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# Morphological Investigation of the Minor Posterior Malleolar Fragment of the Ankle

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## Abstract

**Objective:** To investigate the morphological characteristics of the minor posterior malleolar (PM) fracture based on CT scans.

**Methods:** There were 106 patients(54 males, 52 females) whose PM fragment was found less than 25% of the distal tibial articular surface. The correlation between the Lauge-Hansen classification and the morphological characteristic of the CT scans of the minor PM fracture were studied. These PM fractures were classified according to the morphological characteristics. The fragment width and fragment height on the sagittal plane (the unit of measurement was mm); the cross angle, and sagittal angle (the unit of measurement was °) were measured.

**Results:** These PM fractures were classified into two types. The morphological characteristics of type A were that impact area and small broken bone could be found on posterior tibial plafond; the fracture line was directed by talus impact and the articular surface was involved. The morphological characteristics of type B were that the fragment was limited to the Volkmann triangle; the fracture line was irregular and the articular surface was intact. There were 71 cases of type A and35 cases of type B. The fragment width, cross angle and sagittal angle of type A were more than that of type B. The fragment height between type A and type B had no significant difference($P > 0.05$).

**Conclusions:** The two type fractures might had different injury mechanism. The effect of two kinds of fractures on the stability of ankle joint were different. It determined appropriate surgical approaches.

***Keywords:*** *Ankle; Posterior Malleolar Fracture; Lauge-Hansen Classification; CT Scans*

## Introduction

Ankle fracture was one of the common fractures, in which posterior malleolar (PM) fracture accounted for 14% - 44% [1,2]. The clinical outcome of the ankle fractures with posterior fragment was relatively poor [3,4]. Bimalleolar fractures including PM fragment had a high incidence of post traumatic osteoarthritis compared to bimalleolar fractures without PM fragment [5], even if the short-term outcome was similar [6]. Therefore the treatment of PM fractures had attracted more and more attentions. Generally, most of the orthopedists chose to open reduction and internal fixation when the fragment more than 25% of distal tibial articular surface [7]. However, the figure had been challenged by recent literatures and argued the importance of even smaller posterior malleolar fragment to ankle joint stability, so the indications for surgical fixation had expanded. The purpose of this study was to study morphological characteristics of the minor PM fracture on CT scans, which could provide a theoretical basis for classifying and treating the PM fracture.

## Materials and Methods

**Materials:** The patients with PM fragment which was found less than 25% of the distal tibial articular surface were included in the study. The exclusion criteria were patients with age below 18 years, ankle degeneration, ankle old fractures, ankle tumor, and spiral fractures of middle and lower part of the tibia with a posterior fragment. According to the inclusion and exclusion criteria, a total of 106 patients (54 males, 52 females) met the research criteria. The CT scans included 3D construction of these patients were collected in our department from Jan. 2013 to Jan. 2016.

### Methods

1. All the PM fractures were classified by the classical classification of ankle joint fractures-Lauge-Hansen classification. The Lauge-Hansen system classifies fracture types by identifying the mechanism of injury with the first word describing the position of the foot and the second word describing the direction of the force.

2. The morphological characteristics of the PM fracture were studied by three orthopedists. The correlation between the Lauge-Hansen classification and the morphological characteristic of the CT images of the minor FM fragment were analyzed. These PM fractures were classified based on the morphological characteristic of the CT images included 3D construction of ankle joint.

3. Measurement Parameters: The CT images were measured by two orthopedists and a radiologist. The measurement parameters included the fragment width and height on sagittal plane (see Figure 1), the unit of measurement was mm; the cross angle: the angle between fracture line and the tibial axis line on cross plane, the plafond plane was selected as measuring plane; the sagittal angle: the angle between neutral axis and the major fracture line of the posterior fragment (see Figure 2), the unit of measurement was °. The Picture and Archiving Communication System (PACS) of our hospital was used to measure the parameters. The length accuracy of the PACS software was 0.01 mm, and the angle accuracy was 0.1°. The measured results by the three physicians were averaged. All the parameters were estimated with 95% confidence interval. The measurement data were analyzed by two sample t test (a = 0.05). The SPSS 21.0 software was used for statistical analysis.

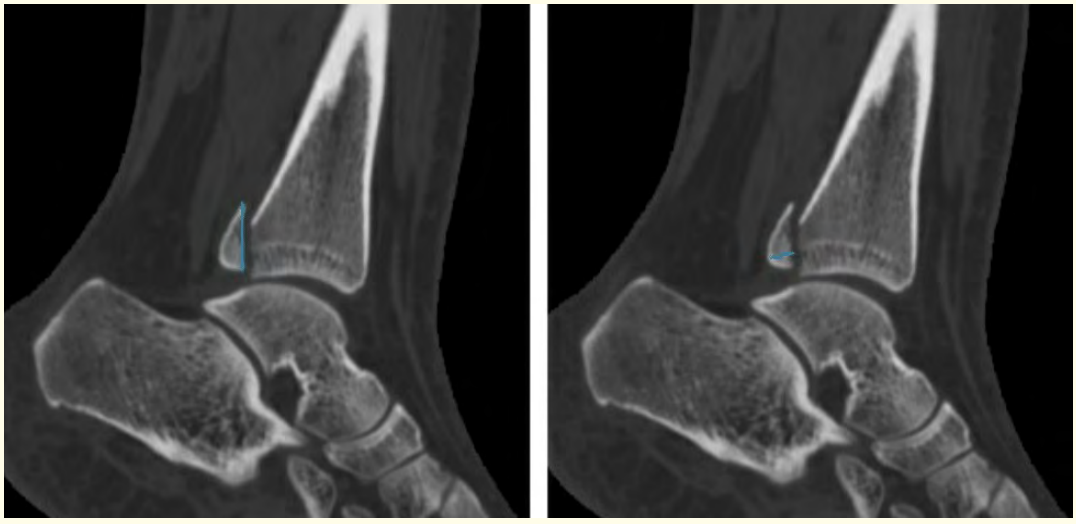

***Figure 1:*** *Measuring the maximum width and height of the fragment on the sagittal plane.*

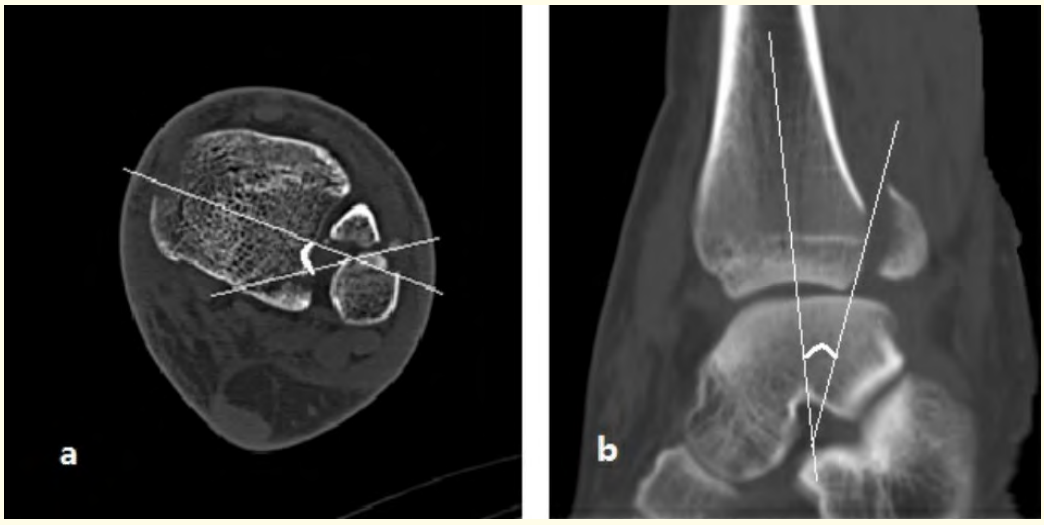


***Figure 2:*** *a: Cross angle: the angle between fracture line and the tibial axis line on cross plane, the plafond plane was selected as measuring plane; b:sagittal angle: the angle between tibial neutral axis line and the major fracture line of the posterior fragment.*

## Results

One hundred and six patients were collected totally. These posterior malleolar fractures were classified into two types: type A and type B. A total of 64 cases of supination external rotation, 3 cases of pronation external rotation, and 4 cases of unable classified were found in type A; 8 cases of supination external rotation, 25 cases of pronation external rotation, and 2 cases of unable classified were found in type B (Table 1). The morphological characteristics of the type A were that impact area and small broken bone could be found on tibial posterior fornix; the fracture line was directed by talus impact and the articular surface was involved (Figure 3). The type A was recorded in 71 (67%) cases (39 males, 32 females; 28 left ankles, 43 right ankles) with age of 45.1 years on average (Table 2). The morphological characteristics of type B were that the fragment was limited to the Volkmann triangle; the fracture line was irregular and the articular surface was intact (Figure 4). Type B was recorded in 35 (33%) cases (15 males, 20 females; 14 left ankles, 21 right ankles) with a mean age of 44.6 years (Table 2). The mean of fragment width, fragment height, cross angle, the sagittal angle of type A were 8.27 mm, 19.17 mm, 26.5°, 25.1° respectively. The mean of fragment width, fragment height, cross angle, sagittal angle were 4.73 mm, 17.15 mm, 22.7°, 20.2° respectively. The fragment width, cross angle and sagittal angle of type A were more than that of type B. The fragment height between type A and type B had no significant difference (Table 3).

| Type | SPE-Ⅲ | SPE-Ⅳ | PRE-Ⅳ | Unable classification |
|---|---|---|---|---|
| A | 27 | 37 | 3 | 4 |
| B | 3 | 5 | 25 | 2 |

***Table 1:*** *Outcome of Lauge-Hansen classification united with the morphological characteristic.*

*SPE: Supination External Rotation; PRE: Pronation External Rotation*

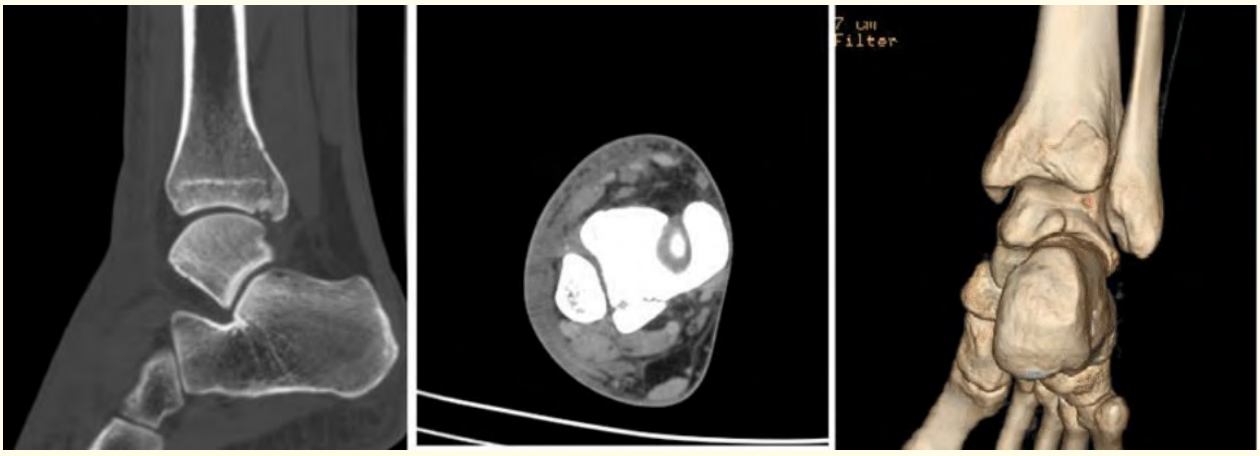

***Figure 3:*** *a: Impact area and small broken bone were found on posterior tibial plafond; the fracture line was directed by talus impact and the articular surface was involved. b, c: The fragment was less than 25% of the distal tibial articular surface.*

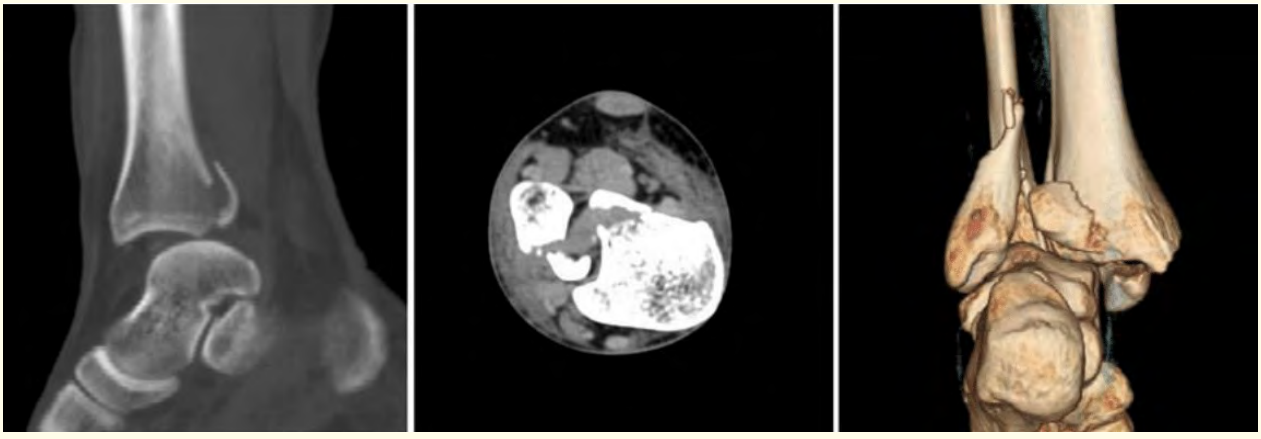

***Figure 4:*** *a, c: The fragment was limited to the Volkmann triangle, the fracture line was not regular and only through a small amount of articular surface or above the level of the articular surface. b: The fragment was less than 25% of the distal tibial articular surface.*

| Type | Case | % | Male/Female | Left/Right | Age (Years) | Mean Age (Years) |
|---|---|---|---|---|---|---|
| A | 71 | 67 | 39/32 | 28/43 | 19-78 | 45.1 |
| B | 35 | 33 | 15/20 | 14/21 | 18-80 | 44.5 |

***Table 2****: General materials.*

| Type | Width (mm) | Height (mm) | Cross angle (°) | Sagittal angle (°) |
|---|---|---|---|---|
| A | 8.27 ± 2.12 | 19.17 ± 5.42 | 26.5 ± 4.3 | 25.1 ± 5.4 |
| B | 4.73 ± 1.29 | 17.15 ± 3.68 | 22.7 ± 4.0 | 20.2 ± 4.6 |
| P | <0.01 | 0.2 | 0.0058 | 0.0043 |

***Table 3:*** *Measuring data and statistical data.*

## Discussion

Ankle fracture was common, approximately accounted for 3.9% of all fractures [1]. Since the ankle joint was a weight-bearing joint, the goals of treatment were anatomical reduction, ankle joint stability and early functional exercise [8]. Various publications pointed out the clinical outcomes of the patients with PM fracture were unsatisfactory [5,9,10]. On the other hand, the literatures also pointed out that the size of the posterior fragment has no connection with the clinical outcome, which indicated that the orthopedists should pay attention to the minor PM fracture even if the fragment was small.

To the best our knowledge, there were no literatures systemically studying the morphological characteristics of the minor PM fracture. In the study, the minor PM fractures were divided into two types based on the morphological characteristics. The type A fractures mostly were supination external rotation; the type B fractures mostly were pronation external rotation. As we know, the biggish posterior fragment was impacted by the talus, however, the minor posterior fragment can be impacted by the talus or avulsed by the posterior tibiofibular ligament. Based on the Lauge-Hansen classification, the injury mechanism of the PM fracture was related to the position of the ankle joint and the center of the violence. The ankle joint of type A fracture located at supination position, due to rotational force, the talus external rotated, the posterior malleolus suffered from fracture due to impact of the talus. The type A fracture was similar to impact fracture. The type B fracture was in pronation position, the momentary rotational violence through excessively drag the posterior tibiofibular ligament lead to avulsion fracture. The type B fracture was similar to avulsion fracture. Though all ankle fractures did not easily conform to the Lauge-Hansen classification and the injury mechanism of PM fracture was not been completely solved the problem. However, the system arose from the clinical, experimental, and radiographic observations of the authors. So the Lauge-Hansen classification was selected as basis to analyze the injury mechanism of the PM fracture in this study.

Based on the measuring and statistical data, the fragment width, the cross angle and sagittal angle of type A fracture were more than that of type B fracture. The fragment of type A tended to block; the fragment of type B tended to flake.

The surgical indications of the PM fracture remained a subject of debate, especially for the minor PM fragment. One of the reasons was that there was absence of a generally accepted classification and criteria for internal fixation. The classification specialized for PM fractures were classified by Haraguchi., *et al*. was reported in 2006 [11]. The author classified PM fractures used CT images into three types: posterolateral oblique type, medial extension type, and small shell type. However, in the classification, only transverse CT scans were obtained. The injury mechanism and stability of ankle joint, as well as the height of the fragment, were not assessed. It was criticized in the literature that the classification was not scientific [12].

A preliminary classification of the minor fractures was made in the study. Defining the type of the PM fracture was helpful to the treatment. Michelsen., *et al*. [13] believed that the ankle fracture could be treated conservatively if the ankle joint was stable enough because the mechanical characteristics of the ankle joint were not been destroyed. On the contrary, if ankle joint lost the stability, which caused the talus moved abnormally, the articular cartilage would be gradually damaged and caused traumatic arthritis of the ankle joint in the end. Type B fractures mostly were pronation external rotation fracture that tended to be unstable of syndesmotic, which was due to the fact that the ligament attachment was destroyed by avulsion violence. The syndesmotic instability was an important reason resulted in the

whole ankle instability and traumatic arthritis [14]. Internal fixation of posterior malleolus could provide 70% of stability for the ankle joint [15]. Therefore, the type B fracture combined with syndesmotic instability was an indication of internal fixation even the fragment was too small to fix with a screw [16]. If isolated PM fracture was in the type A fracture, nonoperative treatment could be effective [17,18]. Even the posterior fragment combined with the lateral malleolus and (or) medial malleolus without tibiotalar joint subluxation or dislocation, the posterior fragment could also be treated by conservative therapy properly with anatomic reduction of the lateral malleolus fracture and medial malleolus.

This study had made the detailed analysis of characteristics of minor PM fracture and provided a theoretical basis for the classifying further and the treating of PM fracture. The weakness of this study was lack biomechanical simulation test. It will provide the platform for other researcher to focus on the biomechanics of the PM fracture and the clinical relevance of the fragment.

## Conclusions

The two type fractures might had different injury mechanism. The effect of two kinds of fractures on the stability of ankle joint were different. It determined appropriate surgical approaches.

## Declarations

Ethics approval and consent to participate: The study was registered and carried out with the approvals of Ethical Institutional Review Boards of our hospital. Written informed consents were obtained from eligible patients and the study was designed to conform to the Declaration of Helsinki.

## Consent to Publish

All authors read and approved the manuscript.

## Availability of Data and Materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

## Competing Interests

The authors declare that they have no conflict of interest.

## Funding

No authors received financial support for the research.

## Authors' Contributions

z.Ruan and g.Zhang conceived and designed the study. g.Zhang; r.Hu; s.Ding; and f.Pan performed the experiments. g.Zhang wrote the paper and edited the manuscript.

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