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ORIGINAL ARTICLE

Is Bone Morphology a Determinative Risk Factor for the Type of Ankle Fracture?

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Background: The aim of this study was to investigate the relationship between the radiographic bone morphology of the ankle and the observed fracture type.

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Methods: We retrospectively reviewed the patients who had visited our emergency department with ankle injuries between June 2012 and July 2018. All patients were treated with open reduction and internal fixation. Patients were categorized in two groups based on the fracture patterns (groups 1 and 2). Group 1 consisted of isolated lateral malleolar fractures, while group 2 comprised bimalleolar fractures. Group 1 was further divided into two groups; namely group A and B based on their classification into Weber type B and C fractures, respectively. Four radiographic parameters were measured postoperatively by standing whole-leg anteroposterior view of the ankle; talocrural angle (TCA), medial malleolar relative length (MMRL), lateral malleolar relative length (LMRL), and the distance between the talar dome and distal fibula.

Results: One hundred and seventeen patients were included in group 1-A, 89 patients in group 1-B, and 168 patients in group 2. The values of TCA and MMRL were significantly higher in group 2 than in group 1. Lateral malleolar length/medial malleolar length ratio was also significantly different between the two groups. However, there were no significant differences between the groups in terms of LMRL and the distance between the tip of the distal fibula and talar process. LMLR and MMRL values between groups A and B were not significantly different (p=0.402 and p=0.592, respectively). However, there was a significant difference between the

two groups in terms of TCA and the distance between the tip of the distal fibula and talar process.

Conclusions: The talocrural angle, medial malleolar relative length, and lateral malleolar length/medial malleolar length were significantly higher in patients with bimalleolar fracture than in patients with isolated lateral malleolar fractures.

Fractures and sprains are both common in the ankle, which is one of the most frequently injured parts of the body [1]. Several studies have investigated the etiological factors and biomechanical aspects of ankle injuries and have established associations with the energy level, age, BMI, injury mechanism, activity level, previous ankle fracture, and regional bone density [2, 3, 4, 5]. However, the mechanism of ankle trauma is still not well understood; leading to controversy in our understanding of the factors and mechanisms contributing to ankle injury [6, 7].

The structural characteristics of the ankle joint, especially the degree of bony constraint, may be a contributing factor to the outcome of the type of fracture [8, 9]. It was hypothesized that compared with a lateral ankle sprain, defined as a ligament injury to one or more of anterior-posterior (AP) talofibular or calcaneofibular ligaments, a lateral malleolar fracture would show a greater degree of bony constraint in the ankle joint.

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The aim of this study was to investigate the relationship between the radiographic bone morphology of the ankle and the observed fracture type.

Materials and Methods

This retrospective study was approved by our institutional review board. Adult patients who had visited our emergency department with ankle injuries between June 2012 and July 2018 were included in the study. All patients underwent standard anteroposterior, mortise, and lateral ankle radiographs according to our institutional protocol that helps in detecting subtle bony injuries or ligamentous injuries with ankle mortise widening. Informed consent was obtained from all patients who agreed to participate in this study.

Exclusion criteria were: (1) patients aged below 18 and over 65 years; (2) patients with previous lower extremity surgery, infection, tumor, trauma, or any other condition that could have altered the ankle anatomy; (3) patients with trimalleolar fracture; (4) patients with inadequate radiographs (i.e. more than 3 mm of superimposition of the talar trochlear on the lateral view); (5) patients with tibial pilon fractures; (6) patients with talus fractures, and (7) patients with avulsion fractures of the lateral malleolus (i.e. small bony fragment at the tip of the fibula). Patients with recurrent ankle sprains were recruited based on the latest injury to avoid duplication of data.

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All patients were treated with open reduction and internal fixation. Patients were categorized in two groups based on the fracture patterns (groups 1 and 2). Group 1 consisted of isolated lateral malleolar fractures, while group 2 comprised bimalleolar fractures. Group 1 was further divided into two groups; namely group A and B based on their classification into Weber type B and C fractures, respectively.

Radiographic Evaluation

Radiographic images were digitally obtained, using a picture archiving and communication system (PACS) (Ankara Turkey), and radiographic indices were measured using the PACS software. Radiographic indices evaluating the anatomical structures of the ankle were retrieved from a literature review, and those that were considered to represent bony constraint of the ankle joint were selected based on a consensus of two orthopedic surgeons (S.G.B and O.P). Anatomical reduction was performed and the injured sides of the ankles were selected and included in the data analysis according to the surgeons. All patients were operated with standard surgical technique. Medial malleolus was treated with two percutaneous screws and open reduction-plate fixation was performed for lateral malleolar fractures.

Four radiographic parameters were measured postoperatively by standing whole-leg anteroposterior view of the ankle; talocrural angle (TCA), medial malleolar relative length

(MMRL), lateral malleolar relative length (LMRL), and the distance between the talar dome and distal fibula.

- TCA is the angle between the longitudinal axis of the tibia and a line connecting the tips of the lateral and medial malleoli **(Figure- 1).**

- MMRL is the ratio of the length of the medial malleolus to the width of the talar dome, where the medial malleolar length is the perpendicular distance between the medial malleolar tip and the continuous line of the distal tibial articular surface **(Figure 2-B).**

- LMRL is the ratio of the length of the lateral malleolus to the width of the talar dome, where the lateral malleolar length is the perpendicular distance between the lateral malleolar tips to the continuous line of the distal tibial articular surface **(Figure 2-A).**

-The distance between the tip of the distal fibula and the talar process was also measured **(Figure 2-C).** ***Statistical Analyses***

SPSS (Chicago, IL) and Microsoft Excel (Redmond, WA) were used for data analyses. Statistical significance was accepted at $p<0.05$. Descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, and maximum) were used to evaluate the study data. The quantitative data was evaluated for normal distribution by Kolmogorov-Smirnov and Shapiro-Wilk tests and graphical evaluations. Student's t-test and Mann Whitney U test were used for

comparison of two groups of quantitative data with and without normal distribution, respectively.

Results

A total of 374 patients were finally included. In the bimalleolar fracture group, the mean (SD) age of the 168 patients (112 men, 56 women) was 40.95±15.9 years. In the lateral malleolar group, there were 117 and 89 patients in group A and B with mean ages of 42, 44 ± 16,43 and 39,3 ± 12,51 years, respectively. There was no significant difference between the groups (p= 0,66).

The mean values of the measured parameters in groups 1 and 2 were: TCA, 12,68° ± 2,96° and 16,72°±2,56°; MMRL, 11,47 ± 2,46 and 15,3 ± 2,88 mm; LMRL, 27,78 ± 3,2 and 26,2 ± 3,74 mm; and the distance between the tip of distal fibula and talar process, 2,94 ± 1,74 and 2,76 ± 2,2 mm, respectively. Lateral malleolar length/medial malleolar length ratio was 1,84 ± 0,35 in group 1, while 1,75 ± 0,18 in group 2 **(Table-1).**

The values for TCA and MMRL were significantly higher in group 2 than in group 1 (p= 0,002 and p= 0,007, respectively). Lateral malleolar length/medial malleolar length ratio was significantly different between the two groups (p= 0,0096). There were no significant

differences between the groups in terms of LMRL and the distance from the tip of the distal fibula and talar process (p= 0,267 and p= 0,452, respectively).

The mean values of the parameters in groups A and B were: TCA, 12,78°± 2,66° and 19,3° ± 5,9°; LMRL, 26,43 ± 3,11 and 25,8 ± 6,85 mm; and MMRL, 15,74 ± 2,17 and 14,32 ± 3,67 mm, respectively. There were no significant differences in LMLR and MMRL between groups A and B (p= 0,402 and p=0,592, respectively). However, there was a significant difference between the two groups in terms of TCA (p<0,0001). The Lateral malleolar length/medial malleolar length ratio was 1,76 ± 0,22 in group A and 1,92 ± 0,49 in group B, and the difference was statistically significant (p= 0,001). The distance between the tip of the distal fibula and talar process was significantly higher in group A than in group B (3,38 ± 1,29 mm vs. 2,35 ± 2,05 mm, respectively; p<0,0001) **(Table-2).**

4. Discussion

Although risk factors in lateral radiograph measurements associated with ankle instability have been reported in the literature [10-13], limited studies have investigated the same for the measurements in the AP plane [7, 9]. Min Lee et al. examined the difference between the radiological measurements of sprains and lateral malleolar fractures. As the fibular length increased, an increased risk of fracture was observed. In our study, there was no difference in the fibular length between groups A and B. This may be attributed to the fact that,

contrary to Lee et al.'s study, we only examined patients with ankle fractures. In the same study, when the TCA was evaluated, they observed a difference between the lateral malleolar fracture and the sprain groups. Shorter length of the medial malleolar and longer length of the fibula were associated with a higher risk of lateral malleolar fracture. In our study, a relationship between medial malleolar length and medial malleolar fracture was found.

In a study evaluating the relationship between the distal tibia and distal fibula by Lee et al. [6], ligamentous injury was found to be related to the TCA. Similarly, we found a relationship between fracture and TCA in groups 1 and 2 and in groups A and B. Elise et al. [14] reported that the ratio between the lateral and medial malleolar length were contributing factors for foot dislocation. In our study, there was a significant difference regarding the length ratios between groups 1 and 2 and between groups A and B. We believe that there is a difference between the TCA and length ratio and the possibility of inversion instability of the talus after an ankle sprain.

Morphological studies have been performed for the fifth metatarsal fracture of the foot. The relationship between metatarsal channel diameter, four to five metatarsal angles, metatarsal length, and fracture risk has been demonstrated. With this method, suitable shoe and orthosis planning can be made for athletes at risk [15, 16]. By using the values obtained in

our study, we think that the use of shoes and orthotics can be improved according to the risk of ankle fracture.

Panchbhavi et al. [8] measured the distance between the lateral process of the talus and the tip of the distal fibula. In the radiographic evaluation, the distal tip of the fibula was proximal to the process. Similarly, we determined that the distal tip of the fibula was proximal to the lateral process of the talus. We also found that there was a significant difference between the lateral malleolar type B and C fractures in terms of the distance between the tip of the fibula and the talar process. Consequently, we think that the ligamentous strains between the talus and fibula are different after an ankle sprain. However, further biomechanical studies are needed to explore this subject. In the study of Sugimoto et al. [17], lateral ankle instability increased with TCA. We observed that the angles between groups 1 and 2 were significantly different. This may be attributed to the higher TCA in group 1 that led to a higher risk of lateral instability.

To the best of our knowledge, studies on the relationship between fracture pattern and ankle morphology are not available. In our study, we aimed to overcome this gap in the literature. One of the missing aspects of our study is the fact that BMI, neurological deficits, and injury mechanisms were not evaluated because of the retrospective nature of the study. Moreover, biomechanics of the ankle that should be evaluated on three planes were only

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evaluated in the AP plane. Additionally, trimalleolar and Weber type A fractures have not been included in the study.

This is the first study to demonstrate that ankle morphology affects the fracture pattern. We think there is a need for clinical and biomechanical studies on standing CT images with larger sample sizes. The relationship between fracture formation mechanism, ligament damage, and morphology can be investigated, and studies on the relationship between osteochondral lesions of the talus and morphology are also needed.

Conclusions

In our study, we found TCA, MMRL, and lateral malleolar length/medial malleolar length to be significantly higher in patients with bimalleolar fracture than in patients with isolated lateral malleolar fractures. While patients with Weber type C fractures had significantly higher TCA and lateral malleolar length/medial malleolar length than in patients with Weber type B fractures; the latter had significantly higher distances between the tip of the distal fibula and talar process than in patients with Weber type C.

Financial Disclosure: None reported.

Conflict of Interest: None reported.

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Table 1. Comparison of all Radiological Parameters in Both Groups

	Isolated lateral malleolus fracture group (Group 1)		Bimalleolar fracture group (Group 2)		
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	p value
Talocrural angle, º	12.68 ± 2.96	6.2 –33.8	16.72 ± 2.56	7.8 – 39.1	0.002*
Medial malleolar relative length, mm	11.47 ± 2.46	11.2 –28.9	15.3 ± 2.88	7.6 – 19.9	0.007*
Lateral malleolar relative length, mm	27.78 ± 3.2	6.9 – 36.7	26.2 ± 3.74	13.7 – 32.6	0.267
Distance between talar dome and distal fibula, mm	2.94 ± 1.74	0 – 8.9	2.76 ± 2.2	-5 – 8.3	0.452
Lateral malleolar length/medial malleolar length ratio	1.84 ± 0.35	0.55 – 2.85	1.75 ± 0.18	0.76 – 4.14	0.0096

SD: Standard deviation; Min: Minimum; Max: Maximum; mm: Milimeter; *<0.05

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Table 2. Comparison of all Radiological Parameters in Both Groups

	Weber Type B fracture group (Group 1-A)		Weber Type C fracture group (Group 1-B)		
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	p value
Talocrural angle, º	12.78 ± 2.66	6.2 – 33.8	19.3 ± 5.9	1.7 – 35.1	<0.0001*
Medial malleolar relative length, mm	15.74 ± 2.17	10.8 – 20.5	14.32 ± 3.67	6.9 – 16.7	0.592
Lateral malleolar relative length, mm	26.43 ± 3.11	15.3 – 37.4	25.8 ± 6.85	11.7 – 28.9	0.402
Distance between talar dome and distal fibula, mm	3.38 ± 1.29	0 – 6.6	2.35 ± 2.05	0 – 8.9	<0.0001*
Lateral malleolar length/medial malleolar length ratio	1.76 ± 0.22	0.83 – 2.54	1.92 ± 0.49	0.55 – 2.86	0.001*

SD: Standard deviation; Min: Minimum; Max: Maximum; mm: Milimeter; *<0,05

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Figure 1: Talocrural angle is the angle between the longitudinal axis of the tibia and a line connecting the tips of the lateral and medial malleoli.

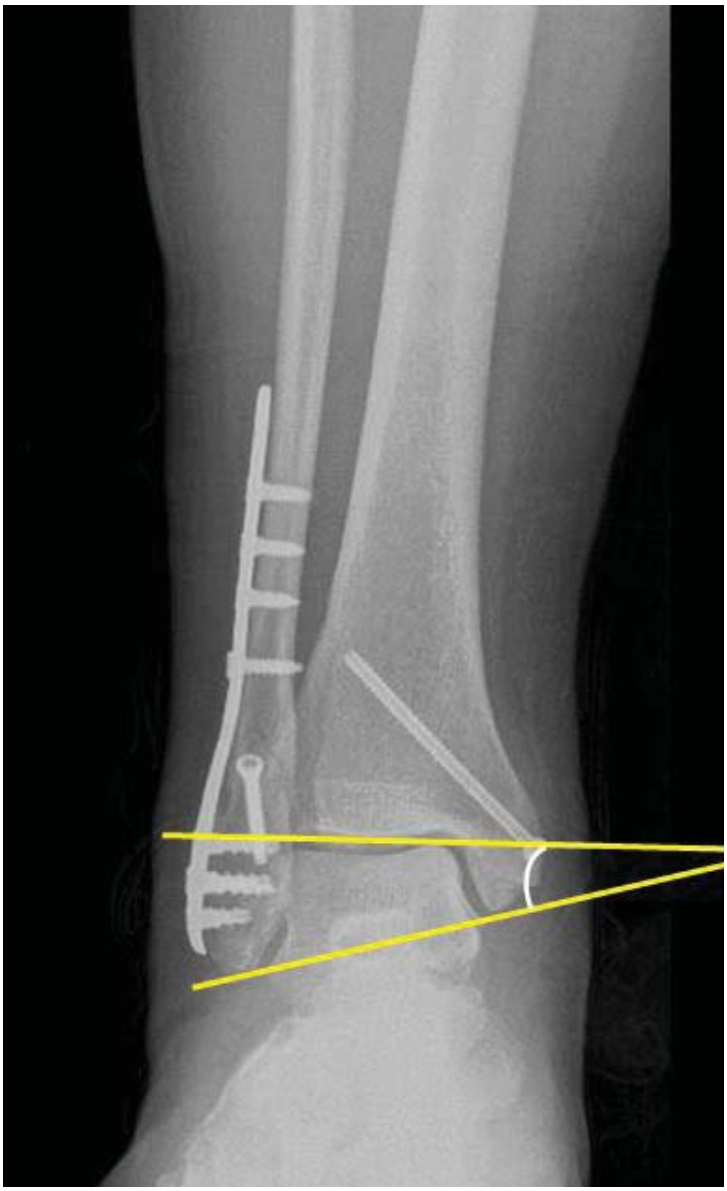

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Figure 2: A denotes the lateral malleolar length, which is the perpendicular distance between the lateral malleolar tip and the continuous line of the distal tibial articular surface. B indicates the medial malleolar length, which is the perpendicular distance between the medial malleolar tip and the continuous line of the distal tibial articular surface. C denotes the distance between the tip of the distal fibula, and the talar process was also measured.