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Evaluation of Posterior Malleolar Fractures and the Posterior Pilon Variant in Operatively Treated Ankle Fractures

Paul J. Switaj, MD[1], Brian Weatherford, MD[2], Daniel Fuchs, MD[1], Brett Rosenthal, MD[1], Eric Pang, MD[1], and Anish R. Kadakia, MD[1]

Abstract

Background: Substantial attention has recently been placed on fractures of the posterior malleolus. Fracture extension to the posteromedial rim ("posterior pilon variant") may result in articular incongruity and talar subluxation. Current classification systems fail to account for these fractures. The relative frequency of this fracture, its associated patient characteristics, and the reliability of its diagnosis have never been reported in such a large series.
Methods: We retrospectively identified 270 patients who met our inclusion criteria. Basic demographic data were collected. The fractures were classified according to Lauge-Hansen and AO/OTA. Additional radiographic data included whether the fracture involved the posterior malleolus and whether the fracture represented a posterior pilon variant. Univariate statistical methods, chi-square analysis, and interobserver reliability were assessed.
Results: The relative frequency of posterior malleolus fracture was 50%. The relative frequency of the posterior pilon variant was 20%. No significant difference was noted with respect to the frequency of posterior malleolar or posterior pilon variant between the subgroups of the AO/OTA and Lauge-Hansen classification systems when compared to the overall fracture distribution. Patients with posterior malleolar fractures and posterior pilon variants were significantly older. Females were significantly more likely than men to sustain posterior malleolar fractures and posterior pilon variants. Patients with diabetes trended toward a greater risk of both types of fractures. Interobserver reliability data revealed substantial agreement for posterior malleolar fractures and posterior pilon variants.
Conclusion: These data represent the highest reported rate of posterior malleolar involvement in operatively treated ankle fractures and is the first to describe the percentage of the posterior pilon variant in such a large series. The interobserver reliability data demonstrate substantial agreement in identification of posterior malleolar fractures and the posterior pilon variant based on plain radiographs. Certain patient characteristics such as age, sex, and diabetes may be associated with these fractures.
Level of Evidence: Level III, retrospective cohort study.

Keywords: ankle fracture, classification, posterior malleolus, posterior pilon, trimalleolar

Introduction

Ankle fractures are a common orthopaedic injury that occur at a rate of 187 per 100 000 person-years and are the fourth most common fracture to require operative repair.[7,15] Substantial attention has recently been placed on fractures that involve the posterior malleolus.[1,5,11,14,22,35,38,39,41] There is a wide range in the reported prevalence of posterior malleolar involvement in ankle fractures, varying from 7% to 44%.[4,6,20,35] The relevance and operative management of posterior malleolar fractures continues to be a source of controversy.

An increasingly recognized fracture morphology has been described, characterized by posteromedial extension of the fracture of posterior rim of the tibia including a portion of the medial malleolus with varying articular impaction.[3,18,22,39] The presence of this fracture pattern with posteromedial involvement appears critical to talar stability and prevention of posteromedial subluxation, independent of involvement of the posterolateral tibia.[40] This variant can be diagnosed and evaluated with a combination of plain radiographs and computed tomography (CT) scans. On plain radiographs, the anterior-posterior view can show a double contour medially above the medial malleolus or a

[1]Northwestern University, Department of Orthopaedic Surgery, Chicago, IL, USA
[2]R Adams Cowley Shock Trauma Center, Baltimore, MD, USA

Corresponding Author:
Paul Joseph Switaj, MD, Northwestern University, 711 West Gordon Terrace, Chicago, IL 60613, USA.
Email: paul.switaj@gmail.com

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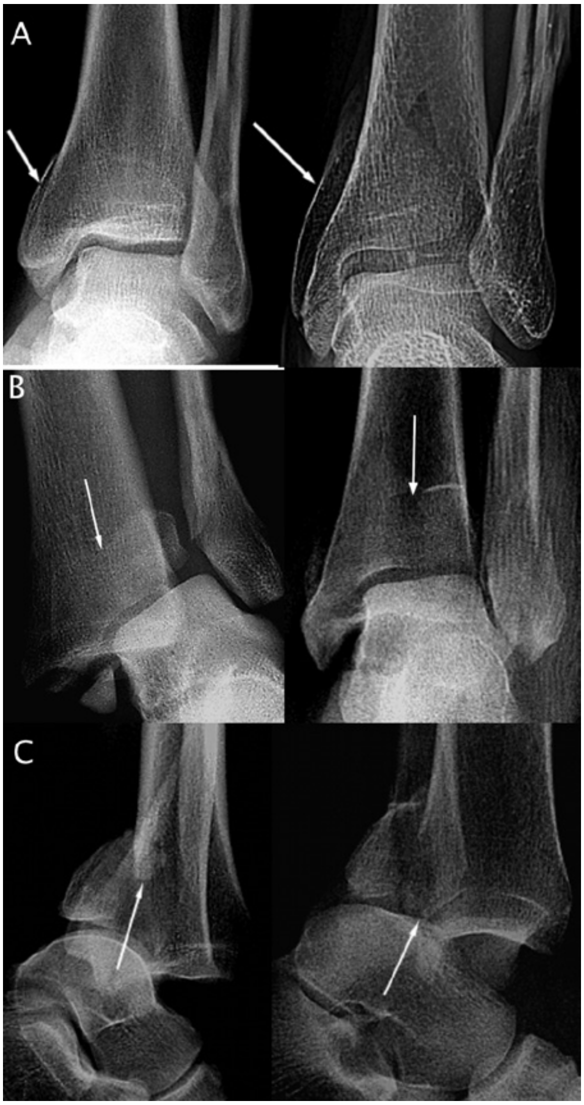

Figure 1. These radiographs represent the characteristics of the posterior pilon variant fracture pattern (A) Anterior-posterior radiographs with arrows demonstrating the medial malleolar double contour sign. (B) Mortise radiographs with arrows demonstrating the sagittal split of posterior malleolus. (C) Lateral radiographs with arrows demonstrating posterior articular impaction.

split posterior malleolar fragment (Figure 1A and 1B). Additionally, evidence of articular impaction on the lateral view may be noted (Figure 1C).[40] Various descriptive names have been applied to this fracture pattern, including “posterior pilon variant.”[1,17,19]

Identification of posterior malleolar fractures is critical for proper operative intervention. Reduction and fixation of the posterior malleolus increases syndesmotic stability[13] and may decrease the rate of non-anatomic reduction of the articular surface, which has been shown to correlate with worse outcomes at 1 year.[2] Increased recognition of posterior malleolar fractures, and specifically posteromedial fracture involvement, may alter the surgeon’s selection of operative approach, reduction strategies, and implant selection.[1,12,40] Recognition of the various forms of posterior malleolar fractures is often difficult, in part because the traditional classification systems fail to adequately address the posterior malleolar anatomy.

The purpose of this study was to report the relative frequency of the posterior malleolar fracture and posterior pilon variant in a large consecutive series of operative ankle fractures and to investigate the patient and fracture characteristics associated with these fractures. An additional aim was to assess the interobserver reliability in identifying the posterior pilon based on plain radiographs and its relationship to 2 commonly used classification systems.

Methods

Institutional review board approval was obtained prior to initiation of this study. We retrospectively identified 862 skeletally mature patients who presented to our hospital with ankle fractures from 2007 to 2013. Of these, 327 were deemed unstable and were treated operatively. All bimalleolar and trimalleolar fractures, with or without dislocation, were managed operatively. Fibular fractures that presented with >5 mm of medial clear-space widening statically or on stress examination were deemed to be unstable.[9,10,33] Patients were excluded from our analysis if they had prior ankle fracture, prior ankle surgery, or preexisting ankle deformity. Of these 327 patients, 270 had preoperative radiographs that were deemed adequate for classification by 2 independent reviewers by having at least 3 standard views (anterior-posterior, lateral, mortise) of the ankle without plaster obstructing interpretation. Basic demographic and injury data were collected. The median age of patients was 46.2 years (range, 17-86 years; interquartile range, 32-58 years). There were 155 female patients (57.4%). The mean BMI was 29.6. Of the 270 patients, 27 were diabetics (10%).

Using preoperative radiographs, 2 reviewers (1 foot and ankle fellowship-trained surgeon, 1 orthopaedic trauma fellowship-trained surgeon) classified the fractures according to the Lauge-Hansen[24] and AO/OTA[26] classification systems. Each observer was asked to classify the fracture patterns according the Lauge-Hansen system, namely, supination-adduction (SAD), supination-external rotation (SER), pronation-abduction (PAB), and pronation-external rotation (PER). According to the AO/OTA system, the class and main subgroups were used. For example, a trimalleolar ankle fracture with the fibula fracture at the level of the syndesmosis would be classified as a 44-B3. Additionally, the reviewers reported on the presence of a posterior malleolus fracture and whether the fracture met the criteria of a

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posterior pilon variant. The posterior pilon variant pattern was defined by the presence of a medial malleolar double-contour sign,[40] a posterior malleolus fracture in the sagittal plane (split posterior malleolus),[37] or posterior malleolar impaction (Figure 1).

Statistical analysis was performed with the JMP Pro statistical software package (v10.02). Consensus classification was used, which was defined as any fracture classification made in agreement between both reviewers. Any classifications that were not in agreement were excluded from statistical analysis of consensus data. Univariate statistical methods, based on absolute and relative frequencies and contingency tables, were applied to calculate relative risk confidence intervals. Chi-square analysis was performed on the distribution of fracture classifications. In order to evaluate the interobserver reliability, we used combined observer agreement percentage and the kappa coefficient. A kappa value of 1.00 means perfect agreement and a value of 0.00 is equal to that of chance alone. A kappa value less than 0.20 characterizes the agreement as slight, 0.21 to 0.40 as fair, 0.41 to 0.60 as moderate, 0.61 to 0.80 as substantial, and 0.81 to 0.99 as almost perfect agreement.[23]

Results

Fracture Classification

For the Lauge-Hansen system consensus classification (n = 223), we determined that 4% were PAB, 13% PER, 2% SAD, and 80% SER. For the AO/OTA system, consensus classification (n = 189) demonstrated 0% as AO/OTA A, 81% as AO/OTA B, and 19% as AO/OTA C (Table 1).

Comparing these distributions to historical numbers is difficult, as most studies report the distributions as a percentage of all ankle fractures, both operative and nonoperative.[6,7,34] There is limited literature on the distribution of operative ankle fractures, with most studies reporting a smaller percentage of SER-type patterns (48%-70%) and a higher percentage of PER (23%-27%) and PAB-type patterns (2.5%-17%).[29,30,42]

Posterior Malleolar Fractures

Based on plain radiographs, the consensus relative frequency (n = 241) showed that 50% of operative ankle fractures had a posterior malleolus fracture (Table 2). Of all posterior malleolar fractures, the consensus data (n = 101) demonstrated 4% as PAB, 12.9% PER, 0% SAD, 83.2% SER, 0% as AO/OTA A, 82.6% as AO/OTA B, and 17.4% as AO/OTA C (Table 1).

While there did appear to be a trend toward increased frequency of SER and AO/OTA B type patterns in posterior malleolar fractures and posterior pilon variants, with the numbers available, chi-square analysis demonstrated no significant difference in the distribution of Lauge-Hansen or AO/OTA classifications when comparing fractures with and without posterior malleolar involvement (P = .09, P = .20, respectively).

Table 1. Consensus Fracture Distribution of Operative Ankle Fractures.

	Overall Distribution (%)	Posterior Malleolar Fracture Distribution (%)[a]	Pilon Variant Fracture Distribution (%)[b]
PAB	4	4	2
PER	13	13	10
SAD	2	0	0
SER	80	83	88
AO/OTA A	0	0	0
AO/OTA B	81	83	92
AO/OTA C	19	17	8

Abbreviations: PAB, pronation-abduction; PER, pronation-external rotation; SAD, supination-adduction; SER, supination-external rotation.
[a]No significant difference from the overall distribution based on numbers available. P = .09 Lauge-Hansen, P = .20 AO/OTA.
[b]No significant difference from the overall distribution based on numbers available. P = .37 Lauge-Hansen, P = .16 AO/OTA.

Table 2. Fracture Consensus Relative Frequency.

	%
# of Posterior Malleolar Fractures / Total # of Fractures	50
# of Posterior Pilon Variant / Total # of Fractures	20
# of Posterior Pilon Variant / # of Posterior Malleolar Fractures	40

Posterior Pilon Variant

Based on plain radiographs, the consensus relative frequency (n = 246) showed that 20% of operative ankle fractures were a posterior pilon variant. Further evaluation of our series demonstrated that 40% of posterior malleolar fractures represented a posterior pilon variant (Table 2). Of the posterior pilon fractures, the consensus data (n = 48) demonstrated 2.4% PAB, 9.5% PER, 0% SAD, 88.1% SER, 0% as AO/OTA A, 92.1% as AO/OTA B, and 7.9% as AO/OTA C (Table 1).

With the numbers available, chi-square analysis demonstrated no significant difference in the distribution of Lauge-Hansen classifications when comparing fractures with and without posterior pilon involvement (P = .37). Similarly, no significant difference in the distribution of OTA classifications was present (P = .16).

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Table 3. Interobserver Reliability.

Classification	Kappa	Observed Agreement (%)
Lauge-Hansen	0.60	83
AO/OTA without subgrouping	0.67	87
AO/OTA with subgrouping	0.57	70
Posterior malleolar	0.79	91
Posterior pilon variant	0.74	89

[a]A kappa value less than 0.20 characterizes the agreement as slight, 0.21 to 0.40 as fair, 0.41 to 0.60 as moderate, 0.61 to 0.80 as substantial, and 0.81 to 0.99 as almost perfect agreement.

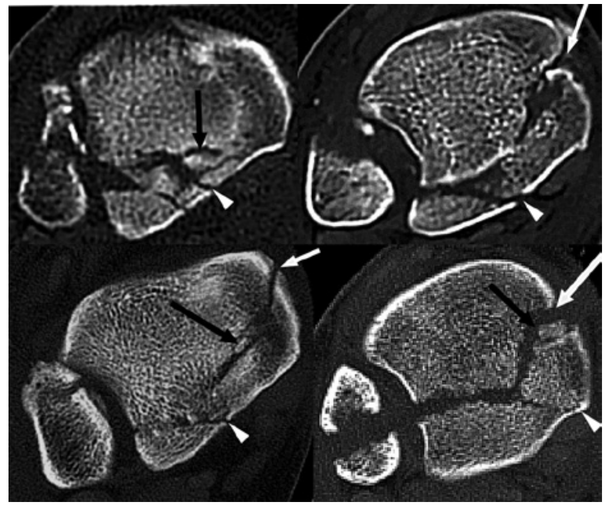

Figure 2. Axial CT scans demonstrate the characteristics of the posterior pilon variant. The white arrowheads demonstrate the sagittal split, the black arrows the articular impaction, and the white arrows the medial extension.

Interobserver Reliability and Observed Agreement

The kappa value for interobserver reliability of the Lauge-Hansen classification system was 0.60, indicating "moderate" agreement (Table 3). The observed agreement percentage was 82.6%. The kappa value for AO/OTA classification system with subgroups was 0.57, indicating moderate agreement. The observed agreement percentage was 70.0%. When just main groups for the AO/OTA classification were considered, there was a kappa value of 0.67, indicating substantial agreement. The observed agreement was 87%. These values are consistent with previously published data.[25,31,36]

The kappa value regarding identification of posterior malleolar fractures was 0.79, indicating substantial agreement. The observed agreement percentage was 91.1%. When using the radiographic parameters outlined previously for defining a posterior pilon variant, the observers demonstrated a kappa value of 0.74, indicating substantial agreement. The observed agreement percentage was 89.3%.

Subgroup Analysis

CT Evaluation. In our series, 21 of 270 (7.8%) operative ankle fractures received preoperative CT scans, with 18 of these meeting consensus classification for presence or absence of posterior malleolar fractures. Based on plain radiographs, 15 of these patients had posterior malleolar fractures, with 12 of these patients having posterior pilon variant fractures. CT scans confirmed a posterior pilon variant fracture pattern in all 12 of these patients (Figure 2) and confirmed a posterior malleolar fracture without characteristics of the pilon variant in the remaining 3. The CT evaluation for remaining 3 fractures demonstrated that 1 posterior malleolar fracture had been missed on plain radiographic examination but did not represent a posterior pilon variant.

Age. In consensually classified fractures, the mean age of patients without a posterior malleolar fracture (n = 121) was 42.8 years, whereas patients with posterior malleolar fractures (n = 119) had a mean age of 49.0 years. The mean age of patients without a posterior pilon (n = 198) was 44.3, whereas patients with a posterior pilon fracture (n = 47) had a mean age of 52.1. A significant difference in age was seen for both posterior malleolar (P = .003) and posterior pilon fractures (P = .005; Table 4).

BMI. In consensually classified fractures, the mean BMI of patients without posterior malleolar fractures (n = 108) was 29.3, whereas the mean BMI of patients with posterior malleolar fractures (n = 108) was 30.1. The mean BMI of patients without posterior pilon fractures (n = 177) was 29.7; whereas the mean BMI of patients with posterior pilon fractures (n = 41) was 30.0. BMI did not appear to be significantly different in our analysis of posterior malleolar and posterior pilon fractures (P = .37 and P = .73, respectively; Table 4).

Gender. In the study, 57.1% of patients were female. Per consensus evaluation, 55.5% of females had a posterior malleolar fracture (compared to 42.3% of males) and 24.3% had the posterior pilon variant (compared to 13.2% of males). Calculated relative risk demonstrated that females were 1.31 (95% CI, 1.0-1.7) times more likely to sustain a posterior malleolar fracture and 1.83 (95% CI, 1.0-3.3) more likely to sustain a posterior pilon variant (Table 4).

Diabetes. Ten percent of patients with ankle fracture had diagnosed diabetes at the time of operation. Per consensus

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Table 4. Subgroup Analysis of Posterior Malleolar Fracture and Posterior Pilon Variants.

	Without Posterior Malleolar (Mean)	With Posterior Malleolar (Mean)	Without Posterior Pilon (Mean)	With Posterior Pilon (Mean)
Age (years)	42.8	49.0[a]	44.3	52.1[b]
BMI (kg/m^2)	29.3	30.1	29.7	30.0
		Posterior Malleolar (Relative Risk 95% CI)	Posterior Pilon (Relative Risk 95% CI)	
Female gender		1.3 (1.0-1.7)	1.8 (1.0-3.3)	
Diabetes		1.4 (0.9-1.9)	1.9 (0.9-3.5)	

[a]Represented a significant difference with numbers available (*P* = .003).
[b]Represented a significant difference with numbers available (*P* = .005).

evaluation, 65.2% of patients with diabetes had a posterior malleolar fracture (compared to 48.2% of patients without diabetes), and 33.3% had a posterior pilon (compared to 18.0% of patients without diabetes). Calculated relative risk demonstrated that diabetics were 1.35 (95% CI, 0.9-1.9) times more likely to sustain a posterior malleolar fracture and 1.85 (95% CI, 0.9-3.5) more likely to sustain a posterior pilon variant. These relative risks trended toward significance but did not meet the predetermined alpha level (Table 4).

Discussion

Significant attention has been focused on the size of the posterior malleolus fragment and its effect on ankle stability and contact stress.[8,28] The morphology of the posterior malleolus fracture has received far less consideration in classification and treatment algorithms. An increasingly recognized fracture pattern has been previously defined, which is characterized by a posteromedial fragment involving a portion of the medial malleolus, in combination with the posterolateral fragment.[3] In addition, there can be articular impaction present, which is uncommon for rotational ankle fractures.[12,40] The significant involvement of the posterior tibial articular surface along with the variable articular impaction likely represent a more complex injury pattern than has been traditionally described in rotational ankle fractures. Proposed mechanisms that produce this fracture morphology include an abduction-external rotation force, forced hyperplantarflexion, and a combination of rotational and axial load.[12,19,21]

This pattern is in contrast to fractures of the posterior malleolus seen in rotational ankle fractures, which involve a posterolateral triangular fragment at the area of the posterior-inferior tibiofibular ligament (PITFL) insertion (Figure 3). Various descriptive names have been applied to this fracture pattern.[1,17,19,27] In our practice, we identify them as "posterior pilon variant" fractures to differentiate them from purely rotational trimalleolar fractures with the typical posterolateral fragment.[22] The incidence of this fracture type has been reported to be 6% to 8% of operative ankle fractures,[12,40] or 19% of all ankle fractures with a posterior malleolar fragment,[18] but has been thought to be underestimated.[39] This was the case in our series, where 40% of all operative ankle fractures with a posterior malleolar fracture represented a posterior pilon variant. Our data represent the highest reported rate of posterior malleolar involvement in operative ankle fractures (50%) and the highest rate of posterior pilon variant in operative ankle fractures (20%). We believe this is due to the increased vigilance in identifying this previously under-recognized fracture pattern at our institution.

Limitations of this study include its retrospective nature and lack of CT scan evaluation. The posteromedial fracture pattern can most definitively be visualized on an axial CT scan. It has been suggested in the literature that all ankle fractures with a posterior malleolus component require CT scan imaging for adequate understanding.[19] Although CT evaluation was limited in this study, the advanced imaging available demonstrated no false positives for the posterior pilon variant. Data regarding patient outcomes were beyond the scope of this study and not collected. At our institution, we are now prospectively evaluating ankle fractures with patient-reported outcome measures to investigate any clinical impact of this fracture pattern.

Evidence exists that ankle fractures with a posterior malleolus component, and specifically posterior pilon variants, have a poorer prognosis.[4,20,28,35,38] Recent studies have demonstrated that any articular incongruity is associated with inferior short-term clinical outcomes.[2] However, there is insufficient evidence to determine the indications for internal fixation of the posterior malleolus fragment. As a result, there is little consensus regarding surgical indications, or methods of reduction and fixation, of the posterior malleolus.[16]

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Figure 3. Anteroposterior, lateral plain radiographic views, and axial CT scan of (A) a non-pilon variant posterior malleolar fracture and (B) a posterior pilon variant. In Figure 3A, a minimally displaced avulsion-type fracture of the posterior malleolus is seen on the lateral radiograph and confirmed on the axial CT scan denoted by the white arrows. In Figure 3B, medial extension of the posterior malleolar fracture seen on the plain radiographs confirmed on the CT scan. White arrows denote the medial extension and black arrowheads denote the zone of articular impaction.

Despite this lack of consensus, the presence of the posterior malleolar fracture should be an important consideration when deciding whether an ankle fracture requires operative intervention to achieve ankle stability and restore articular congruency. While the posterolateral fragment attached to the posterior tibiofibular ligament may be indirectly reduced by means of ligamentotaxis, this will not have any significant effect on the posteromedial fragment as it has no soft tissue or bony link to the PITFL. Failure to directly expose and reduce the posteromedial fragment may lead to malunion of the posteromedial fragment with resultant articular incongruity or posteromedial instability of the talus.[40] Additionally, this recognition of posteromedial fracture involvement may affect the surgeon's selection of operative approach needed to achieve appropriate reduction and fixation[1,12,40]

Unfortunately, identifying this pattern can be challenging, as the appearance of the posteromedial fracture fragment may be subtle, especially after reduction and splint application (Figure 4). In our institution, we have a heightened awareness of the radiographic characteristics of the posterior pilon. This is supported by the "substantial" agreement in identification of posterior malleolar fractures and the posterior pilon variant based on plain radiographs. The difficultly in identifying this fracture pattern is compounded by the fact that both the LH and the AO/OTA

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Figure 4. Supination-external rotation type fracture pattern both (A) prereduction and (B) postreduction. While the characteristic medial malleolar double contour sign and sagittal split is readily evident on the prereduction radiographs as shown by the arrows, the reduction and overlying plaster of the postreduction radiographs obscures these signs. This demonstrates the need to fully assess pre-reduction radiographs for the posterior pilon variant fracture pattern.

classification systems, while essential for education, fail to adequately describe these posterior pilon variants. Our analysis of the posterior malleolar fractures and posterior pilon variants did not show any significant association with a specific LH or AO/OTA classification. Thus, we can infer that fractures of the posterior malleolus and posterior pilon variant can occur in all fracture types across all traditional mechanisms and are not accounted for by conventional systems (Figures 5 to 7).

To our knowledge, we are the first to identify patient variables associated with posterior malleolus and posterior pilon fractures. We found that female gender, increasing age, and diabetes may be associated with both fractures of the posterior malleolus as well as the posterior pilon variant. This may be a result of the diminished bone quality traditionally found in this subset of patients.[32] These factors could heighten a practitioner's level of suspicion for identifying these fractures.

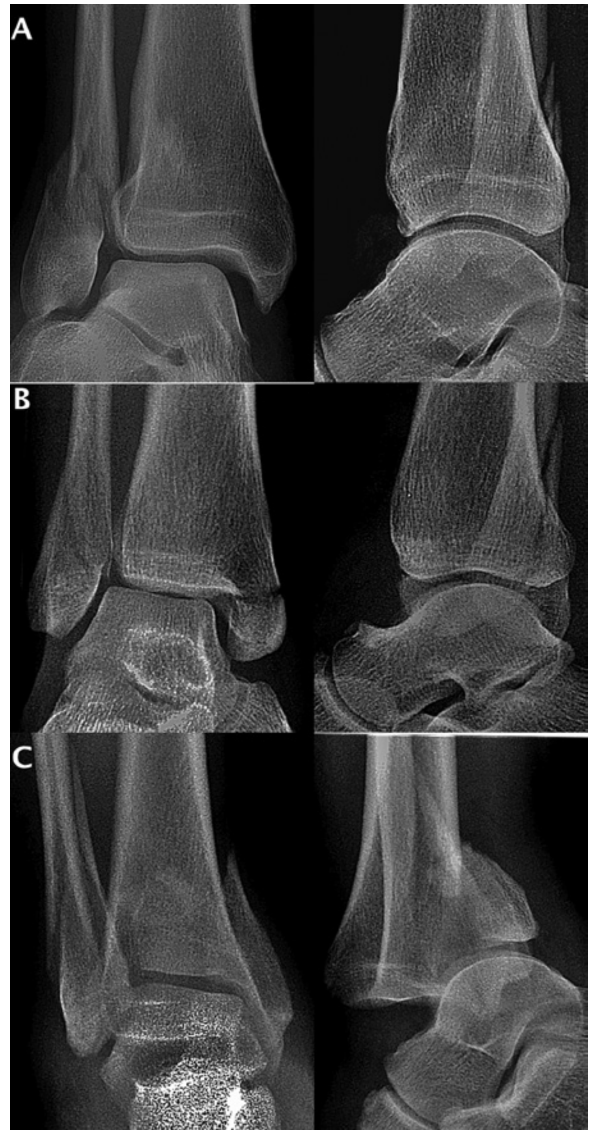

Figure 5. Radiographic representations of the continuum of AO/OTA 44-B, supination-external rotation (SER) type fracture patterns. (A) 44–B, SER-type with no posterior malleolar fracture. (B) 44–B, SER-type with a posterior malleolar fracture. (C) 44–B, SER-type posterior pilon variant based on medial extension of the fracture and sagittal split.

In conclusion, this represents the largest series reporting the fracture and patient characteristics in operative ankle fractures. The relative frequency of the posterior malleolar fracture and posterior pilon variant in operatively treated ankle fractures was 50% and 20%, respectively, and appears to be more common than previously reported. Identification of the posterior pilon variant and posterior malleolar fractures demonstrate substantial interobserver reliability, had a

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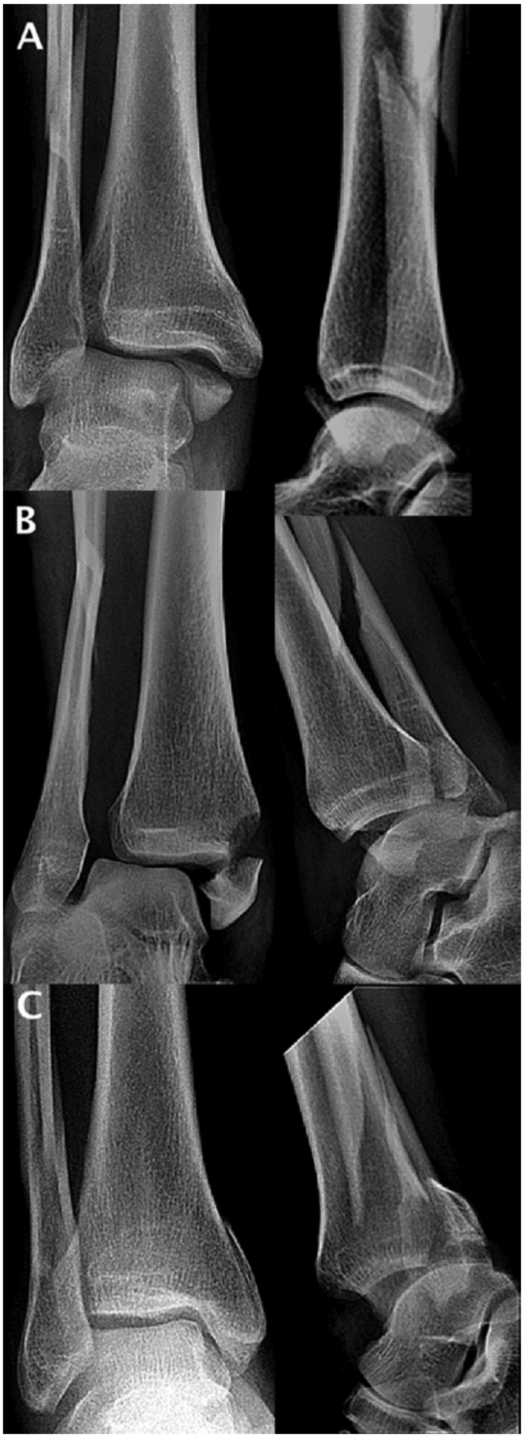

Figure 6. Radiographic representations of the continuum of AO/OTA 44-C1, pronation-external rotation (PER) type fracture patterns. (A) 44–C1, PER-type with no posterior malleolar fracture. (B) 44–C1, PER-type with a posterior malleolar fracture. (C) 44–C1, PER-type posterior pilon variant based on medial extension and characteristic medial malleolar double contour sign.

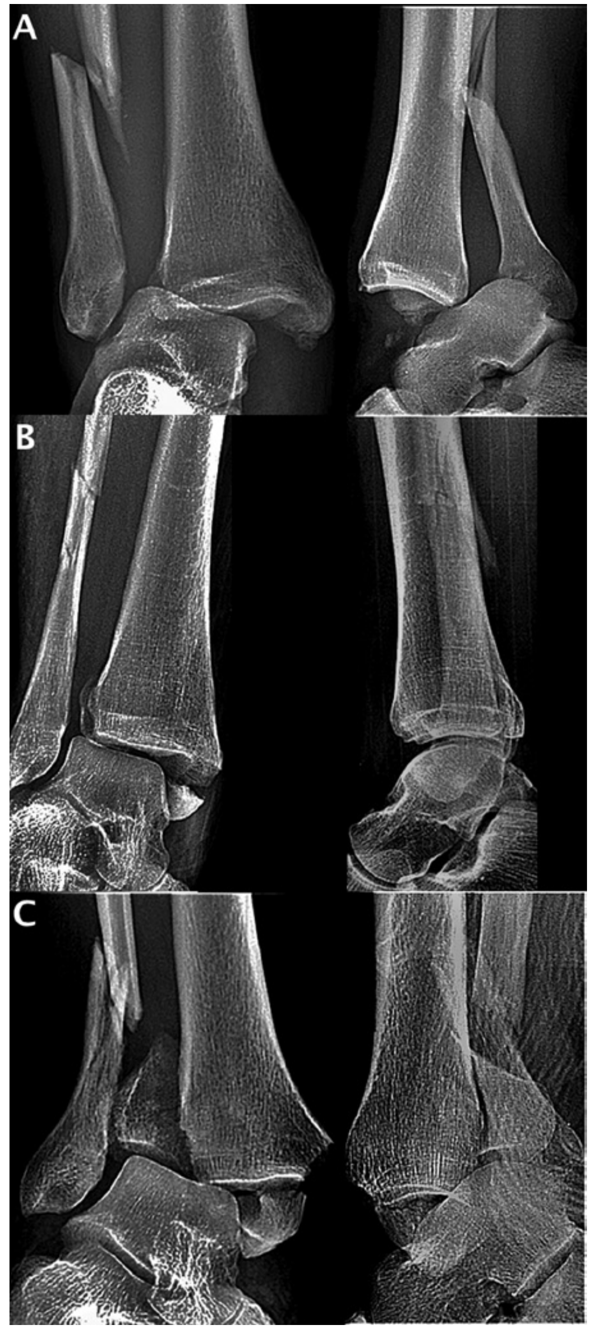

Figure 7. Radiographic representations of the continuum AO/OTA 44–C2, pronation-abduction (PAB) type fracture patterns. (A) 44–C2, PAB-type with no posterior malleolar fracture. (B) 44–C2, PAB-type with a posterior malleolar fracture. (C) 44–C2, PAB-type posterior pilon variant based on medial extension and a sagittal split.

high level of CT correlation, and may occur with increased frequency in older, diabetic female patients.

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Declaration of Conflicting Interests

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