Typology of Posterior Malleolus Fractures of the Ankle - A Surgical Management View

Research Article

Mayank M1, Trappel J1, Hyde-Page M2, Maruo Holledge M3, Lu J3,4*

1 Department of Orthopaedic Surgery, John Hunter Hospital, Newcastle, NSW, Australia.
2 School of Medicine, University of Newcastle, Australia.
3 Department of Orthopaedic Surgery, Manning Hospital, NSW, Australia.
4 Department of Orthopaedics, United Family Hospital, Beijing, 100016, China.

Abstract

**Objectives:** Although historical studies frequently classify posterior malleolus fractures (PMFs) according to fragment size, none of them have provided guidelines for surgical decision-making, and optimal management of PMFs. This study aims to classify PMFs based on preoperative computed tomographic (CT) scans, initial injury radiographs, and intra-operative image intensifier (II) screening.

**Methods:** Between 2013 and 2015, 40 consecutive patients with bi- or tri-malleolar fracture/dislocation of ankle joints, with one or more posterior fragments, were treated at our institute. All patients had preoperative initial injury radiographs and intra-operative II, and preoperative CT scans. We reviewed the patients' preoperative initial injury radiographs, CT scans, and II data to determine the stability of the ankle joints in coronal and sagittal planes, and classified the PMFs.

**Results:** 40 fractures have been categorised into three types: Type I fracture is an isolated PMF with and without sagittal plane instability. This is further sub-classified into two depending on the fracture pattern noted on the CT. Type II fracture is either a bi or tri-malleolar fracture, associated with a Weber B or Weber C fracture pattern. These are further classified depending on the presence or absence of syndesmotic diastasis. Type III fracture is a PMF associated with an ipsilateral tibial diaphyseal fracture, which is further subdivided based on sagittal or coronal plane instability.

**Conclusions:** Bi- or tri-malleolar fractures of the ankle with associated posterior malleolar fractures appear to be highly variable. We identified certain types of PMFs which we can categorise. Ankle stability in the coronal and sagittal planes on initial injury radiographs, intra-operative II and preoperative CT scans are critical for the classification of PMFs and we use this classification to decide how to manage PMFs, regardless of fragment size.

**Keywords:** Posterior Malleolus; Tri-Malleolar; Ankle Fracture; Classification; Stability of Ankle; Outcome; Internal Fixation.

Introduction

Posterior malleolus fractures (PMFs) are relatively common ankle injuries. The most common of these are tri-malleolar ones with an incidence of approximately 7-14.2% [1, 2]. Isolated fractures of the postero-lateral tibial lip (Volkman’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 appears 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 tibio-fibular ligament (PITFL). This has been demonstrated through cadaver studies to contribute 42% to syndesmotic stability [5, 6]. Ankle fractures involving the posterior malleolus are said to have worse clinical outcomes because of articular surface incongruity and the resultant development of post-traumatic arthritis [5, 7]. However there is no consensus on how to best evaluate ankle stability following fracture, either radiologically or clinically. There is no clear guide to deciding the best way to reduce and stabilise the posterior tibial malleolus. This study proposes a review of patterns for PMFs using a combination of initial injury radiographs with CT scan findings, and intra-operative II screening.
ing, aiming to provide a guide for best surgical management.

Material and Methods

Ethical approval for the study was obtained from the two institution review boards. We retrospectively analysed the plain radiographs and CT scans of 40 patients with a posterior malleolar fracture, to two institutions. These were a tertiary level major trauma centre and a rural referral hospital. Radiographs and operative notes for all patients who underwent ankle operative fixation in the two institutions between June 2013 to September 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, prior to operation and post reduction of fracture, were reviewed. CT scans were analysed to shed more light on the fracture patterns and for evidence of syndesmotic injury. The aim was to analyse the various fracture patterns of the PMFs, and their Pilon variants, in order to formulate a comprehensive classification system. Indications for ORIF as per the radiographs and CT scans were noted, including the fragment ratio and articular impaction of the PMFs. The type of fixation as shown by intra-operative and postoperative radiographs and patient operative notes was analysed.

Out of the 40 patients, 18 were male and 22 female. The average age was 44.24 years (range, 14 to 86). Of these, all patients had a pre-operative CT to assess fracture pattern, and 35 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 (20 out of 40 patients). Screw fixation of the PM was seen in 11 patients, while 4 patients had a combination of plate and screw fixation. A postero-lateral approach was used in 24 patients and postero-medial approach in 5 patients. A combination of postero-medial and postero-lateral approach was utilised in 6 patients. The decision for the surgical approach was made according to the fracture pattern and according to the surgeon preferences.

An extensive literature search was then performed, using MEDLINE (1996 to present), PubMed and Cochrane databases of systematic reviews, to find journal articles referring to posterior malleolar fractures. Keywords used were ankle fractures, tri-malleolar, posterior malleolus, outcome, and internal fixation. Search results were limited to humans and articles in English language.

Results

All patients had preoperative radiographs CT scans preoperative planning, and those with a dislocation or subluxation had an additional post-reduction radiograph prior to surgical fixation. Preoperative initial injury radiographs were carefully analysed for fracture patterns which 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 in AP and mortise views; 3) presence of the double contour sign, indicating a postero-medial fragment; 4) articular fragment size; 5) associated fibula fracture classified as per Weber classification.

A total of 40 patients from the cohort had CT scans, which were used to analyse fracture patterns, and compared with initial injury radiographs. CT scans were 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 related to articular impaction or depression.

A combination of initial injury plain radiographs and CT scans were used to make a classification of the PMFs, to aid in their operative management. The system was partly based on the CT classification proposed by Haraguchi et al., [8] The initial injury radiographs of AP, lateral, and mortise views were used to classify the fibula fractures as per the Danis [9], Weber [10] and Lauge-Hansen [11] classifications. The classification of PMFs based on CT scans is presented in Table 1. In this study of 40 patients, 20 cases are PL (postero-lateral oblique fracture), 5 cases are postero-medial-anterior (PMA) fracture, 10 cases are postero-lateral (PL) fracture extending to postero-medial (PM) fracture (PL + PM), and 5 cases are posterior rim (PR) fracture patterns (Table 1).

We subsequently used the following modifiers to further classify the PMFs: 1) presence of syndesmotic injury as determined by pre-operative initial injury radiographs, CT or intra-operative II screening, 2) presence of associated fibula fracture classified as per Danis [9], Weber [10] and Lauge-Hansen [11], and 3) evidence of sagittal or coronal plane instability as determined by preoperative radiographs and CT, particularly any evidence of tibio-talar subluxation or dislocation on the sagittal plane. This new, modified classification system can be used to decide the management of the PMFs (Table 2).

This can be summarised as follows: Type I fractures include some isolated PMFs or PMFs with non-displaced malleoli fractures, with or without (B or A) sagittal plane instability on initial injury radiographs. Non-displaced medial or lateral malleolus fractures may be present but with no coronal plane instability. These are further sub-classified depending on the fracture pattern noted on CT (as per the classification system mentioned above) as A1, A2, B1, and B2. I-A1 are posterior rim or PITFL injuries alone. These do not usually require surgical management, unless there is a syndesmosis instability under II screening. I-A2 fractures are PMFs of displaced PL, PMA, PL+PM on CT scans. Although there are no sagittal plane instabilities, and with no displaced malleoli fractures, these displaced PMFs need to be fixed surgically. I-B1 are either non-displaced PMFs or PR types, and they do not require surgical fixation of the PMFs, even though there are sagittal plane instabilities. I-B2 are displaced PMFs of PL, PMA, PL+PM which need to be managed surgically by fixation.

Type II fractures include either bi or tri-malleolar fractures associated with a Weber B (A), or Weber C (B), fracture pattern. These are further classified depending on the presence or absence of syndesmotic injury. Basically PMFs without syndesmotic diastase, or PR type, can be managed without fixing the PMFs. If syndesmotic diastasis is present, either on initial injury radiographs, or intra-operative II, syndesmotic fixation is mandatory, in addition to PMF fixation. However when the PMF height is less than 1 cm, fixation with plate or screws may not be achievable, and those cases have to be managed by syndesmosis screws.

Type III are PM fractures associated with an ipsilateral tibial diaphyseal fracture. They are further subdivided into two. Type IIIA include cases with no sagittal or coronal plane instability and PR type. These cases can be managed without fixation of the PMFs.
Table 1. A combination of initial injury plain radiographs and CT scans were used to see a typology of the PMFs. The system was partly based on the CT classification proposed by Haraguchi et al.[8]

Type IIIB is for surgical fixation of PMFs of PL, PMA, PL+PM type with more than a 2 mm articular step, if they are unable to be reduced closely, or with sagittal instability.

In terms of the fixation of the PMFs, our preferred method involves two or three screws in a parallel position to enhance the lag screw effect. An inverted triangular configuration of the lag screw placement was most commonly used in our cases (Figure 1). Postero-lateral fractures can be fixed using a postero-lateral approach. Presence of an additional posteromedial fragment may require an additional posteromedial approach.

If AP radiographs showing the double contour sign indicate an additional postero-medial fragment (Figure 2), we recommend CT evaluation, in order to ascertain the exact fracture pattern, its displacement and comminution, articular impaction and fragment size. In most PMF cases, the PITFL tends to stay intact. Therefore, with secure fixation of the PMFs, we can stabilise the syndesmosis [12, 13]. However we recommend that intra-operative screening under image intensifier should always be performed after stabilising the PMFs to rule out any possibility of occult syndesmotic diastasis.

Discussion

PMFs and syndesmotic instability/incongruity

PMFs lead to ankle instability and incongruity through PITFL disruption causing post-traumatic arthritis, as confirmed by Launenhuijzen 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 patho-mechanical determinants of post-traumatic arthritis [16]. We agree that the postero-anterior (sagittal plane) instability caused by PMFs, with secondary medial lateral instability (coronal plane), is a far more important patho-mechanical cause of post-traumatic arthritis.

PMFs not only affect joint articular surface congruency, but also cause syndesmotic instability in the coronal and sagittal planes. Although syndesmotic injury can be treated by standard trans-syndesmotic fixation, which has a high rate of syndesmotic mal-reduction (52%) [25], fixation of the posterior malleolus was biomechanically superior to syndesmotic screw fixation in Ogilvie-Harris et al’s [6] cadaveric study. When Miller et al., [13] compared the functional outcomes of three groups with open posterior malleolus fixation, locked syndesmotic screws and combined fixation; he concluded that syndesmotic fixation through the posterior malleolus is at least equivalent to that with syndesmotic screw. 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 [26]. Whether or not avoidance of syndesmotic fixation, after treatment of PMFs, is clinically feasible would require a random clinical trial with a long term follow-up, which could have a huge impact on the management of syndesmotic diastasis with PMFs.

We can further explain the PMF stages as follows. Stage I: involves non displaced PMFs with no syndesmotic diastasis, usually no sagittal plane instability. Stage II: PMF fragment hinged on 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 or pronation - external rotation plus axial forces causing rupture of anterior inferior tibi
Table 2. We utilised typology of Figure 1 and modified to further classify the PMFs: 1) presence of syndesmotic injury as determined by pre-operative initial injury radiographs, CT scan, or intra-operative II screening, 2) presence of associated fibula fracture classified and 3) evidence of sagittal or coronal plane instability, particularly any evidence of tibio-talar subluxation or dislocation on the sagittal plane. This new, modified classification system can be used to decide the management of the PMFs.

**Type 1: PMFs with or without non-displaced malleoli fractures.**

| A | No Sagittal plane instability |
|---|-------------------------------|
| IA1 | PL type of PITTFL injury alone | Non-surgical management or fixation of syndesmosis after intra-operative II screening |
| IA2 | Displaced PL, PMA, PL+PM type and failed closed reduction | Surgical fixation |

| B | Sagittal plane instability |
|---|-----------------------------|
| IB1 | Non-displaced PMFs or PR type | Non-surgical management |
| IB2 | Displaced PL, PMA, PL+PM type | Surgical fixation |

**Type 2: displaced bi- or tri-malleolar fractures with sagittal plane instability.**

| A | Weber B lateral malleolar fracture |
|---|----------------------------------|
| IA1 | Without syndesmotic diastasis or RP type | Non-surgical management |
| IA2 | Syndesmotic diastasis, and/or displaces PL, PMA, PL+PM type | Surgical fixation +/- Syndesmosis fixation |

| B | Weber C lateral malleolar fracture |
|---|----------------------------------|
| IB1 | Without syndesmotic diastasis or Non-displaced PMFs or BP | Non-surgical management |
| IB2 | Syndesmotic diastasis, and/or displaces PL, PMA, PL+PM type | Surgical fixation +/- Syndesmosis fixation |
Type 3: PMFs with diaphysial fracture of ipsilateral tibia.

| Type | Description                                                                 | Surgical Management                        |
|------|------------------------------------------------------------------------------|--------------------------------------------|
| IIIA | PR type, no sagittal and coronal instability on initial injury radiographs or intra-operative I.I | Non surgical management                    |
| IIIB | PL, PMA, PL+PM type with > 2 mm articular step, unable to be reduced closely or with sagittal instability | Surgical fixation +/- Syndesmosis fixation* |

Figure 1. Our preferred method to fix PMFs is an inverted triangular configuration of the lag screw placement.

Figure 2. AP radiographs showing the double contour sign indicate an additional postero-medial fragment. The postero-medial fragment was fixed by our novel postero-medial approach.

Figure 3. A variety of different approaches have been described for fixation of the posterior malleolus including the percutaneous anterior to posterior screws. It uses ligamentotaxis to reduce the posterior malleolus in the presence of an attached and intact PITFL. However this type of reduction cannot always ensure adequate articular reduction and malrotation correction in PMFs.
ofibular ligament (AITFL), distal fragment of fractured fibula shifting anteriorly or posteriorly on the sagittal plane, that can also be externally or internally rotated depending on the foot position at the end of the injury (as determined from CT scans for rotational profile of distal fibula). This stage is always combined with sagittal and/or coronal plane instability. Thus, careful viewing imaging data for PMFs with syndesmotic instability or incongruity is required.

**Guideline for surgical decisions regarding PMFs**

Operative indications for surgical treatment of PMFs are not currently well defined. Most orthopaedic surgeons consider two main indications for surgical fixation of the posterior malleolus, where the ankle is considered unstable and a posterior fragment larger than 25-33% of the articular surface of the plafond and/or greater than 2 mm displacement after fibular reduction [8, 13, 19, 27].

In the most recent meta-analysis no consensus was found in the literature regarding which fragment sizes of PMFs should be fixed, as supported by Gardner et al., [27] who observed great variation between surgeons [16]. Two authors found that fragments smaller than 25% needn’t be fixed when anatomical reduction is acceptable, while Laungenhuijsen et al., [14] found that anatomical reduction should be achieved when the fragments are larger than 10% of the tibial articular surface [15, 20].

Our modified classification of PMFs emphasized ankle stability rather than fragment size, challenging traditional operative indications. Ankle stability should be assessed using preoperative initial injury radiographs and intra-operative II images that would be helpful in decision-making about whether to operate on PMFs. The postero-lateral approach is a workhorse for PMF fixation treatment, more frequently used in literature and the present study.

Haraguchi et al., [8] classified PMFs, based on the orientation of the fracture line, as postero-lateral oblique type (67%), mediolateral extension type (19%), and small-shell type (14%). The study did not produce guidelines for surgical decision-making. Based on our modified classification of PMFs, we can also detect postero-lateral fractures extending postero-medially. We made a classification with correlating types B and C of the Danis-Weber system. Other classifications such as the Lauge-Hansen classification [9-11] do not evaluate the severity of fracture, and they are therefore not prognostic. Our stability-based PMF classification system would be more practical for guiding surgical decision making.

Method of reduction do not always include internal fixation, showing the mechanism of ligamentotaxis can be effective in maintaining joint congruity [14]. Harper's [28] cadaveric study has shown that if the fibula is in a stable anatomical position, no postero-talar subluxation will occur and therefore PMFs need not be fixed. Most avulsion fractures can be treated non-operatively with success. However, taking into account the biomechanics of the syndesmosis, Weening and Bhandari [26] recommend the fixation of all posterior malleolus fragments. This may be due to superior syndesmotic stability obtained through fixation of the posterior malleolus over the use of trans-s Syndesmotic screw fixation, as demonstrated by Gardner et al.'s cadaveric study where fixation of the PMF restored 70% of syndesmotic stability compared with 40% through syndesmotic screw fixation [25]. Syndesmotic reduction plays a significant role in contributing to functional outcome as even minimal displacement may lead to post-traumatic arthritis [26, 29]. This suggests that anatomic reduction of all displaced PMFs can prevent posterior talar subluxation and restore articular congruency to minimize post-traumatic osteoarthritis and improve the prognosis of tri-malleolar fractures [30]. However, we found no consensus in the literature on the treatment of syndesmotic injury. We believe posterior malleolus fixation is more accurate and more stable than syndesmotic screw fixation. We are awaiting the long-term outcomes for those patients who have had anatomic reduction and fixation of the posterior malleolar fragment, without syndesmosis transfixation.

**Surgical approach**

A variety of different approaches have been described for fixation of the posterior malleolus: the medial approach, postero-medial approach, postero-lateral trans-malleolar approach and the percutaneous anterior to posterior screws (Figure 3).

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 because its deep position can be difficult to access. Incorrect approach often results in malrotation of the posterior malleolus, especially if reduction is not under direct vision. The medial approach is suitable for the medial fragment. Approximately 40% of the posterior malleolus fracture lines extend into the medial malleolus. The medial approach through the posterior location of the tarsal tunnel may cause irritation to the structure in the tunnel, especially the tibialis posterior tendon. We have developed a novel postero-medial approach without disturbing the tibialis posterior tendon: subperiosteal dissection of the postero-medial fragment, proceeding to elevate the tibialis posterior tendon sheath and periosteum together, while retracting laterally to expose the posterior malleolus fragment, allowing a screw fixation with countersink. Repair of the periosteum was meticulously performed at the end of surgery (Figure 2). The postero-medial approach is suitable for large postero-medial biased fragments, which allow fixation of the posterior and medial malleoli from the same incision. The skin incision follows the postero-medial border of the distal tibia and medial malleolus, and continues in line with the tibialis posterior tendon, toward the talonavicular joint. Bois and Dust's [31] retrospective study demonstrated the satisfactory short and mid-term clinical results of this technique. However this approach allows limited visualisation of the posterior malleolus fragment, and an additional postero-lateral approach may be required if the posterior malleolus is split into two parts.

Direct reduction and fixation of the posterior malleolus, using a postero-medial approach, allows appropriate visualisation and stable fixation, with studies demonstrating satisfactory clinical outcomes [32, 33]. The longitudinal skin incision is made above 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. This approach allows adequate fixation of postero-medial 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 be reduced spontaneously after the fibular fracture is reduced. The traditional method for fixation of the posterior malleolus utilises the anterior approach, using indirect reduction and an anteroposterior screw. It uses ligamentotaxis to reduce the posterior malleolus in the presence of an attached and intact PITFL [26] (Figure 3). However this type of reduction cannot always ensure adequate articular reduction and malrotation correction in PMFs.

Our study showed that anti-glide plate fixation vs. screw only fixation could achieve equally rigid fixation in terms of a one year follow-up. We used at least three cannulated screws in a triangle configuration, as recommended in the fixation of neck of femur fractures [34]. 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 used as required.

**Diagnosis of PMFs**

The PMFs can range in size from small extra-articular fragments to some comprising more than 40% of the articular surface of the tibia [8]. Conventional plain radiography (i.e. AP, mortise, and lateral) is still necessary in the primary diagnosis and estimation of fragment size, especially with a fracture of the dorsal tibial margin, which is best seen in the standard lateral view [17]. Given the variables in size and location of PMFs, diagnosis can be difficult, and result in many PMFs being underestimated or missed [5]. A lateral view with external rotation of the ankle may help increase diagnostic yield [18]. Plain radiographs of the ankle may underestimate the size of the fragment, and make it difficult to estimate the percentage of the joint surface affected. In addition, it is difficult to find occult posterior malleolus fragments, due to the high fracture line variability and lack of regulation [8, 19]. This can lead to worse clinical outcomes through delays in appropriate operative management.

Although pre-reduction radiographs for fractures that were dislocated/subluxed provide a wealth of information regarding the possibility of sagittal or coronal instability, and the presence of syndesmotic injury, CT scan do not have images of lines overlapping and therefore show greater accuracy for detection. Three-dimensional imaging has been demonstrated to be a useful tool in the detection of occult fragments associated with tibial shaft fractures [20, 21]. Perioperative CT scans provide more appropriate assessment and visualisation of PMFs; they can detect the greatly varied fracture lines that X-ray cannot distinguish. Therefore CT scans are recommended, in combination with plain radiography, for the diagnosis and measurement of fragment size, articular impaction and comminution [5].

Tibial shaft fractures, commonly spiral low-energy fractures of the distal third of the tibia, are often associated with occult posterior malleolus fractures, though the exact prevalence is difficult to assess due to low detection rates. PMFs may be overlooked in this setting, while addressing the more obvious and painful tibial shaft fractures. Stuerman et al., [22] suggested that additional attention should be paid to the ankle in the presence of the following criteria: indirect trauma with a rotation component or pronation- eversion trauma, spiral fractures of the tibia in the distal third, and tibial shaft fractures associated with a fracture of the fibula in the proximal third or an intact fibula. These indications provide a guide to increasing diagnostic suspicion, and therefore do not replace appropriate radiographic examination.

Hou et al., [23] concluded that a CT or MRI should be conducted in this context after a detection rate as low as 32-64% was found using only plain radiographs. A “communication line” seen on plain radiographs, connecting the medial inferior apex of the spiral tibia fracture line with the posterior superior apex of the posterior malleolus fracture, may be a useful diagnostic clue [21]. Perioperative use of CT scans may prompt identification of PMF type and assist in surgical decision-making around stabilisation [24].

**Conclusion**

In conclusion, ankle coronal stability largely depends on medial, lateral, and posterior structures, and 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 practice surgical management.

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