Pathoanatomy of Posterior Malleolar Fractures of the Ankle

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Background: The functional outcome following ankle fractures that involve a posterior malleolar fragment is often not satisfactory, and treatment of this type of fracture remains controversial. Thorough knowledge of the pathologic anatomy of the posterior malleolar fracture is essential for planning appropriate treatment. Thus, we conducted a computed tomographic study to clarify the pathologic anatomy of the posterior malleolar fracture.

Methods: Between 1999 and 2003, fifty-seven consecutive patients with a unilateral ankle fracture with one or more posterior fragments were managed at our hospital. We reviewed the patients' preoperative computed tomographic scans to determine (1) the ratio of the posterior fragment area to the total cross-sectional area of the tibial plafond and (2) the angle between the bimalleolar axis and the major fracture line of the posterior malleolus. Each fracture was categorized according to the location of the major fracture line on the computed tomographic image at the level of the tibial plafond.

Results: The fifty-seven fractures were categorized into three types: (1) the posterolateral-oblique type (thirty-eight fractures; 67%), (2) the medial-extension type (eleven fractures; 19%), and (3) the small-shell type (eight fractures; 14%). Two of the eleven medial-extension fractures extended to the anterior part of the medial malleolus, and the other nine actually consisted of two fragments. The average area of the fragment comprised 11.7% of the cross-sectional area of the tibial plafond for posterolateral-oblique fractures and 29.8% for medial-extension fractures. In the cases of seven of the nine fractures that comprised >25% of the tibial plafond, the fracture line extended to the medial malleolus. The angles between the bimalleolar axis and the major fracture line of the posterior malleolus varied.

Conclusions: The fracture lines associated with posterior malleolar fractures appear to be highly variable. A large fragment extending to the medial malleolus existed in almost 20% of the posterior malleolar fractures in the current study, and some fragments involved almost the entire medial malleolus. Because of the great variation in fracture configurations, preoperative use of computed tomography may be justified. The information obtained from this study will be helpful for conducting basic research of this condition and for determining appropriate surgical approaches.

The functional outcome following an ankle fracture that involves a posterior malleolar fragment is often not satisfactory[1,2], and much controversy exists about the diagnosis and treatment of this type of fracture. Most authors have agreed that small avulsion fragments can be treated nonoperatively[1,3,4], but there is some question about whether anatomical reduction and fixation is essential for larger fragments[1,3,4]. It also remains uncertain whether early weight-bearing is prudent after internal fixation or closed treatment of a posterior malleolar fracture.

Several experimental studies have been conducted in an effort to establish principles of treatment. Some of those studies focused on the role of the posterior malleolus in stabilizing the ankle[5-8], whereas others focused on the contact area or pressure within the ankle joint with or without a posterior malleolar fracture[5,9-12]. However, the means by which posterior malleolar fractures have been simulated have been inconsistent. In some studies[5,9,10,12], the osteotomy was performed to make a wedge-shaped fragment, with the medial point of the cut fixed at the posterior corner of the medial malleolus, whereas in others[6,7], the plane of the osteotomy was parallel to the bimalleolar axis. Because various posterior malleolar fracture patterns are possible, any single osteotomy model may provide only a limited representation of the spectrum of injuries.

Because the indications for internal fixation of a posterior malleolar fracture are frequently based on the size of the fragment[1,13,14], accurate assessment of fragment size is critical. Many authors have used lateral radiographs for such assessment, but this single-plane evaluation has proved unreliable[15]. An oblique view showing the posterior malleolus has been described[16-18], but it has not been validated clinically.

The lack of agreement among previous studies may be due to the absence of comprehensive data about the pathoanatomy of the posterior malleolar fracture. A sound knowledge of the fracture anatomy should help investigators to conduct appropriate basic research and assist orthopaedic

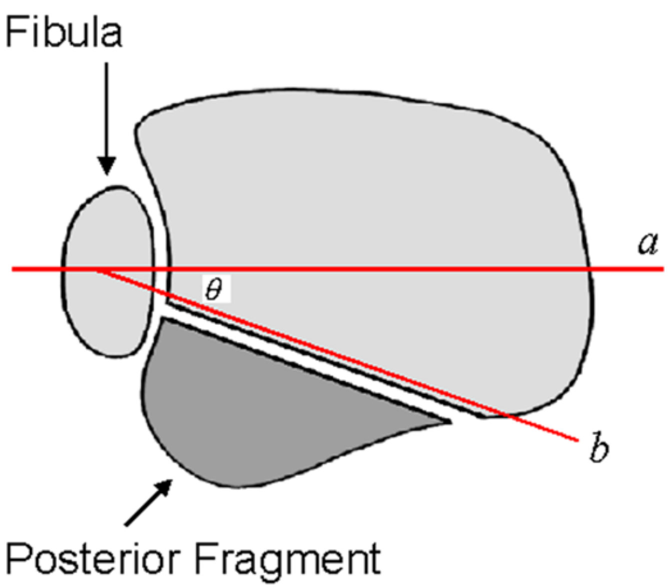

Fig. 1
Diagram showing measurement of the angle between the bimalleolar axis *(a)* and the major fracture line of the posterior malleolus *(b).* The average angle between *a* and *b* represents the average amount of external rotation required to view the fracture line parallel to the x-ray beam on a lateral radiograph.

surgeons to successfully manage patients who have posterior malleolar involvement. Thus, we studied the computed tomographic scans of patients who had a posterior malleolar fracture with one or more posterior fragments to clarify the pathoanatomy of such fractures.

Materials and Methods

Patients

From 1999 through 2003, fifty-seven consecutive patients (sixteen female patients and forty-one male patients) who had a malleolar fracture of the ankle involving one or more posterior fragments were managed at our hospital. A preoperative computed tomographic scan of each fracture was made. On the basis of the mortise or lateral radiographic view, all fractures were judged to be unstable on the basis of the position of the talus. All fractures were treated with open reduction and internal fixation. Nineteen (33%) of the fifty-seven ankle fractures involved posterior subluxation or dislocation at the time of presentation. Thirty-three fractures occurred in the right ankle, and twenty-four occurred in the left ankle. The mean age of the patients was forty-three years (range, thirteen to eighty years). Informed consent was obtained from all patients or their guardians, and the study was approved by our hospital's internal review board.

Conventional mortise and lateral radiographs were made. The fractures as they appeared on plain radiographs were categorized on the basis of the Lauge-Hansen classification system[19]. Specifically, forty-four supination-external rotation fractures were classified as stage III (four fractures) or stage IV (forty fractures), seven pronation-external rotation fractures

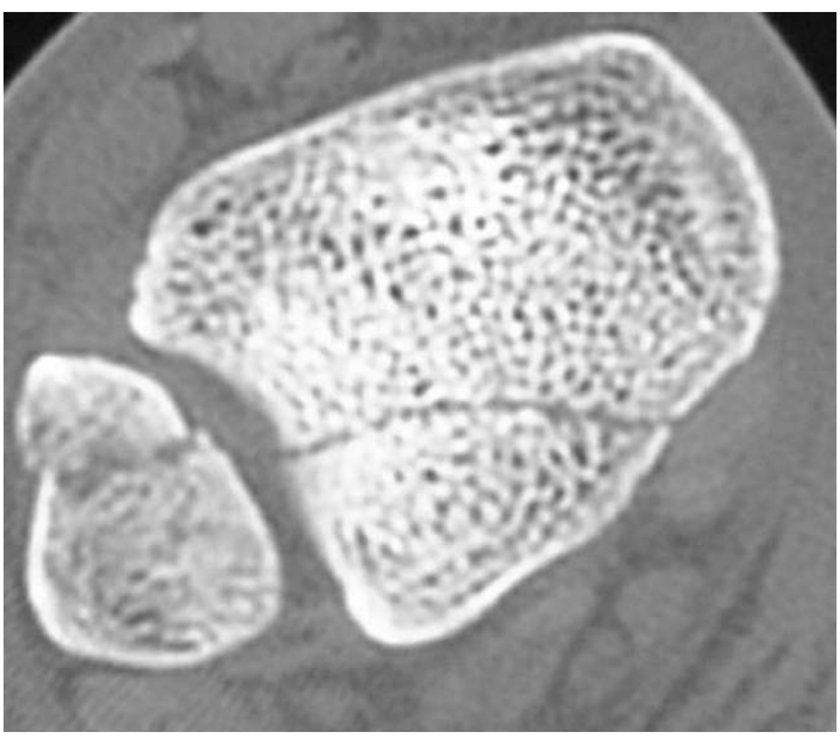

Fig. 2
Transverse computed tomographic scan showing a type-I fracture of the posterior malleolus, with a triangular fragment involving the posterolateral corner of the tibial plafond.

Fig. 3-A

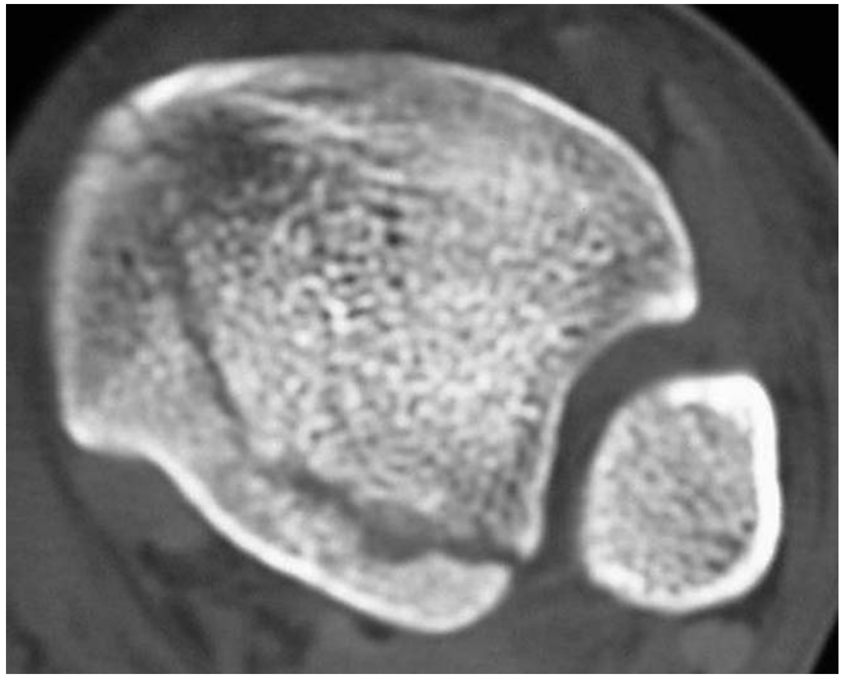

Fig. 3-B

Figs. 3-A and 3-B Anteroposterior radiograph (Fig. 3-A) and computed tomographic scan (Fig. 3-B) showing a trimalleolar fracture of the ankle. The transverse computed tomographic scan shows a type-II fracture of the posterior malleolus, with extension of the fracture line to the anterior part of the medial malleolus.

were classified as stage IV, and six pronation-abduction fractures were classified as stage II (four fractures) or stage III (two fractures). Computed tomographic scans were made in the transverse plane in 2 or 3-mm increments from the proximal extent of the fracture line of the posterior malleolus to the inferior border of the lateral malleolus.

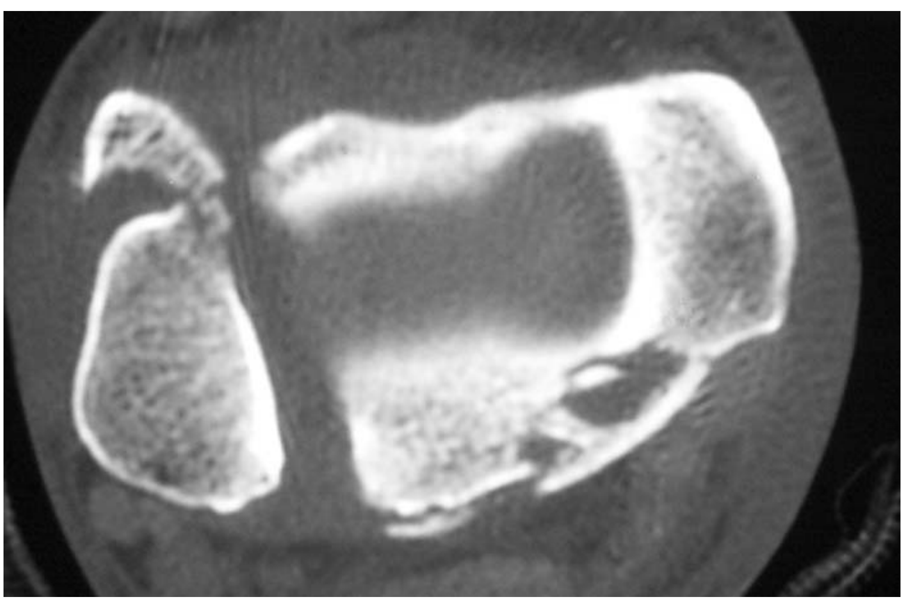

Fig. 4

Transverse computed tomographic scan showing a type-III fracture of the posterior malleolus, with small shell-shaped fragments at the posterior lip of the tibial plafond.

Fig. 5-A

Fig. 5-B

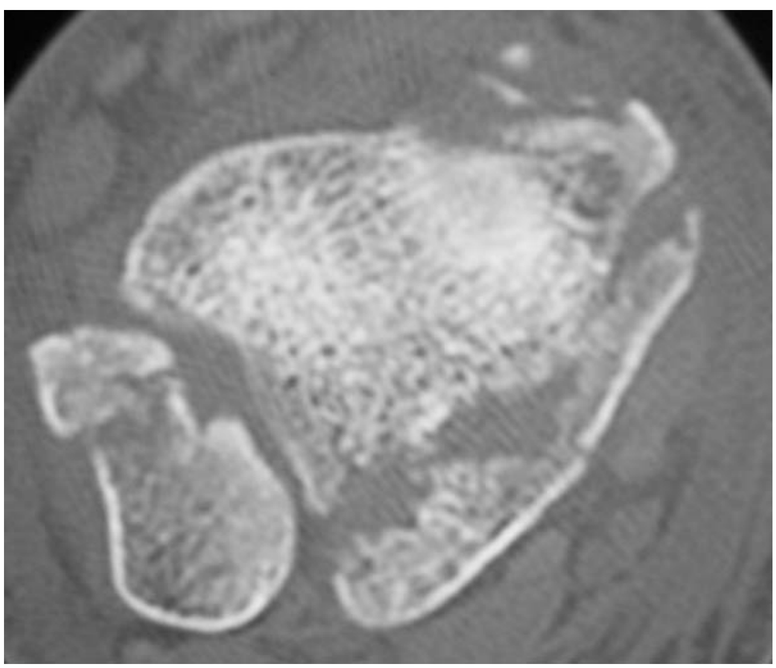

Fig. 5-C

Figs. 5-A, 5-B, and 5-C Anteroposterior radiograph (Fig. 5-A), lateral radiograph (Fig. 5-B), and computed tomographic scan (Fig. 5-C) showing a trimalleolar fracture of the ankle. The transverse computed tomography scan shows a type-II fracture of the posterior malleolus, with two fragments (posterolateral and posteromedial).

Measurements

In each case, a computed tomographic image at the level of the tibial plafond was scanned into a personal computer. With the use of image-analyzing software (ImageTool 3.0; The University of Texas Health Science Center at San Antonio, San Antonio, Texas), we measured the area of the posterior malleolar

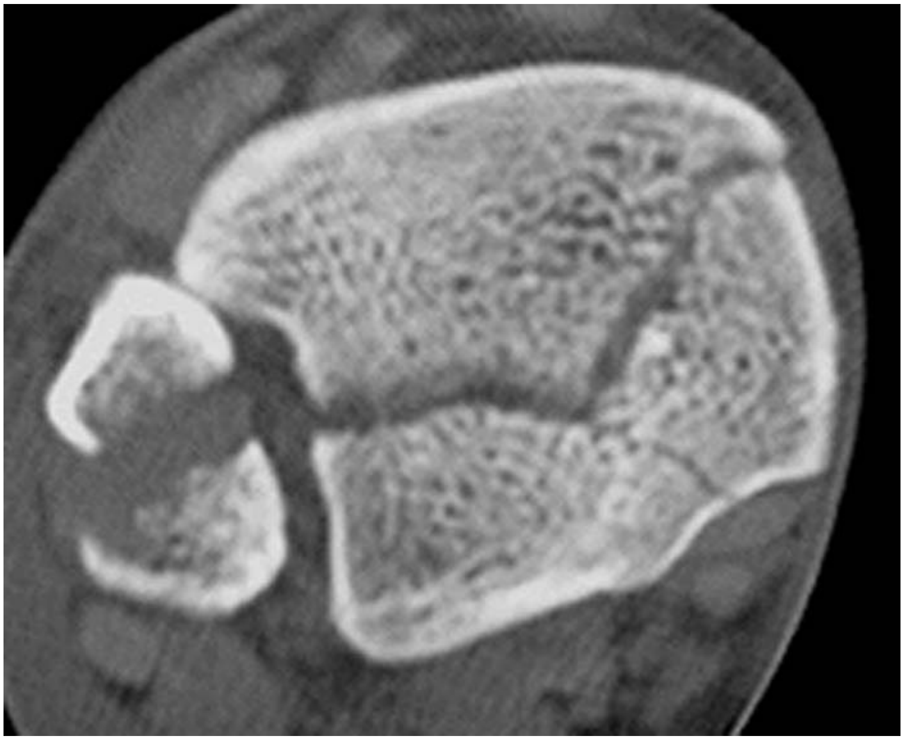

Fig. 6

Transverse computed tomographic scan showing yet another type-II fracture of the posterior malleolus. The fracture line extends to the anterior part of the medial malleolus.

fragment and the remaining cross-sectional area of the tibia. We calculated the ratio of the fragment area to the total cross-sectional area of the tibial plafond.

We identified the bimalleolar axis with use of one of the computed tomographic images representing both malleoli. We then measured the angle between the bimalleolar axis and the major fracture line of the posterior malleolus on the image at the level of the tibial plafond (Fig. 1) to determine the best view for diagnosis of the posterior malleolar fracture, that is, to determine the average angle of external rotation required to view the fracture line parallel to the x-ray beam on a lateral radiograph.

Results

On the basis of the computed tomographic images, the posterior malleolar fractures were categorized into three types. Posterolateral-oblique (type-I) fractures were characterized by a wedge-shaped fragment involving the posterolateral corner of the tibial plafond (Fig. 2), transverse medial-extension (type-II) fractures were characterized by a fracture line extending from the fibular notch of the tibia to the medial malleolus (Figs. 3-A and 3-B), and small-shell (type-III) fractures were characterized by one or more small shell-shaped fragments at the posterior lip of the tibial plafond (Fig. 4). On the basis of this new classification scheme, thirty-eight (67%) of the fifty-seven fractures (including twenty-seven supination-external rotation fractures, six pronation-external rotation fractures, and five pronation-abduction fractures) were classified as type I, eleven (19%) of the fifty-seven fractures (including ten supination-external rotation and one pronation-abduction fracture) were classified as type II, and eight (14%) of the fifty-seven fractures (including seven supination-external rotation fractures and one pronation-external rotation fracture) were classified as type III. Nine of the eleven type-II fractures had two fragments (posterolateral and posteromedial) (Figs. 5-A, 5-B, and 5-C). Two of the eleven type-II fractures extended to the anterior part of the medial malleolus (Fig. 6).

Twelve of the thirty-eight type-I fractures, six of the eleven type-II fractures, and one of the eight type-III fractures were associated with posterior subluxation or dislocation. With the numbers available for study, we did not detect a significant difference in the prevalence of posterior subluxation or dislocation among fracture patterns ($p = 0.15$, Cochran-Mantel-Haenszel test).

The average area of the posterior malleolar fragment comprised 11.7% of the cross-sectional area of the tibial plafond for type-I fractures and 29.8% of the cross-sectional area for type-II fractures. Because some of the type-III fractures had a cross-sectional area that was very small, we discontinued measurement of this parameter for this fracture type. In the cases of seven of the nine fractures that comprised >25% of the tibial plafond, the fracture line extended to the medial malleolus (consistent with a type-II fracture).

The angles between the bimalleolar axis and the major fracture line of the posterior malleolus varied (range, –9° to

40°, with a positive value indicating that the fracture line extended posteromedially from the fibular notch of the tibia). In the cases of fourteen fractures, including all type-III fractures, we could not clearly identify the major fracture line of the posterior malleolus because of its irregularity (Figs. 3-B and 6). When we excluded such cases, the average angle (and standard deviation) between the bimalleolar axis and the major fracture line of the posterior malleolus was 20.9° ± 9.4° for thirty-seven type-I fractures and 6.5° ± 10.8° for six type-II fractures.

Discussion

Although the advent of computed tomography has enabled us to understand more clearly the fracture anatomy of several joints, we are not aware of any computed tomographic study that has clearly documented the extent and pattern of posterior malleolar fractures. The present study confirmed that a posterior malleolar fracture can be classified as one of three types: the posterolateral-oblique type, the medial-extension type, or the small-shell type. Our findings also showed that a medial-extension (type-II) fracture usually has two fragments and that some fragments involve almost the entire medial malleolus.

Some of the medial fragments of the type-II fractures that we observed matched fragments of the so-called posterior collicular fractures of the medial malleolus. Pankovich and Shivaram[20] reported four cases of posterior collicular fracture of the medial malleolus. Ebraheim et al.[21] reported six cases of posterior collicular fracture, five of which occurred in patients with trimalleolar fractures. Recently, Karachalios et al.[22] reported a trimalleolar fracture with a double fragment of the posterior malleolus. On the radiographs, it was clear that the medial fragment was due to a posterior collicular fracture. Weber[23] reported on ten such fractures. In the present study, the type-II pattern accounted for almost 20% of the observed posterior malleolar fractures and was not necessarily rare. In addition, posteromedial fragments in two of the eleven type-II fractures extended beyond the posterior colliculus; nearly the entire medial malleolus was involved (Figs. 3-B and 6).

Because most of our type-II fractures included part of the medial malleolus and consisted of two fragments, it could be argued that our type-II fracture is a type of posterior malleolar fracture. In 1911, Destot[24] used the term malleolar fracture to describe a fracture involving the posterior tibial margin. In 1932, Henderson[25] defined the posterior malleolus as "the anatomic prominence formed by the posterior inferior margin of the articulating surface of the tibia"and was the first to use the term trimalleolar fracture. These definitions were not based on actual anatomy but rather on the osseous configuration as seen on a lateral radiograph. Fractures involving the entire posterior tibial margin (from the fibular notch of the tibia to the medial malleolus) as well as fractures of the posterior tubercle traditionally have been regarded as posterior malleolar fractures[6,13,26,27], although the prevalence of this type of fracture has not been established. In most instances, the so-called posterior collicular fracture of the medial malleolus has occurred in cases of trimalleolar fracture[21,23]. An isolated posterior collicular fracture is rare. In the current study, both type-II fracture fragments shared the same major fracture line, and some of the type-II fractures did not have two fragments. Thus, we have chosen to discuss the two-fragment fracture as a type of posterior malleolar fracture (specifically, a transverse medial-extension fracture). The present study showed that most fractures that traditionally would have been described as a fracture involving the entire posterior tibial margin[6,13,26,27] were, in reality, a combination of a large fracture of the posterior tubercle and a posterior collicular fracture of the medial malleolus (consistent with a type-II fracture according to our system) and that a posterior malleolar fracture consisting of two fragments is not necessarily rare. Our findings should alert the orthopaedic surgeon to the existence of such a fracture type.

Our findings also indicate that in experimental studies dealing with posterior malleolar fractures involving the tibial plafond, the osteotomy that is used to create a simulated posterior malleolar fracture should be performed in two ways to create different types of fragments: (1) a wedge-shaped fragment in the posterolateral corner of the tibial plafond (consistent with a type-I fracture), with an average angle of 21° between the osteotomy line and the bimalleolar axis, and (2) a fragment parallel to the bimalleolar axis (consistent with a type-II fracture).

Ebraheim et al.[16] reported a case of a trimalleolar fracture that was associated with nonunion of the posterior malleolus, a fracture that had been missed on anteroposterior and lateral radiographs of the ankle. The investigators used thirteen cadaveric feet with simulated posterior malleolar fractures (although they did not define their method of fracture creation) to study the external-rotation lateral radiograph for visualization of the fracture, and they concluded that the average external rotation angle required to show the posterior malleolar fracture accurately was 50°. Because we found that the angle between the bimalleolar axis and the major fracture line of the posterior malleolus was highly variable and that the fracture lines often were irregular, we concluded that it is not possible to assess accurately the size of the posterior malleolar fragment on plain radiographs, even with use of special radiographic views[16-18]. Therefore, we believe that the use of computed tomography to identify the exact size, location, and orientation of the fracture fragment or fragments is justified. On the basis of the current study, we concluded that the average external rotation angles required to show the posterior malleolar fracture accurately on the external-rotation lateral radiograph are 21° and 7° for type-I and type-II fractures, respectively; however, for each patient, one scan at the level of the tibial plafond is sufficient for this purpose. Guidelines for fixation of the posterior malleolar fracture may need to be re-evaluated in a future computed tomography-based study.

Most investigators have recommended internal fixation for posterior fragments comprising >25% to 30% of the tibial plafond[1,13,14,17,27,28]. In our study, nine (16%) of the fifty-seven fractures (including two type-I and seven type-II fractures) had posterior fragments comprising >25% of the tibial plafond. For internal fixation of the posterior malleolus, there are three choices for the surgical approach to the fragment: lateral, medial, and posterolateral. For a lateral or medial approach[13,27-32], the incision may be longer and slightly more posterior than that used for the medial or lateral malleolus. The posterolateral approach offers more direct access[13,27,30,33] because space is created between the peroneal and Achilles tendons. Recommendations for use of the lateral or posterolateral approach are based on the fact that the posterior malleolar fracture usually exists in the posterolateral corner of the tibia. In the present study, however, the lines of most of the fractures that comprised >25% of the tibial plafond extended to the medial malleolus. Because of this finding and because the lateral malleolus is located on the lateral side, a large number of fractures requiring stabilization of the posterior malleolus may be best approached medially for reduction of the posterior malleolar fragment.

Our surgical decision-making process and its results were beyond the scope of the present study. However, our basic criteria for posterior fixation are as follows. We perform open reduction and fixation of a type-I fracture only when we detect persistent intra-articular displacement of the fragment after reduction of the lateral and, if present, medial malleolar fractures. For a type-II fracture with two fragments, we fix only the medial fragment of the two posterior fragments; fixation of this fragment makes the type-II fracture with two fragments equivalent to a type-I fracture. If persistent intra-articular displacement of the lateral fragment is detected after reduction of both the malleoli and the medial fragment of the posterior malleolus, we fix the lateral fragment. We fix all one-part type-II fractures. Additional study is needed to validate these criteria.

In conclusion, posterior malleolar fractures can be classified into three types, and fracture lines of posterior malleolar fractures vary greatly. A large fragment extending to the medial malleolus was present in almost 20% of the observed posterior malleolar fractures and is thus not necessarily rare. Some of these fragments involved the entire medial malleolus. Assessing the size of posterior malleolar fragments radiographically may be impossible because of the irregularity of the fracture line. The lines of fracture in cases that might require posterior malleolar stabilization can extend to the medial malleolus, and this should favor a medial approach to reduce the posterior malleolar fragment. Our findings should alert the orthopaedic surgeon to the prevalence of medial-extension-type fractures and may justify preoperative use of computed tomography. Our findings will be useful to investigators conducting basic research of this condition. Guidelines for the fixation of the posterior malleolar fracture may need to be reevaluated on the basis of computed tomographic findings. ■

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