Modified Classification of Posterior Malleolus Fracture of Ankle

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Abstract

1. Introduction
Objective: Our study aims to classify posterior malleolar fractures (PMF) based on preoperative computed tomography (CT), initial injury radiographs, and intraoperative image intensifier screening.
Design: Retrospective study
Setting: Two hospitals: (1) Level I trauma centre and (2) Level II rural trauma center.
Patients: Between June 2013 and March 2015, 50 consecutive patients with bi- or trimalleolar ankle fractures with one or more posterior fragments or a posterior inferior tibiofibular ligament (PITFL) injury who underwent operative fixation were selected for the study.

2. Material and Methods:
Preoperative and intraoperative image intensifier screening and CT were reviewed to determine stability of the ankle joint and classify the PMF. Of 50 patients, 34 underwent CT. We also noted the type of operative fixation and whether the PMF was fixed.

3. Results:
The 34 fractures with CT scans were categorised into the following:
Type I fracture is an isolated PMF.
Type II fracture is either a bi- or trimalleolar fracture associated with a Weber B or C fracture pattern. These are further classified depending on the presence of syndesmotic injury.
Type III PMF is associated with an ipsilateral tibial diaphyseal fracture. This is further subdivided based on sagittal or coronal plane instability.
All the above categories are further subdivided, as per our CT-guided classification mentioned in the text.

4. Conclusion: The ankle stability on initial injury radiographs, intraoperative image intensifier screening, and preoperative CT is critical for classification and management of PMF, regardless of the fragment size.

Key words: posterior malleolus, trimalleolar, ankle fracture, classification, stability of ankle, outcome, internal fixation
Level of evidence: Level IV

Introduction

Posterior malleolus fractures (PMFs) are relatively common among ankle fractures, the most common of which are trimalleolar, with an incidence of approximately 7–14.2% [1,2]. Isolated fractures of the posterolateral tibial lip (Volkmann’s Triangle) are rare, with an estimated incidence of 0.5–1% [1,3,4]. PMFs have also been associated with tibial shaft fractures, with an incidence of 1–25%, which still seem to be underestimated in the literature [3,4].
The posterior malleolus plays an integral role in ankle joint stability through its anatomical relationship with the posterior inferior tibiofibular ligament (PITFL), which has been shown through cadaver studies to account for 42% of syndesmotic stability [5,6]. Ankle fractures involving the posterior malleolus are said to have worse clinical outcomes, possibly related to incongruity and the resultant development of posttraumatic arthrosis [5,7]. However, there is no radiologic or clinical consensus on how to best evaluate ankle stability following a fracture. There is no clear guide on the best way to reduce and stabilize the posterior tibial malleolus.
This study proposes a new classification for PMFs using a combination of initial injury radiographs, computed tomography (CT), and intraoperative image intensifier screening, aiming to provide a guide for best surgical management.

Material and Methods

Approval for the study was obtained from the local ethics committee (Hunter New England). We retrospectively analysed the plain radiographs and CT images of 50 patients presenting with a PMF to two institutions, i.e., a tertiary hospital major Level 1 trauma centre and a rural referral hospital Level II trauma centre. Radiographs and operative notes for all patients who underwent operative fixation in the two institutions from June 2013 to March 2015 were reviewed. Patients who had a PMF or PITFL injury
irrespective of posterior malleolar fixation were included in the study. Patients with comminuted plafond injuries were excluded from the study. Preoperative radiographs (AP, lateral, and mortise views) prior to and after reduction of the fracture were reviewed. The aim was to analyse the various fracture patterns of the PM and pilon variants in order to formulate a comprehensive classification system. Indications for open reduction and internal fixation (ORIF) as per the radiographs and CT scans were noted, including the fragment ratio and articular impaction of the PM.

Preoperative initial injury radiographs were carefully analysed for fracture patterns, and included the following: (1) evidence of dislocation or subluxation of the talus in the coronal and/or sagittal plane; (2) evidence of any syndesmotic widening on AP and mortise views; (3) presence of the double contour sign, indicating a posteromedial fragment; (4) articular fragment size; and (5) associated fibular fracture categorized according to the Weber classification. CT was also useful in assessing syndesmotic injury, indicated by widening of the syndesmosis anteriorly or posteriorly on the axial scans. Other important information obtained on CT was articular impaction or depression. Postoperative radiographs and operative notes were used to ascertain the type of fixation and the presence of syndesmotic injury.

An extensive literature search was then performed using MEDLINE (1996 to present), PubMed, and the Cochrane database of systematic reviews to find journal articles on PMF. Keywords used were ankle fractures, trimalleolar, posterior malleolus, outcome, and internal fixation. Search results were limited to humans and articles in English.

Results

The 50 patients comprised of 22 men and 28 women. The average age of the cohort was 46.68 years (age range, 14–86 years). Thirty-four patients had a preoperative CT to assess fracture pattern. Thirty-five patients had internal fixation of the posterior malleolus associated with lateral and/or medial malleolar fixation. Choice of fixation varied, with plate fixation being the most popular (21 of the 35). Screw fixation of the PM was performed in 14 patients. Our preferred fixation method for PMF involves 2 or 3 screws in a parallel position to enhance lag screw effect; inverted triangle configuration of the lag screw placement was also used in our series. Five patients had a combination of plate and screw fixation. Posterolateral approach was used in 20 patients and posteromedial approach in 8 patients. A combination of posteromedial and posterolateral approach was utilized in 7 patients. The choice of the surgical approach was made according to the fracture pattern and the surgeon’s preference.

Modified classification of PMF

The system is partly based on the CT classification proposed by Haraguchi et al [8]. The initial injury AP, lateral, and mortise view radiographs were used to categorize the fibular fractures according to the Danis [9], Weber [10], and Lauge-Hansen [11] classifications. The classification of PMF based on CT is presented in Table 1.

We used the following modifiers to further classify PMF: (1) presence of syndesmotic injury as determined by preoperative initial injury radiographs, CT, or intraoperative image intensifier screening; (2) presence of associated fibular fracture classified as per the Danis [9], Weber [10], or Lauge Hansen [11] systems; and (3) evidence of sagittal or coronal plane instability as determined by preoperative radiographs and CT, particularly with any evidence of tibiotalar subluxation or dislocation in the sagittal plane.

Based on CT in 34 of the 50 patients in our study, 18 had type I, 3 had type II, 9 had type III, and 4 had type IV fracture patterns. Four patients had no PMF but had a PITFL injury. Our final proposed classification system is based on sagittal or coronal plane instability on initial injury radiographs and the above-modified CT classification. This classification system can be used to determine management of the particular PMF pattern (Table 2).

<table>
<thead>
<tr>
<th>Type (PL)</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Type I (PL)</td>
<td>Posterolateral with oblique fracture line</td>
</tr>
<tr>
<td>Type II (PMA)</td>
<td>Posteromedial with anterior fracture line</td>
</tr>
<tr>
<td>Type III (PL+PM)</td>
<td>Posterolateral (PL) fracture extending to Posteromedial (PM), fracture line parallel to trans-malleolar axis, usually fragment split in the middle</td>
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<tr>
<td>Type IV (PR)</td>
<td>Posterior rim fracture</td>
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CT based classification of posterior malleolus fracture. Initial injury radiographs and axial CT scans were used to classify the PMF into 4 types. (Figure 1 and Figure 2)
Figure 1 - Initial injury radiographs showing the four types of PMF

Figure 2 - Axial CT scan at the level of syndesmosis demonstrating the four types of PMF.

Table 2
Type I - Isolated PMFs

<table>
<thead>
<tr>
<th>A</th>
<th>No sagittal plane instability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Type IV on CT or PITFL injury alone (Fig 3)</td>
</tr>
<tr>
<td>A2</td>
<td>Type I-III on CT, failed closed reduction</td>
</tr>
</tbody>
</table>

B  Sagittal plane instability

| B1              | Non-displaced or type IV on CT | Nonsurgical management for PMFs |
| B2              | Type I-III on CT with displacement | Surgical fixation |

Type II - Bi or Trimalleolar fracture with sagittal plane instability

<table>
<thead>
<tr>
<th>A</th>
<th>Weber B lateral malleolar fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Without syndesmotic diastasis or type IV on CT</td>
</tr>
<tr>
<td>A2</td>
<td>Syndesmotic diastasis, and/or displaced or type I-III on CT (Fig 4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B</th>
<th>Weber C lateral malleolar fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Without syndesmotic diastasis, non-displaced or type IV on CT</td>
</tr>
<tr>
<td>B2</td>
<td>Syndesmotic diastasis and/or displaced, type I-III on CT*</td>
</tr>
</tbody>
</table>

*Size of PM is irrelevant to fixation. However, if the height is less than 1 cm, fixation with plate or screws may not be achievable. If syndesmotic diastasis is present either on initial injury radiographs or intraoperative II, syndesmotic fixation is compulsory.

Type III PMFs with diaphyseal ipsilateral tibia fracture

<table>
<thead>
<tr>
<th>A</th>
<th>Type IV on CT without instability on initial injury X-rays or intraoperative screening (Fig 5)</th>
<th>Non-surgical management of PMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Type I-III with &gt; 2 mm articular step, unable to be closed reduced or with sagittal instability (Fig 10)</td>
<td>Surgical fixation</td>
</tr>
</tbody>
</table>

Classification PMFs (based on sagittal plane stability on initial injury radiographs and preoperative CT scans)

Figure 3 (1A1): No sagittal plane instability. (A)-Initial injury radiograph showing no fracture line. (B)-CT scan showing non-displaced PMF (Type IV based on our CT classification) with congruent articular surface.
(C) Intra-operative image intensifier screening showed no syndesmotic diastasis (normal Mortise view on the left, stress view on the right).

Figure 4 (IIA2) (A, B)- Initial injury radiographs showing trimalleolar fracture with Weber B fracture of ankle. (C, D)-Post op radiograph showing anatomical reduction of PMF with a buttress plate fixation. (E, F)-Pre-op CT showing Type III PMF.

Figure 7-IIB1. (A)-Weber C ankle fracture with sagittal plane instability. (B)-CT showing type IV posterior rim fracture, which can be managed non operatively.

Figure 5 : (A) Distal tibia diaphyseal fracture with associated PMF. (B) CT showing undisplaced PMF, which can be managed no operatively.

Type I is an isolated PMF with (B) and without (A) sagittal plane instability on initial injury radiographs. These are further sub-classified depending on the fracture pattern noted on CT (as per the classification system mentioned above).

Type II fracture is either a bi- or trimalleolar fracture associated with a Weber B or Weber C fracture pattern. These are further classified depending on the presence or absence of syndesmotic injury.

Type III is a PMF associated with an ipsilateral tibial diaphyseal fracture, which is further subdivided based on sagittal or coronal plane instability.

We recommend the use of CT for all PMF to ascertain the exact fracture pattern, displacement, comminution, articular impaction, and fragment size. With the above knowledge, operative planning can be undertaken. Posterolateral fractures can be fixed using a posterolateral approach. Presence of an additional posteromedial fragment may require an additional posteromedial approach. In PMF, the PITFL tends to remain intact, with secure fixation of the PMF shown to stabilize the syndesmosis [12,13]. Intraoperative screening with an image intensifier should always be performed after stabilizing the PM fracture to rule out any occult syndesmotic diastasis.

We further stage PMF as follows. Stage I: nondisplaced PMF with no syndesmotic diastasis, and usually no sagittal plane instability; Stage II: PMF fragment hinged on the PITFL shifting laterally, with internal rotation of the distal fragment of the fibula, posterior aspect of syndesmotic diastasis, usually combined with sagittal and coronal plane instability; Stage III: Further supination external rotation (SER) or pronation external rotation (PER) plus axial forces causing rupture of the anterior inferior tibiofibular ligament (AITFL), distal fragment of the fractured fibula shifting anteriorly or posteriorly on the sagittal plane, that can also be externally or internally rotated depending on foot position at the end of the injury (determined from CT scans for rotational profile of the distal fibula). This stage is always combined with sagittal and/or coronal plane instability.

Discussion

PMF leads to ankle instability and incongruity through PITFL disruption, which causes posttraumatic arthritis, as confirmed by Laugenhuijzen et al. and De Vries et al. in follow-up clinical studies of 6.9 and 13 years, respectively [14,15]. Incongruity-associated changes in contact stress rates and incongruity-associated instability events may be important pathomechanical determinants of posttraumatic arthritis [16].

On the basis of the fracture-line orientation, Haraguchi et al [8], classified PMF as a posterolateral-oblique type (67%), a medial-extension type (19%), and a small-shell type (14%). The study failed to produce guidelines for surgical decision-making. Based on our modified classification, PMF can also be detected in the posterolateral orientation, but exits posteromedially; corresponding to types B and C of the Danis-Weber system, supination-external rotation type III-IV lesions (SER-III–IV) and pronation in external rotation type IV lesions (PER-IV) are categorized in the Lauge-Hansen classification [9-11]. These two classifications do not evaluate the severity of fracture and they are therefore not prognostic. Our stability-
based PMF classification system should be more practical in surgical decision making.

The posterior malleolus fragment can range in size from a small extra-articular fragment to one comprising more than 40% of the articular surface of the tibia [8]. Conventional plain radiography (i.e., AP, mortise, and lateral views) is still necessary for the primary diagnosis and estimation of the fragment size, with a fracture of the dorsal tibial margin best seen in the standard lateral view [17]. Given the variables in size and location, diagnosis can be difficult, resulting in many PMFs being underestimated or missed [5]. An external rotation-lateral view of the ankle may help increase diagnostic yield [18]. Two-dimensional imaging has been demonstrated to be a useful tool in the detection of occult fragments associated with tibial shaft fractures [19,20]. Perioperative CT provides more appropriate assessment and visualization of PMFs. Therefore, CT is recommended in combination with plain radiography for the diagnosis and measurement of fragment size, articular impaction, and comminution [5].

PMFs may be overlooked in this setting, while more obvious and painful tibial shaft fractures are addressed. Hou et al [21] concluded that CT or magnetic resonance imaging (MRI) should be conducted in this setting after a detection rate as low as 32–64% was found using only plain radiographs.

PMFs not only affect joint articular surface congruency but also cause syndesmotic instability in coronal and sagittal planes. However, syndesmotic injury can be fixed by standard trans syndesmotic fixation, which has a high rate of syndesmotic malreduction (52%) [22]. Fixation of the posterior malleolus was biomechanically superior to syndesmotic screw fixation in the Ogilvie-Harris et al [6]. cadaveric study. Miller et al [13]. compared the functional outcomes of 3 groups with open posterior malleolus fixation, locked syndesmotic screws, and combined fixation, and concluded that syndesmotic fixation through the posterior malleolus is at least equivalent to syndesmotic screws. Patients who receive a syndesmotic screw may undergo additional fixation of the posterior malleolus fragment, showing that 16–36% of syndesmotic screws may be unnecessary [23]. Whether or not avoidance of syndesmotic fixation after fixation of PMFs is clinically feasible would require a random clinical trial with long term follow-up, and could have a huge impact on management of syndesmotic diastasis in PMFs.

Operative indications for surgical treatment of PMFs are not currently well defined. Most orthopaedic surgeons consider 2 main indications for surgical fixation of the posterior malleolus: where the ankle is considered unstable, and there is a posterior fragment larger than 25-33% of the articular surface of the plafond, and/or there is greater than 2 mm displacement after fibular reduction [8,13,24]. In the most recent meta-analysis, no consensus was found in the literature regarding what fragment size in PMF should be fixed, supported by the report of Gardner et al. [24], who observed great variation among surgeons [16]. Two authors stated that fragments smaller than 25% need not be fixed when anatomical reduction is acceptable, while Langenhuijsen et al [14]. stated that anatomical reduction should be achieved when the fragments are larger than 10% of the tibial articular surface [15,19].

Our modified classification of PMFs emphasized ankle stability rather than fragment size, challenging traditional operative indications. In our cases, satisfactory outcomes of fracture fragments larger than 25% were achieved without an internal fixation, demonstrating that even large posterior fragments do not have to be fixed if there is no sagittal plane instability. Ankle stability should be assessed using preoperative initial injury radiographs and intraoperative fluoroscopic images to aid in decision-making on whether to operate on PMFs. The posterolateral approach is a workhorse for fixation of PMFs, and was frequently used in the present study. Most PM avulsion fractures can be treated nonoperatively with success. However, taking into account the biomechanics of the syndesmosis, Weening and Bhandari [23] recommend the fixation of all posterior malleolus fragments. This may be due to the superior Syndesmotic stability obtained through fixation of the posterior malleolus compared to the use of trans-syndesmotic screw fixation, as reported in the cadaveric study of Gardner et al., wherein fixation of the PMF restored 70% of syndesmotic stability, compared with 40% through syndesmotic screw fixation [22]. Syndesmotic reduction plays a significant role in contributing to functional outcome; even minimal displacement may lead to posttraumatic arthritis [23,25]. This suggests that anatomic reduction of all displaced PMFs can prevent posterior talus subluxation and restore articular congruency to minimise posttraumatic osteoarthritis and improve the prognosis of trimalleolar fractures [26]. However, we found no consensus in the literature on the treatment of syndesmotic injury. Our study demonstrated that stable syndesmosis can be achieved after fixation of PMFs under intraoperative image intensifier screening (Fig. 6).
Weber C distal fibular fracture with syndesmotic diastasis on initial injury radiographs with coronal and sagittal plane instability. (B) CT scans showing posterior rim fracture (type IV) with fragment impaction. (C) Intra operative II images showing there is no syndesmotic diastasis after anatomic reduction and fixation of PMFs.

We believe posterior malleolus fixation is more accurate and more stable than syndesmotic screw fixation. We are awaiting long-term follow up outcomes for those patients who had anatomic reduction and fixation of the posterior malleolar fragment without syndesmosis transfixation.

A variety of different approaches have been described for fixation of the posterior malleolus: the medial, posteromedial, posterolateral-lateral transmalleolar approaches, and the use of percutaneous anterior to posterior screws. Many factors such as the type and size of the PMF, ankle stability, and the height of the fibular fracture line should be considered when choosing the best approach. The most important factor to consider is the location of the fracture fragment; a deep position can be difficult to access. Incorrect approach often results in malrotation of the posterior malleolus, especially if reduction is not performed under direct vision.

The medial approach is suitable for the medial fragment. Approximately 40% of the PMF lines extend into the medial malleolus. The medial approach though the posterior location of the tarsal tunnel might cause irritation of the structure in the tunnel, especially the tibialis posterior tendon. We have developed a novel posteromedial approach without disturbing the tibialis posterior tendon: sub periosteal dissection of the posteromedial fragment, proceeding to elevate the tibialis posterior tendon sheath and periosteum together, while retracting laterally to expose the posterior malleolus fragment, allowing screw fixation with countersink. Repair of the periosteum was meticulously performed at the end of surgery. However, fixation of the medial fragment side is not stable and displacement may occur during screwing. The posteromedial approach is suitable for large posteromedial based fragments, which allow fixation of the posterior and medial malleoli from the same incision. The skin incision follows the posteromedial border of the distal tibia and medial malleolus and continues in line with the tibialis posterior tendon toward the talonavicular joint.

Direct reduction and fixation of the posterior malleolus using a posterolateral approach allows appropriate visualization and stable fixation, with studies demonstrating satisfactory clinical outcomes [29,30]. The longitudinal skin incision is made over the interval between the posterior border of the fibula and the lateral border of the Achilles tendon. The posterior malleolus fragment is accessed and fixed via the interval between the peroneus brevis and flexor hallucis longus. This incision has the added benefit of allowing simultaneous reduction and fixation of the lateral malleolus. The approach allows adequate fixation of posterosmedial fragments but provides poor access to the posterior malleolus corner and the medial aspect of the medial malleolus.

The majority of PMFs are avulsed; therefore, most will reduce spontaneously after the fibular fracture is reduced. The traditional method for fixation of the posterior malleolus utilized the anterior approach, with indirect reduction and an anteroposterior screw. Ligamentotaxis is used to reduce the posterior malleolus in the presence of an attached and intact PITFL [23]. (Fig. 7)
However, this type of reduction cannot always ensure adequate articular reduction and malrotation correction in PMFs.

We used at least 3 cannulated screws in triangle configuration, which is recommended in fixation of femoral neck fractures [31]. However, a biomechanical study is required to confirm this claim. The buttress plate maintains reduction, prevents superior migration of the fragment, and can be placed in the intramuscular plane through the posterolateral approach, thus causing less irritation. Excessively large or crushed fragments can be fixed with screws in combination with the support plate, with external fixation or traction as required.

In conclusion, ankle coronal stability largely depends on medial, lateral, and posterior structures. However, the sagittal stability is mainly provided by the posterior malleolus. Therefore, we should restore posterior constraints to maintain sagittal stability and the articular congruity. Our study and resultant classification system accurately describes PMF types encountered in clinical practice and provides a guide for best surgical management.

Author contributions and conflict of interest declaration

All authors were responsible for writing and proof reading of the manuscript and are in agreement with the contents of this paper. None of the authors received any funds, grants for this paper. There is no conflict of interest to declare.

References


