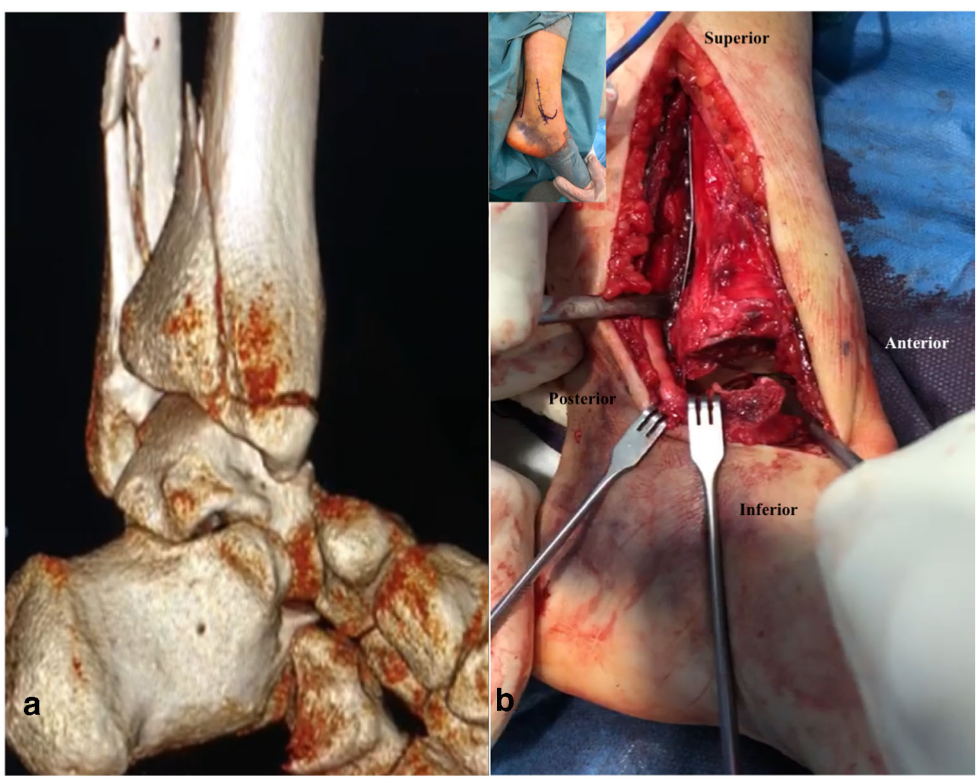


Fig. 8 A 3-D reconstruction medial view of a left ankle trimalleolar fracture (**a**). Intra-operative view of the same case with the modified posteromedial approach. Direct joint visualization through medial malleolar focus (**b**)

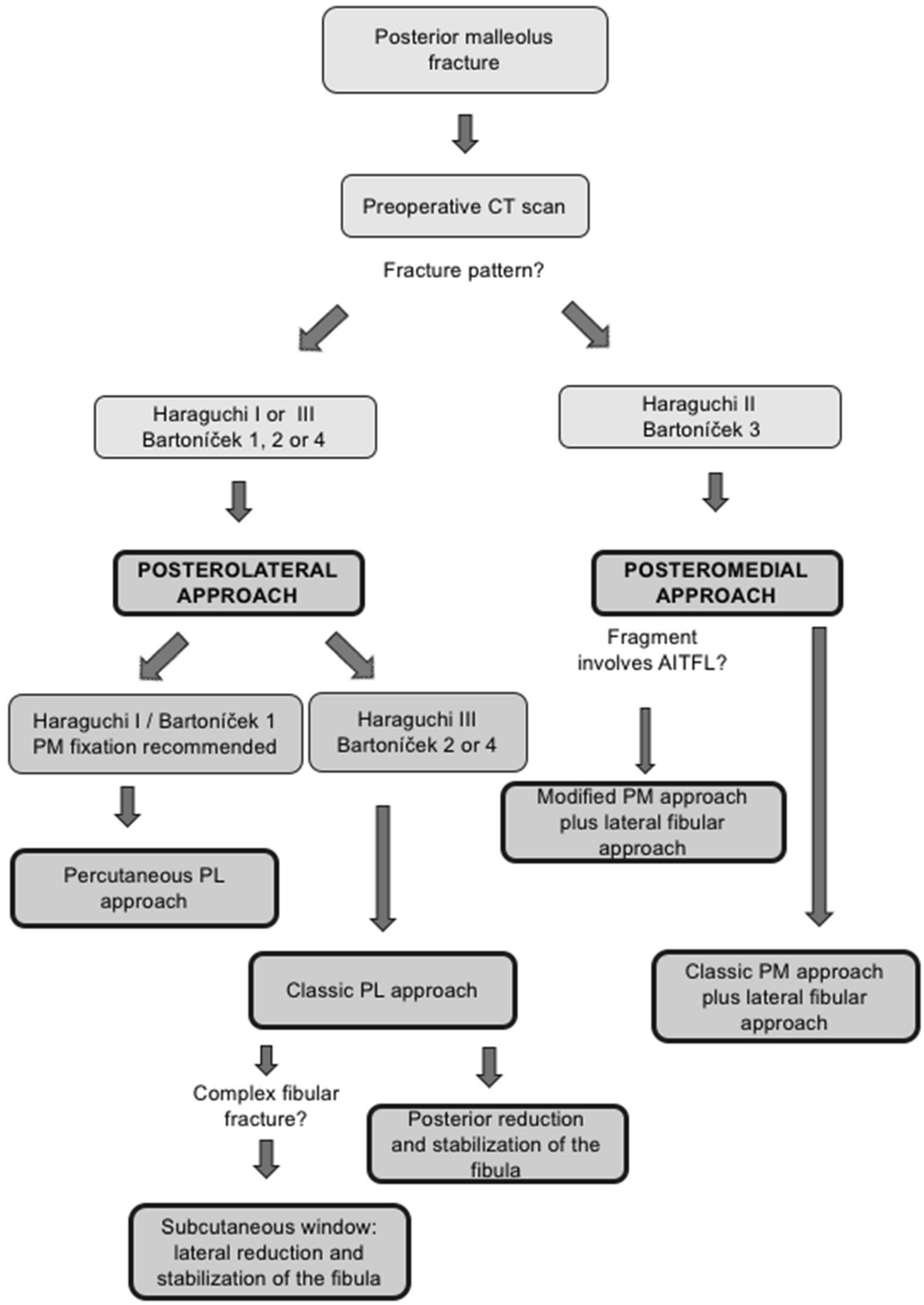


Fig. 9 Decision-making algorithm for posterior malleolus fractures

Most of the fractures are type I of Haraguchi classification or type 2 of Bartoníček and Rammelt classification; that is, cisural involvement with simple fragment. In these cases, the classic or modified posterolateral approach allows an excellent reduction of the posterior malleolus and control of the fibula in the incisura fibularis. In addition, the stability of the fibular fracture with the use of posterolateral antiglide plates is superior to that obtained with lateral reconstruction plates [33]. However, this approach does not allow a proper visualization of the medial malleolus and usually requires an extra medial approach which is associated with soft tissue problems due to cutaneous bridges. This fact is considered a limitation in type 2 Haraguchi fractures or type 3 Bartoníček and Rammelt fractures [11, 15, 26].

When facing a complex fibular fracture, the reduction through a posterior approach is more difficult and the modified posterolateral approach with a subcutaneous window just posterior to peroneal tendons might be a more convenient strategy.

We remark that PLA increases the risk of tendon impingement and sural nerve injury [21].

The main advantage of the modified PMA is that the distal tibial articular surface can be visualized through the unreduced medial malleolar fracture, which provides direct reduction of the PM fragments. There are also some limitations to the PM approach. The neurovascular bundle is close to the dissection but not usually visualized. Overstretching the soft tissues has the potential result of *tibialis posterior* nerve or artery injuries.

Finally, the choice of the best surgical approach to address the posterior malleolus in ankle fractures will depend on the extension pattern of the fracture, the comminution of the fibular and tibial malleolus and the surgeon's experience with each approach.

For the best decision-making, we think the knowledge and experience with all the approaches and their modifications are essential as well as the ability to identify all the fracture features based on CT images.

Conclusion

When addressing the posterior malleolus in an ankle fracture, surgeons should choose the most adequate approach based on the fracture pattern and their own experience. The anatomical reduction and stable fixation of the intra-articular fractures may be critical regardless of the fixation technique.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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