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Pathoanatomy and Associated Injuries of Posterior Malleolus Fracture of the Ankle

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Abstract

Background: We present a classification system that progresses in severity, indicates the pathomechanics that cause the fracture and therefore guides the surgeon to what fixation will be necessary by which approach.

Methods: The primary posterior malleolar fracture fragments were characterized into 3 groups. A type 1 fracture was described as a small extra-articular posterior malleolar primary fragment. Type 2 fractures consisted of a primary fragment of the posterolateral triangle of the tibia (Volkmann area). A type 3 primary fragment was characterized by a coronal plane fracture line involving the whole posterior plafond.

Results: In type 1 fractures, the syndesmosis was disrupted in 100% of cases, although a proportion only involved the posterior syndesmosis. In type 2 posterior malleolar fractures, there was a variable medial injury with mixed avulsion/impaction etiology. In type 3 posterior malleolar fractures, most fibular fractures were either a high fracture or a long oblique fracture in the same fracture alignment as the posterior shear tibia fragment. Most medial injuries were Y-type or posterior oblique fractures. This fracture pattern had a low incidence of syndesmotic injury.

Conclusion: The value of this approach was that by following the pathomechanism through the ankle, it demonstrated which other structures were likely to be damaged by the path of the kinetic energy. With an understanding of the pattern of associated injuries for each category, a surgeon may be able to avoid some pitfalls in treatment of these injuries.

Level of Evidence: Level III, retrospective comparative series.

Keywords: ankle fracture, posterior malleolar, classification

Introduction

Posterior malleolar fractures of the ankle have been reported to occur in more than 40% of ankle fractures.[18] This incidence has been increasing especially in women over the age of 65.[3] A number of studies have reported clinically poorer outcomes in ankle fractures that have sustained a posterior malleolar fracture.[18,29] However, many published studies of these fractures have been limited by considering them to be one homogenous group.[*]

Several papers have considered the effect of size of the fragment as a proportion of the tibial plafond. Biomechanically, the tibiotalar contact area significantly decreases as the size of the fragment surpasses 33%,[15,20] posterior subluxation significantly increases between 25% and 40%,[25,26] and the stress on the remaining joint increases.[9] The size of the fragment has not been demonstrated to correlate with the functional outcome.[6,11,23,31] It has been suggested that the unevenness in reduction and increased fragment size may be related to posttraumatic arthritis[6,32]; however, fixation may not consistently improve the evenness, and radiographic arthritis may not correlate to a clinically significant difference in function.[6]

Attempts have been made to categorize these fractures by the pathoanatomy of their primary fracture fragment.[2,13,21] The clinical relevance of these systems is limited, however, by their failure to understand the posterior malleolar fracture

[*]References 1, 4, 5, 10, 14, 27-30, 32, 34, 35.

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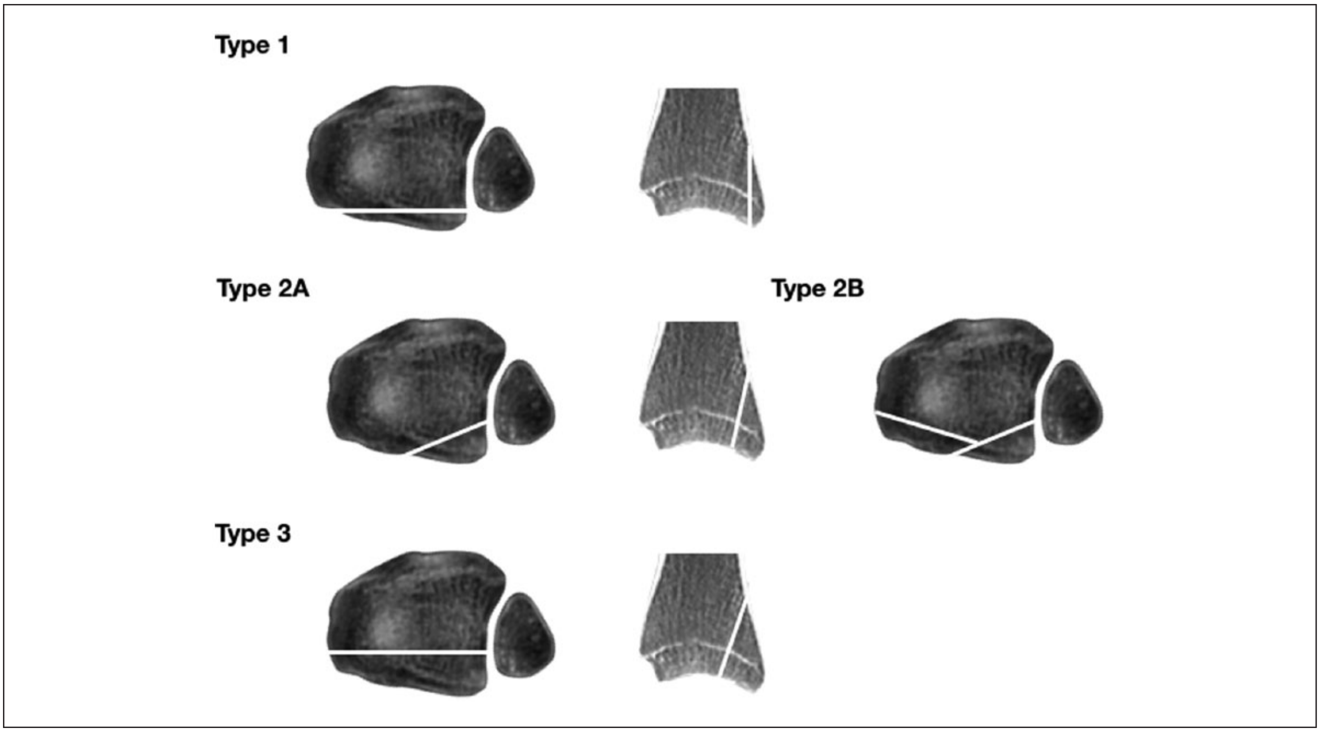

Figure 1. Schematic representation of the different types of posterior malleolar fractures. Axial CT view 5 mm proximal to tibial plafond, and sagittal CT view 1 cm medial to the incisura.

fragment in relation to the pathomechanism and how it integrates into the pattern of the ankle injury as a whole.

Our aim in this study was to identify the injury patterns sustained in combination with posterior malleolar ankle fractures and to integrate this with pathomechanisms to further understand the injury. We have hypothesized 3 distinct pathomechanics groups, related to the anatomy of the ankle complex to explain the 3 primary fracture lines that were observed.

Methods

Between June 2014 and March 2017, we prospectively collected data on 121 consecutively treated patients that attended our unit having sustained a posterior malleolar fracture. It is well recognized that plain radiographs underestimate posterior malleolar fractures,[8] and CT scans are routine for these fractures in our institution as the posterior malleolus is commonly underestimated on radiographs.[22] All radiographs and CT imaging were analyzed using digital imaging software (Vue PACS, Carestream, Version 11.4.1.0324). There were 121 patients included in this study. Within this patient group, there were marginally more women than men (72 females [60%] and 49 males [40%]). The left ankle was more commonly injured than the right (66 left [55%], 55 left [45%]). The average age of this cohort of patients was 48 (range 17-90).

The primary fracture fragments were characterized into 3 groups dependent on a theorized mechanism of injury (Figure 1). A type 1 fracture was described as an extra-articular posterior malleolar primary fragment, sustained by avulsion from the distal posterior tibial cortex by the pull of the posterior inferior tibiofibular ligament (PITFL).[7] The mechanism of this injury was theorized to occur with the ankle in plantarflexion with an unloaded talus and a rotational force applied to the foot. A type 2A fracture consisted of a primary fragment of the posterolateral triangle of the tibia (Volkmann area) extending into the incisura, sustained by the impact of a rotating talus on the tibial plafond (Figure 2). The mechanism of this injury was theorized to occur with the ankle in neutral to plantarflexion, with a loaded talus and a rotational force applied to the foot. If the talus continues to rotate in the mortise, a secondary fragment on the posteromedial aspect of the tibia is produced, usually at a 45° angle to the primary fragment (type 2B). A type 3 primary fragment was characterized by a coronal plane fracture line involving the whole posterior plafond. The mechanism was of the typical posterior pilon fracture with axial loading of a plantarflexed talus.

The cases were anonymized, blinded, and radiographically categorized by 2 blinded foot and ankle consultants. Inter-observer reliability was assessed using Cohen's kappa coefficient. Associated patterns of fracture in the tibial plafond, the medial malleolus, the fibula and diastasis of the

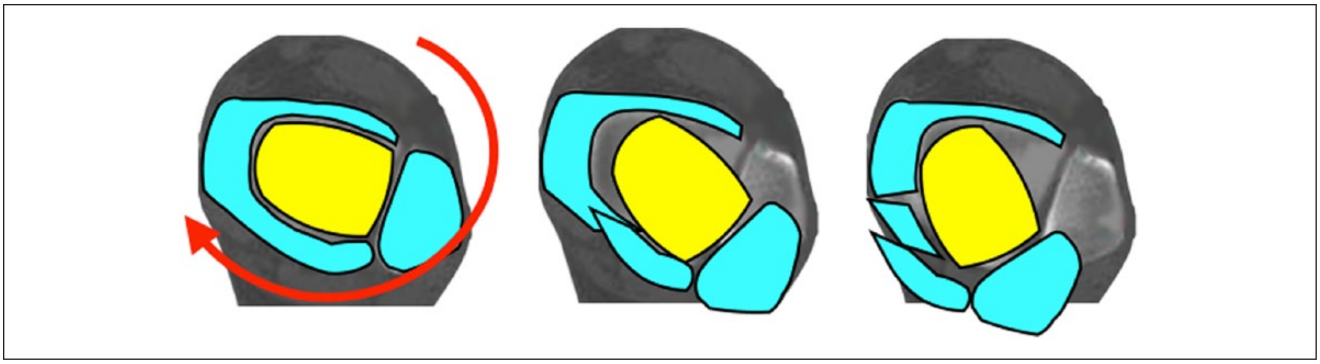

Figure 2. An illustration of the pathomechanics of a type 2 posterior malleolar fracture, where the loaded talus pushes off the posterolateral corner of the tibia when rotated in the conforming tibial plafond. With continued rotation, the posteromedial corner is also fractured as a separate fragment.

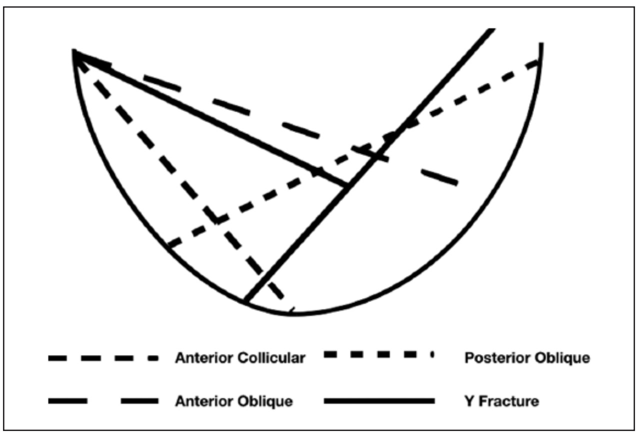

Figure 3. Medial malleolar variability showing the differing fracture patterns.

syndesmosis were noted for each fracture. The medial malleolar fracture configuration was quite variable. Despite the attempt by Herscovici Jr et al[16] at classifying medial malleolar fractures, only the small avulsion fracture (which we term an anterior collicular fracture) was persistently comparable with our series. We categorized the larger fracture fragments into anterior oblique and posterior oblique fractures, which were comparable with the Herscovici Jr type B and C fractures. A separate fracture configuration was a Y shape fracture theoretically caused by a push off posterior fragment and a separate avulsion anteromedially. This variability is illustrated in Figure 3. Medial ligamentous injuries were identified by medial clear space widening of 4 mm without medial malleolar fracture.

The fibular fracture was categorized to low (at or below the syndesmosis), high (above syndesmosis), or long oblique (spans from syndesmosis to above in a long oblique configuration). Syndesmotic diastasis was defined as >5 mm gap between fibula and incisura on CT, as previously described by Yeung et al.[33]

Table 1. Fibular Fracture Anatomy Associated With Posterior Malleolar Fracture Type.[a]

	Fibular Fracture			
Fracture Type	None, n (%)	Low, n (%)	Long Oblique, n (%)	High, n (%)
I	2 (5)	29 (71)	4 (10)	6 (14)
II	4 (7)	31 (56)	8 (15)	12 (22)
III	1 (4)	10 (40)	7 (28)	7 (28)

[a]Percentage given of fibular fracture type per posterior malleolar fracture type.

Table 2. Syndesmotic Injury Associated With Posterior Malleolar Fracture Type.[a]

	Syndesmosis Injury		
Fracture Type	None, n (%)	Full Syndesmotic Injury, n (%)	Posterior, n (%)
I	0	31 (76)	10 (24)
II	28 (51)	16 (29)	11 (20)
III	20 (80)	5 (20)	0

[a]Percentage given of syndesmotic injury type per posterior malleolar fracture type.

Results

When categorized by primary fracture fragment, of the 121 cases, 41 (34%) were type 1, 55 (45%) were type 2, and 25 (21%) were type 3. Of the type 2 fractures, 25 (45%) were the 2B variant, with the presence of a secondary posteromedial fragment. The Cohen's kappa coefficient for interobserver reliability was 0.919. Tables 1 to 3 illustrate the associated injuries with each type of posterior malleolar fracture. Table 4 compares our proposed classification system with the Haraguchi et al classification.[13]

Table 3. Medial Malleolar Fracture Anatomy Associated With Posterior Malleolar Fracture Type.[a]

	Medial Malleolar Fracture					
Fracture Type	Nil, n (%)	Deltoid Injury, n (%)	Anterior Collicular, n (%)	Anterior Oblique, n (%)	Posterior Oblique, n (%)	Y Fracture, n (%)
I	9 (22)	11 (27)	16 (39)	2 (5)	0	3 (7)
II	2 (4)	10 (18)	19 (34)	11 (20)	5 (9)	8 (15)
III	2 (8)	1 (4)	6 (24)	0	8 (32)	8 (32)

[a]Percentage given of medial malleolar fracture type per posterior malleolar fracture type.

Table 4. Comparison of Previous Haraguchi Classification System With Current Proposed Classification System.

Proposed Classification	Haraguchi Classification	Number
1	3	41
2A	1	30
2B	2	25
3	–	25

In type 1 fractures, most cases demonstrated a low fibular fracture (71%). There was a medial-sided injury in 78% of cases, and most injuries were either ligamentous or anterior collicular avulsions. This illustrates the avulsion injury pattern in this fracture type. The syndesmosis was disrupted in 100% of these cases, although approximately a quarter involved the posterior syndesmosis only.

In type 2 posterior malleolar fractures, the fibula fracture was again predominantly low (56%). There was a medial injury in 96% of cases, although these injuries were variable, in keeping with mixed avulsion/impaction etiology. There was syndesmotic diastasis in 49% of cases, with a large proportion being posterior syndesmosis.

In type 3 posterior malleolar fractures, most fibular fractures were either a high fracture or a long oblique fracture in the same fracture alignment as the posterior shear tibia fragment. Almost a third (28%) had no fibular fracture. There was a medial injury in 92% of cases, with only 1 (4%) being ligamentous. The majority, 16 (64%), were Y-type fractures or posterior oblique. This fracture pattern had a low level of syndesmotic injury (20%) with no solitary posterior syndesmotic diastasis, as the distal fibula went posteriorly with the posterior malleolar fracture. Figure 4 demonstrates 3-dimensional CT reconstructions of the 3 different types of posterior malleolar fractures.

Discussion

Our results clearly indicate that posterior malleolar fractures are variable in their nature, and as such should not be grouped together for analysis. Each fracture type had its own injury associations, which in themselves can determine the management and final outcomes of these fractures. On initial analysis, we attempted to use the Haraguchi et al classification[13] to assess the associated injuries; however, this did not address the injury mechanism and as such we have modified the classification as illustrated in Table 4. Our type 1 fracture is comparable to their type 3 small shell–type fractures. Our type 2A fractures are comparable to their type 1 fracture (a posterolateral-oblique type), and our type 2B fractures to their type 2 medial-extension type. We believe we have illustrated in this research that the Haraguchi type 1 (our proposed type 2A) is a "push-off" fracture and not an avulsion fracture as thought in the Haraguchi classification.[13] Our modification of the Haraguchi classification allowed better understanding of this injury as a rotational pilon fracture. The Haraguchi type 3 (our proposed type 1) is a PITFL avulsion fracture, which we believe has been significantly underestimated in the current literature. We have included true posterior pilon fractures in our classification as type 3 fractures, which were not included in the Haraguchi classification. Our fracture classification system progresses in severity, with type 3 fractures being worse than type 1, although this system's prognostic accuracy has not been addressed in this paper.

The value of this classification system is in its guidance of treatment. The knowledge of the mechanism and its associated injury patterns allows thorough treatment planning. With a type 1 injury, the fragment is extra-articular and often too small to fix with a screw. There is, however, in every case a syndesmotic diastasis, be it a full diastasis or a solitary posterior diastasis. The posterior syndesmosis does not open on conventional intraoperative screening techniques,[24] and thus it is prudent to also screen with internal rotation under arthroscopic or live radiologic screening. Intraoperatively, all patients who had posterior syndesmotic displacement on CT had instability on stress testing. We believe a low threshold should be maintained for fixation of the syndesmosis in these cases.

With type 2 cases, where the fracture line ran into the incisura, the posterior malleolar fragment displaced, and thus changed, the shape of the incisura. Only approximately half the injuries had syndesmotic instability, as a

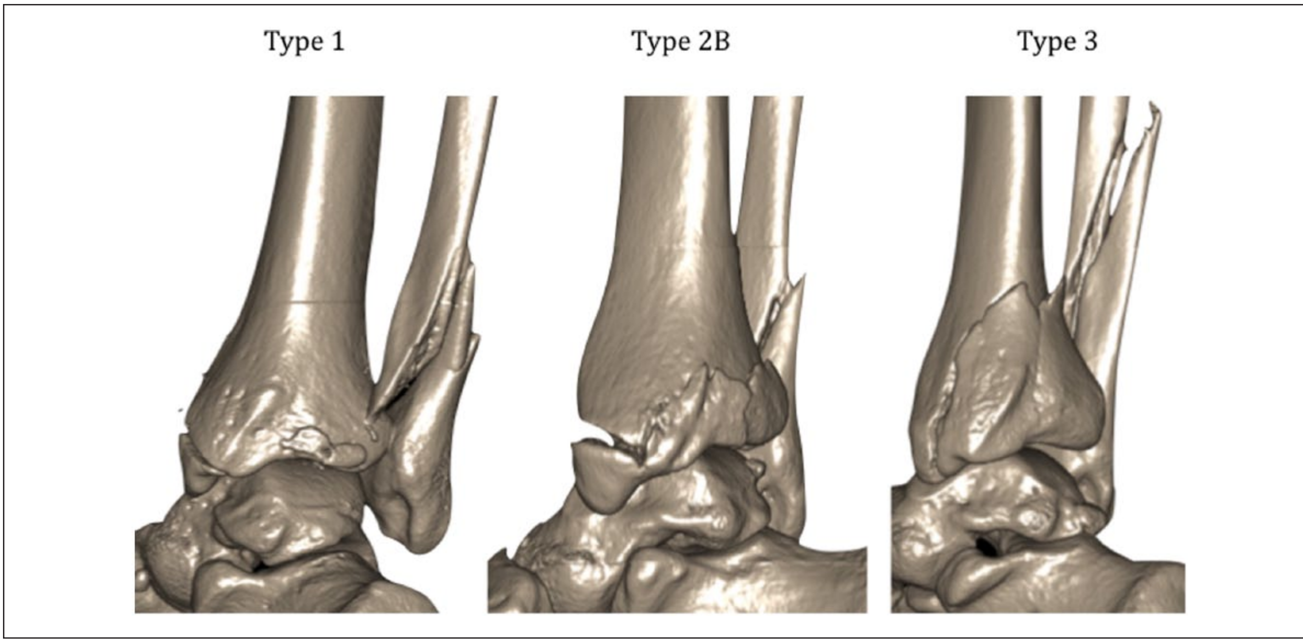

Figure 4. Three-dimensional computed tomographic reconstructions of the different posterior malleolar fractures. The type 1 fracture shows the typical avulsion appearance of the medial malleolus. The type 2B fracture demonstrates the 2 separate posterior malleolar fractures (posterolateral and posteromedial) and an associated anterior oblique medial malleolar fracture. The type 3 fracture exemplifies the long oblique fibular fracture in the same orientation as the posterior pilon fragment.

proportion of the posterior inferior tibiofibular ligament (PITFL) footprint remained intact in these push-off fractures without syndesmotic instability, strengthening the hypothesis that this was not an avulsion injury. In the injuries with syndesmotic diastasis, the PITFL footprint was involved. In these injuries, if the syndesmosis was first reduced into the deformed incisura, the fibular could become posteriorly malreduced in the syndesmosis, and consequently block subsequent anatomical reduction of the posterior malleolar fragment. This complication was also described by Irwin et al,[17] who felt it was prudent to fix the posterior malleolus under direct vision in these cases, as syndesmotic clamping can result in the malreduction. Since the PITFL is attached to the primary fracture fragment, once the posterior fragment is reduced, a proportion of these fractures will require no further syndesmotic stabilization. This finding is in keeping with Gardner et al[12] where in a cadaveric study they found that posterior malleolar fixation conferred 70% syndesmotic stability in comparison to 40% with screw fixation.

In the type 2B variant, the posteromedial fragment occurred in general at 45° to the posterolateral fragment, and propagated below the posterolateral fragment in an anteromedial direction. As such, the posteromedial fragment needed to be reduced and fixed before the posterolateral fragment, as the posterolateral fragment would otherwise prevent the posteromedial fragment anatomical reduction. We believe the preoperative identification of fracture type is important for identifying the surgical approach that will need to be used. A type 2A primary fragment plus fibula fracture should be approached via a single lateral (deep dissection anterior and posterior to peroneal tendons to expose both fractures) or via separate lateral and posterolateral incisions, depending upon size of fragments and patient habitus. A type 2B primary fragment will require an additional posteromedial incision to fully expose, reduce, and fix the medial part of the fracture. This is because of the consistent 45° obliquity of the fracture line splitting the posterior malleolar fragment. If just approached from the lateral side, fixation can only be placed in the same plane as this fracture line. The posteromedial incision is performed either just medial to the Achilles tendon (moving the flexor hallucis longus medially) or between the tibia and tibialis posterior, depending on comminution and fracture pattern.

In type 3 cases, only 20% had a syndesmotic diastasis, with no instances of isolated posterior syndesmotic displacement. This was commonly a consequence of a long oblique fracture of the fibula remaining attached posteriorly to the displacing posterior malleolar pilon fragment and anteriorly, attached to the remaining tibia. The clinical testing of the syndesmosis is therefore in these cases, more likely to be reliable, and a higher threshold for syndesmotic fixation can be maintained. Specific elements to this fracture pattern are the high preponderance of associated posteromedial malleolar injuries. A Y-type fracture was demonstrated in 32% of cases, and in these cases the larger fragment was in the posterior oblique direction with a separate anterior collicular avulsion. This fracture pattern was also described by Klammer et al.[19] In fixation of this fracture, we find it is more successful in reduction and fixation of the larger fragment first, followed by attachment of the smaller anterior fracture fragment to this stable construct. As for the type 2 fractures, the approach will be determined by the fracture pattern. If a Y-type fracture is present, it is usually necessary to carry out a posteromedial incision.

Conclusion

We present a classification system of posterior malleolar fractures based on a large series. The system progresses in severity as well as indicating the pathomechanics that cause the fracture. We have demonstrated predictable associated injuries for each fracture type and how both these factors determine which surgical approaches will be necessary.

Declaration of Conflicting Interests

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