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Foot Malalignment and Proximal Fifth Metatarsal Fractures

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Abstract

Background: Proximal fifth metatarsal fractures are common injuries that are classified into 3 zones according to their anatomical localization. While zone 1 and 2 fractures typically are traumatic, zone 3 fractures may be linked to foot alignment abnormalities, such as hindfoot varus and metatarsus adductus. The aim of the study was to explore the association between hindfoot alignment and different fracture zones, as well as the relationship between traumatic and atraumatic fracture origin and foot alignment.

Methods: We conducted a retrospective cohort study of patients with proximal fifth metatarsal fractures who had received a weightbearing computed tomography (WBCT) scan. Feet with zone 1 and 2 fractures were compared to zone 3 fractures and a healthy control group. Additionally, we compared feet with a traumatic fracture origin with those without. Foot alignment parameters, including the foot and ankle offset (FAO) and the forefoot arch angle (FAA), were analyzed alongside data from semiautomated segmentation reports. $P < .05$ was considered significant.

Results: The study included 45 fractures (23 zone 1 and 2, 22 zone 3) and 19 controls. Zone 3 fractures showed a significant association with higher body mass index ($P < .01$), hindfoot varus ($P < .01$), and metatarsus adductus ($P < .01$) compared with zone 1 and 2 fractures, and they more frequently had a nontraumatic origin ($P < .01$). Zone 3 fractures also showed a significantly higher transverse arch ($P < .01$). No differences have been observed between zone 1 and 2 fractures and the controls. Fractures with atraumatic origin were significantly associated with hindfoot varus ($P < .01$), metatarsus adductus ($P < .01$), hindfoot varus ($P < .01$), and metatarsus adductus ($P < .01$).

Conclusion: Hindfoot varus, metatarsus adductus, and a high transverse arch were significantly associated with zone 3 fractures as well as fractures with atraumatic origin.

Level of Evidence: Level III, retrospective comparative study.

Keywords: fifth metatarsal fracture, stress fracture, weightbearing computed tomography, cone beam, foot alignment

Introduction

Metatarsal fractures are among the most frequent foot injuries, with an annual incidence of approximately 70 per 100 000 people.[30] Fifth metatarsal fractures account for the majority of metatarsal fractures, with more than 70% involving the proximal portion of the fifth metatarsal.[14] The widely used Lawrence and Botte classification categorizes proximal fifth metatarsal fractures into 3 zones based on location. Zone 1 fractures are avulsion fractures of the tuberosity, zone 2 fractures extend into the fourth-fifth intermetatarsal joint, and zone 3 fractures are metaphyseal-diaphyseal junction fractures distal for the fourth-fifth intermetatarsal joint (Figure 1).[4,20] Both zone 2 and zone 3

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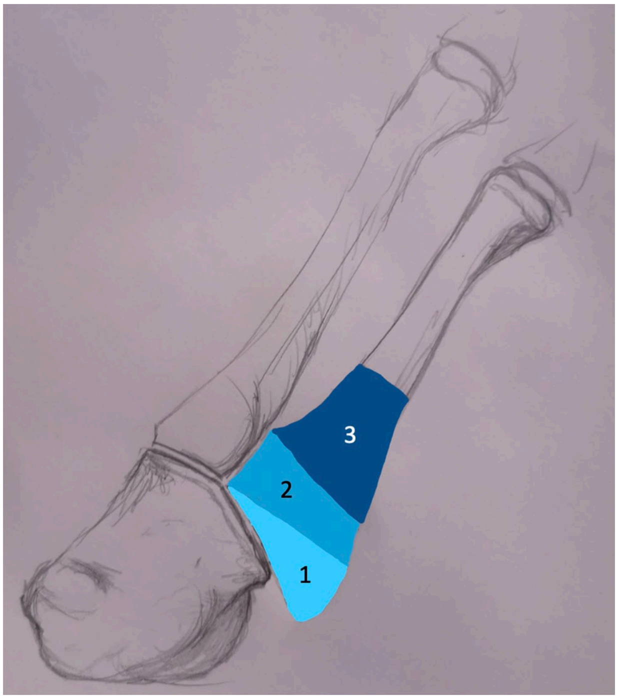

Figure 1. Zones 1, 2, and 3 according to the Lawrence and Botte classification. Zone 2 fractures occur at the fourth-fifth metatarsal conjunction, whereas zone 3 fractures are located distal to this region. (Illustration: Maria Serafin)

fractures have been frequently referred to as Jones fractures.[15]

Proximal fifth metatarsal fractures are thought to have a heterogenous etiology. Zone 1 and 2 fractures are typically acute injuries resulting from an inversion trauma.[8] Zone 3 fractures are generally considered stress fractures resulting from repetitive lateral foot overload, often without a distinct traumatic event. Foot deformities with malalignment like pes cavovarus and metatarsus adductus can contribute to lateral foot overload,[41] increasing the risk of stress reactions or fractures. However, some patients may report an acute trauma, sometimes preceded by prodromal symptoms such as lateral foot pain.[33]

This bimodal distribution of etiology is also evident in the varying treatment approaches and outcomes for these fracture types. Functional, nonoperative treatment generally leads to good union rates and outcomes in zone 1 and 2 fractures.[1,2,7,16] Zone 3 fractures, however, are more often associated with delayed union, nonunion, or refracture and thus may require operative treatment.[28,31] Although some studies have suggested that reduced blood supply in this region may impair bone healing,[26,37] others have emphasized the role of mechanical factors.[10,17,38]

This study aimed to evaluate foot alignment in patients with proximal fifth metatarsal fractures and controls using weightbearing computed tomography (WBCT). WBCT is a 3D imaging modality well suited for evaluating foot and ankle deformities.[3] We hypothesized that zone 3 fractures would be associated with hindfoot varus, metatarsus adductus, and pes cavus deformity, compared with both zone 1 and 2 fractures and controls.

Material and Methods

Study Design

This was an institutional review board (IRB)–approved (IRB number Pro00113556) level III retrospective cohort study. Patients from our institution with *International Classification of Diseases, Tenth Revision* (*ICD-10*), codes S92.35 (fracture of fifth metatarsal bone) and M84.37 (stress fracture, ankle, foot, and toes) who underwent clinical assessment with WBCT between February 2022 and May 2024 were identified through an institutional database search. The WBCT scans (CurveBeamAI, Hatfield, PA, USA) were conducted with a voxel size of 0.37 mm, a 350-mm field-of-view diameter, a 200-mm field-of-view height, an exposure time of 9 seconds, and a total scan time of 54 seconds.

Inclusion and Exclusion Criteria

All patients with proximal fifth metatarsal fractures who underwent WBCT as part of their evaluation during the study period were considered for inclusion. WBCT was ordered by physicians when the initial plain radiographs were deemed insufficient for adequately assessing fracture morphology or displacement.

Patients with diaphyseal or more distal fifth metatarsal fractures were excluded as well as patients with poorly controlled diabetes and neuropathy. Additionally, patients with a history of ankle arthroplasties, hindfoot fusion, or other foot realignment procedures were excluded, along with patients who underwent WBCT while wearing a cast. We also excluded patients with severely nonplantigrade feet or Charcot feet, in which hindfoot alignment could not be reliably assessed.

In total, 53 patients with 57 proximal fifth metatarsal fractures were identified. After applying the exclusion criteria, 41 patients with 45 fractures remained in the study (Figure 2). Fractures were classified according to the Lawrence and Botte system by 2 fellowship-trained senior foot and ankle surgeons, and consensus was obtained on every case. The fractures were graded using WBCT scans in various planes rather than radiographs, as this modality provides a more comprehensive assessment of the fourth-fifth intermetatarsal joint enabling precise differentiation between fracture zones. There were 15 zone 1 fractures, 8 zone 2 fractures, and 22 zone 3 fractures. Among the 4

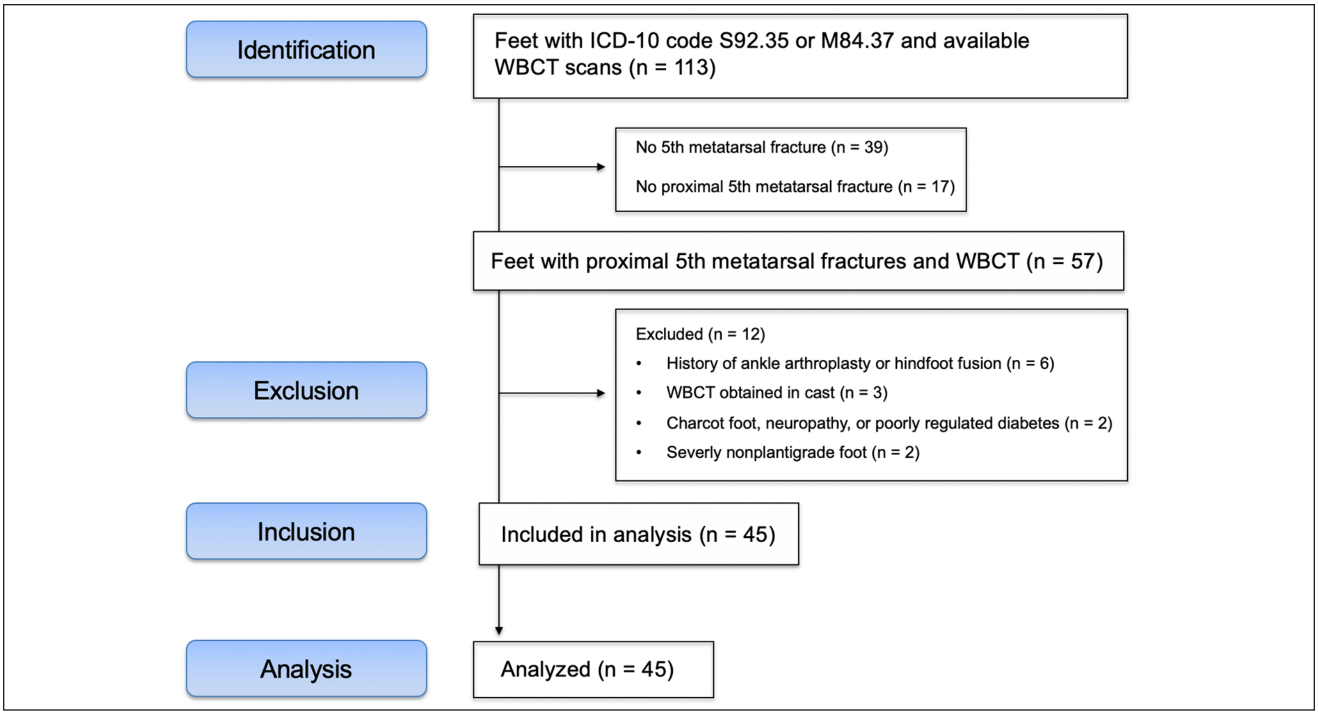

Figure 2. Inclusion flowchart of patients included in statistical analysis.

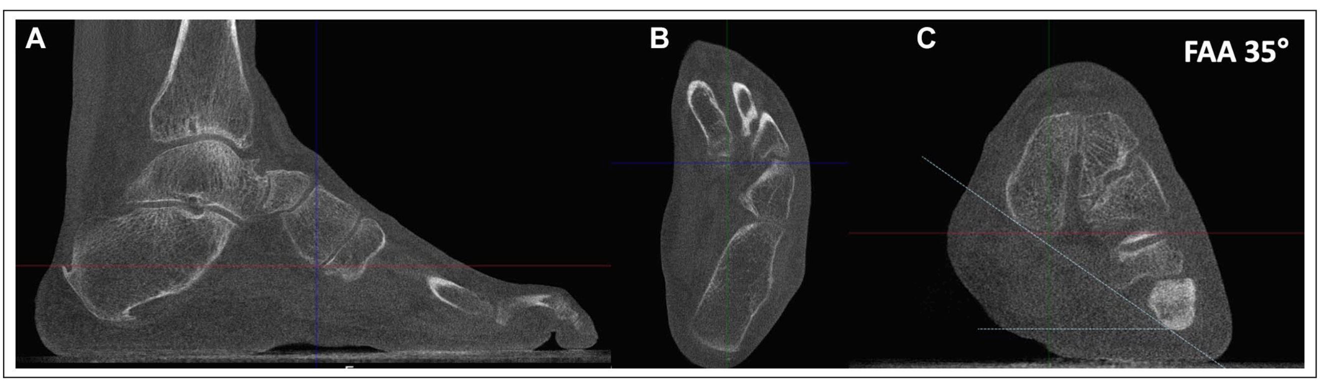

Figure 3. Measurement of the forefoot arch angle (FAA) on weightbearing computed tomographic scan. The lowest point of the medial cuneiform is marked on the (A) sagittal, (B) axial, and (C) coronal plane. The FAA is measured on the coronal plane.

patients with bilateral fractures, 3 presented with bilateral zone 3 fractures, whereas 1 had a zone 3 fracture on one side and a zone 1 fracture on the contralateral side. For subgroup analysis, zones 1 and 2 were combined into 1 group, whereas zone 3 fractures were considered separately. The control group consisted of 19 individuals who underwent bilateral WBCT for other foot and ankle conditions, including benign ankle sprains, hallux rigidus, or Achilles tendinopathy. For this study, their contralateral, unaffected feet and ankles were assessed. For both controls and patients with proximal fifth metatarsal fractures, patient demographics including age, sex, and body mass index (BMI) were obtained through retrospective chart review. It was documented whether the fractures were of traumatic or atraumatic origin. For cases with missing information, the fracture's etiology was classified as "unknown."

Measurements

The forefoot arch angle (FAA) is the angle between a line connecting the most inferior aspects of the medial cuneiform and proximal fifth metatarsal, and a tangent to the floor (Figure 3). It measures the height of the transverse arch of the foot with positive values indicating relatively higher positioning of the medial cuneiform in relation to the fifth metatarsal. High positive values indicate pes cavus.[12]

The foot and ankle offset (FAO) is a semiautomatic 3D biometric foot alignment measurement tool (Talas, CubeView; CurvebeamAI).[24] FAO measures the position of the foot tripod relative to the center of the talus in the axial plane. Negative values suggest varus alignment, with the ankle joint centered laterally from the foot tripod's bisecting line (Figure 4). The average values for FAO were previously described as 2.3% ± 2.9% for normal cases,[24] and a cutoff for varus-related pathologies was defined as FAO < −1.64.[23] Both FAA and FAO were independently measured by 2 fellowship-trained senior foot and ankle surgeons for evaluation of interrater reliability. The first author repeated the measurements after 2 weeks to calculate intrarater reliability.

Semiautomatic segmentation of the bones of the foot and ankle was performed for each patient using commercially available software (BoneLogic, Disior; Paragon28, Englewood, CO), which provided a standard measurements report including the 20 degrees Saltzman view and the posterior hindfoot moment arm (HMA) as indicators of varus or valgus hindfoot alignment; the sagittal Meary angle and the calcaneal inclination angle to assess cavus deformity; the axial Meary angle, along with the first, second, and third tarsometatarsal angles in both the sagittal and the axial planes, to evaluate metatarsus adductus (Figures 5 and 6).

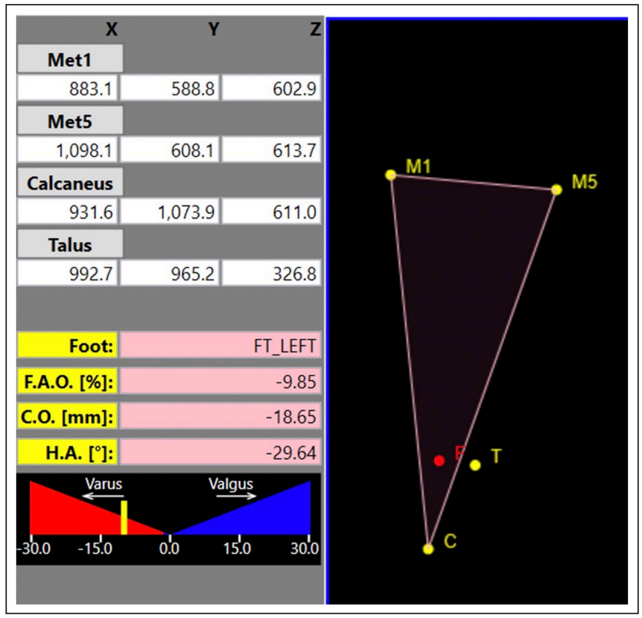

Figure 4. Automated foot and ankle offset (FAO) calculation using Talas in CubeView. The numbers displayed in the upper left corner of the image represent the 3D coordinates (X, Y, Z) of the 4 reference points required for calculating the FAO. The center of the talar head is positioned laterally outside the triangle, indicating a varus alignment of the foot.

Statistics

Statistical analyses were performed using Stata 18.0 (StataCorp, College Station, TX). Continuous variables such as age and BMI were compared between groups using either Student *t* tests or Wilcoxon rank-sum tests, depending on the normality of the data as assessed by the Shapiro-Wilk test. Pearson chi-squared test was applied for categorical data. Intrarater and interrater reliability was evaluated using intraclass correlation coefficients (ICCs), which were interpreted as follows: 0.81 to 0.99, almost perfect reliability; 0.61 to 0.80, substantial; 0.41 to 0.60, moderate; 0.21 to 0.40, fair; and ≤20, slight reliability.[19] To account for the

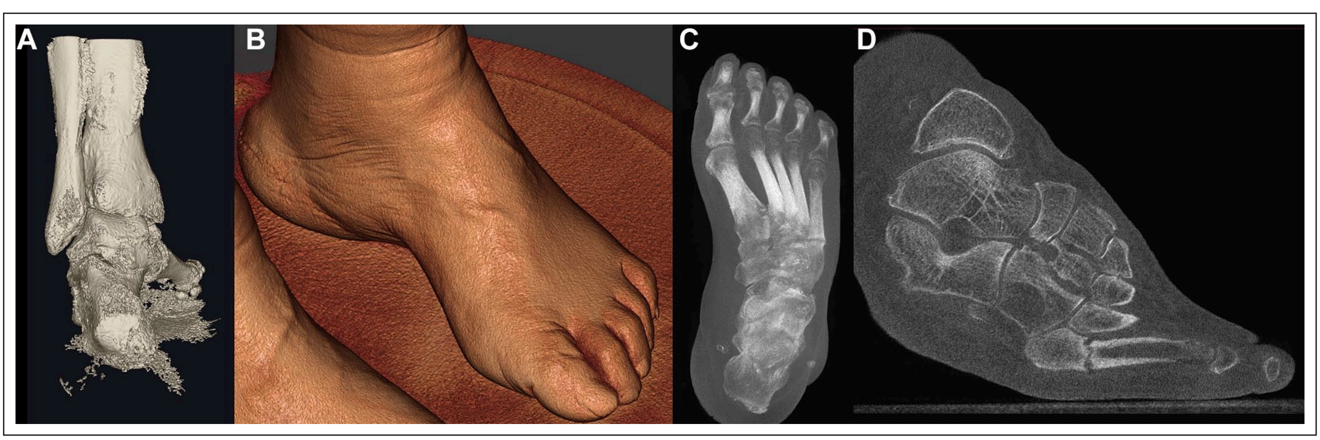

Figure 5. Fifty-one-year-old male patient who sustained a zone 3 fracture without history of trauma. (A) The BoneLogic 3D model shows hindfoot varus, whereas (C) the CubeView 3D rendering skin view illustrates (B) midfoot cavus. An axial weightbearing computed tomography slab demonstrates forefoot adductus. Rotational alignment, perpendicular to the fourth-fifth metatarsal conjunction, localizes the fracture in zone 3, distal for the conjunction (D).

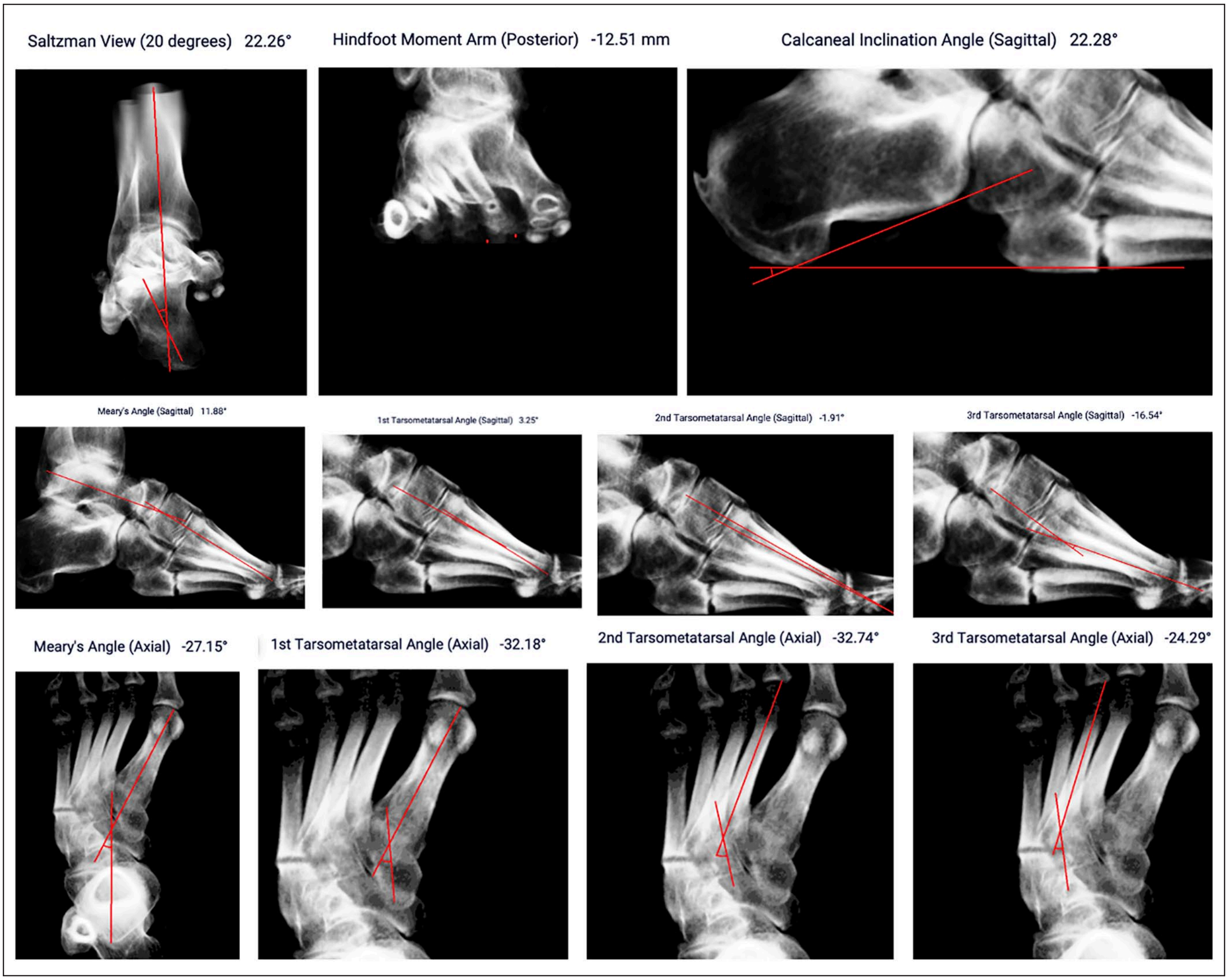

Figure 6. Measurements from the Disior report used in the current study.

Table 1. Patient and Control Cohort Demographics.

	Total	Zone 1 and 2	Zone 3	Controls	Zone 1 and 2 vs Zone 3, *P* value	Zone 1 and 2 vs Controls, *P* Value	Zone 3 vs Controls, *P* Value
Age[a]	50.1 ± 17.9	47.2 ± 20.5	52.4 ± 13.0	51.9 ± 14.2	.32	.41	.91
BMI[a]	32.1 ± 9.1	28.9 ± 7.7	36.1 ± 9.4	33.5 ± 9.3	**<.01**	.14	.69

Abbreviation: BMI, body mass index.
[a]Data are presented as mean ± SD. Boldface indicates significance ($P < .05$).

inclusion of bilateral feet in the analysis of radiographic measurements, a mixed-effects model was used. This model included a random effect for patient ID to address within-subject correlation and clustering of measurements. Group differences between fracture zones and controls were assessed as fixed effects. Pairwise comparisons between groups were conducted using linear combinations of coefficients derived from the mixed-effects model. A P value <.05 was considered as significant.

Results

Patient demographics are summarized in Tables 1 and 2. Of the 41 patients with fifth metatarsal fractures, 21 were

Table 2. Distribution of Laterality and Trauma History Among the Included Fractures.[a]

	Total	Zone 1 and 2	Zone 3	Controls	Zone 1 and 2 vs Zone 3, *P* Value	Zone 1 and 2 vs Controls, *P* Value	Zone 3 vs Controls, *P* Value
Feet	45	23	22	19	–	–	–
Side							
Left	22	13	9	13	.30	.64	.15
Right	23	10	13	6			
Trauma history							
Yes	23	19	4		**<.01**		
No	14	2	12				
Unknown	8	2	6				

[a]The values are presented as numbers. Boldface indicates significance ($P < .05$).

Table 3. Interclass Correlation Coefficients (ICCs) for Intra- and Interobserver Reliability of the Semiautomatic 3D Biometrics and the Manual Measurements.

	Intraobserver Agreement (95% CI); *P* Value	Interobserver Agreement (95% CI); *P* Value
Foot and ankle offset (FAO)	0.96 (0.88-0.96); <.01	0.93 (0.88-0.96); <.01
Forefoot arch angle (FAA)	0.98 (0.96-0.99); <.01	0.97 (0.95-0.98); <.01

female and 20 were male. In the control group, there were 10 females and 9 males. For zone 1 and 2 fracture patients, there were no statistically significant differences in age and BMI compared to the control cohort. The BMI of patients with zone 3 fractures was significantly higher than those with zone 1 and 2 fractures ($P < .01$), but not the control group (Table 1). Additionally, 12 of 22 zone 3 fractures occurred without a chart-recorded traumatic incident, compared with 2 of 23 zone 1 or 2 fractures ($P < .01$) (Table 2). For the manual measurements, both intra- and interobserver reliability were considered almost perfectly reliable at 0.98 and 0.97, respectively (Table 3).

The FAO in zone 1 and 2 fracture feet, as well in the control group, were within the range of normal alignment (mean ± SD 1.99 ± 4.28 vs 1.67 ± 2.52, respectively). However, the mean FAO for zone 3 patients (−4.61) indicated varus alignment, significantly differing from both zone 1 and 2 fractures and the controls ($P < .01$) (Table 4). Both Saltzman view and posterior hindfoot moment arm demonstrated significantly increased varus alignment in zone 3 fractures compared with both zone 1 and 2 fractures and controls ($P < .01$).

The FAA was significantly higher in zone 3 fractures compared with both zone 1 and 2 fractures and controls ($P \leq .01$ and $P = .02$, respectively), indicating a higher transverse arch and cavus foot. The sagittal Meary angle was significantly different between zone 1 and 2 and zone 3 ($P = .04$). However, with the numbers available, no significant difference could be detected in the calcaneal inclination angle.

The axial Meary angle, along with the second and third sagittal and the first, second, and third axial tarsometatarsal angles, showed significant differences between zone 1 and 2 and zone 3 fractures, as well as between zone 3 fractures and controls, indicating a metatarsus adductus configuration in zone 3 feet.

With the numbers available, the measurements in zone 1 and 2 fractures did not demonstrate a significant difference from the control group, except for the first tarsometatarsal angle, which reached significance ($P = .03$).

Fractures of atraumatic origin demonstrated significant differences in all measurements compared to those with a history of trauma ($P < .05$), except for the calcaneal inclination angle ($P = .92$) (Table 4).

Discussion

Our findings indicate that zone 3 fractures are more significantly associated with hindfoot varus, metatarsus adductus, and a high transverse arch, suggesting a relationship between foot and ankle alignment and class of proximal fifth metatarsal fracture. Moreover, fractures of atraumatic origin were found to be significantly associated with these alignment disorders. These results suggest that certain structural deformities may predispose to lateral foot overload, placing certain individuals at risk of stress reactions or stress fractures.

Previous studies on foot alignment in proximal fifth metatarsal fractures have primarily relied on conventional weightbearing radiographs and clinical assessments.

Table 4. Results of the Manual and Semiautomated Measurements Comparing Different Fracture Zones and Controls As Well As Feet With and Without a Traumatic Origin, Irrespective of Fracture Zone.[a]

Measurement	Zone 1 and 2	Zone 3	Controls	Zone 1 and 2 vs Zone 3, *P* Value	Zone 1 and 2 vs Controls, *P* Value	Zone 3 vs Controls, *P* Value	Fractures With Traumatic Origin	Fractures With Atraumatic Origin	Traumatic vs Atraumatic, *P* Value
Number	23	22	19				23	14	
Foot and ankle offset (FAO), %	1.99 ± 4.28	−4.61 ± 8.67	1.67 ± 2.52	<**.01**	.85	<**.01**	2.08 ± 1.30	−5.73 ± 1.62	<**.01**
Saltzman view (20 degrees)	1.7 ± 10.5	16.6 ± 12.8	6.8 ± 11.0	<**.01**	.15	**.01**	2.5 ± 2.5	14.7 ± 3.1	<**.01**
Hindfoot moment arm (HMA), mm	7.3 ± 6.6	−2.4 ± 10.2	5.75 ± 6.8	<**.01**	.60	<**.01**	7.4 ± 1.7	−1.8 ± 2.1	<**.01**
Forefoot arch angle (FAA)	11.7 ± 7.0	19.2 ± 10.4	13.8 ± 4.5	<**.01**	.53	**.02**	12.3 ± 1.9	20.4 ± 2.3	<**.01**
Calcaneal inclination angle (sagittal)	18.3 ± 4.8	17.4 ± 6.4	20.1 ± 6.2	.86	.22	.30	18.6 ± 1.1	18.8 ± 1.4	.92
Meary angle (sagittal)	−11.2 ± 11.9	−5.4 ± 17.0	−5.5 ± 10.1	**.04**	.24	.69	−10.3 ± 2.8	−0.8 ± 3.5	**.03**
Meary angle (axial)	12.9 ± 12.5	−7.3 ± 15.3	12.0 ± 10.9	<**.01**	.99	<**.01**	12.0 ± 2.6	−11.0 ± 3.2	<**.01**
First TMT angle (sagittal)	9.0 ± 3.2	7.1 ± 4.0	12.2 ± 10.0	.62	.03	**.01**	9.5 ± 0.8	6.4 ± 0.9	**.01**
Second TMT angle (sagittal)	8.1 ± 2.8	4.6 ± 4.2	8.1 ± 2.2	<**.01**	>.99	<**.01**	8.5 ± 0.7	3.4 ± 0.9	<**.01**
Third TMT angle (sagittal)	−3.7 ± 4.6	−10.0 ± 5.9	−3.1 ± 4.6	<**.01**	.65	<**.01**	−3.5 ± 1.0	−11.2 ± 1.3	<**.01**
First TMT angle (axial)	−21.8 ± 8.2	−29.5 ± 5.5	−18.9 ± 13.5	**.04**	.13	<**.01**	−23.0 ± 1.4	−30.7 ± 1.7	<**.01**
Second TMT angle (axial)	−19.3 ± 5.8	−28.5 ± 4.3	−19.8 ± 3.5	<**.01**	.76	<**.01**	−20.1 ± 1.1	−28.7 ± 1.3	<**.01**
Third TMT angle (axial)	−20.0 ± 6.2	−26.9 ± 6.6	−19.8 ± 3.5	<**.01**	.85	<**.01**	−20.7 ± 1.2	−26.8 ± 1.5	<**.01**

Abbreviation: TMT, tarsometatarsal.
[a]The measurements are presented in degrees, if not labeled otherwise. Data are presented as mean ± SD. Boldface indicates significance ($P < .05$).

Although Raikin et al[35] observed predominantly varus alignment and higher calcaneal inclination angles (mean 28.5°) and sagittal Meary angles (13.7°), Porter et al[34] found clinical valgus alignment (mean 3.5°) but with a high calcaneal inclination angle (49°), which may be associated with hindfoot varus. Lee et al[22] reported elevated calcaneal inclination in zone 3 fractures (mean 27.4°), whereas Carreira et al[5] found no significant differences in calcaneal inclination (17.5°) or sagittal Meary angle (2.0°) in a cohort dominated by zone 2 fractures. Fujitaka et al[13] noted a higher medial longitudinal arch in Jones fractures but did not specify zones, limiting direct comparison. In contrast to conventional weightbearing radiographs, WBCT offers an opportunity for assessment in the coronal plane. This allows direct evaluation of hindfoot alignment, avoiding the need to rely on sagittal measurements. We assessed hindfoot alignment through coronal plane WBCT-specific variables, including automated measurement of the Saltzman view[36] and the hindfoot moment arm, revealing significant differences between fracture zones. Contrary to that, our findings showed no significant differences between groups regarding the sagittal plan measurements calcaneal inclination angle and sagittal Meary angle. These findings suggest that these measurements may not accurately represent hindfoot varus as previously assumed. Alternatively, this discrepancy could be attributed to WBCT's distinct measurement methods and the impact of rotational deformities. Our zone 3 fracture cohort, with a mean age of 52 years and BMI of 36, also differs demographically from the athletic populations examined in other studies.

Several studies have found an association between metatarsus adductus and proximal fifth metatarsal fractures. On radiographs, the metatarsal adductus angle (MAA) is defined as the angle between the second metatarsal's longitudinal axis and that of the lesser tarsus (navicular, cuboid, and cuneiform bones).[9] Yoho et al[40] reported a mean MAA of 20.2 degrees in 30 zone 3 fractures, significantly higher than controls; however, the authors did not evaluate hindfoot alignment. Wamelink et al[39] found a statistically significant association between zone 3 fractures and metatarsus adductus foot type, reporting a mean MAA of 24.6 degrees. Our study employed WBCT to directly measure axial and sagittal tarsometatarsal angles, finding significant alignment differences between zone 3 fractures compared with zones 1 and 2 and controls in both planes.

Our subanalysis of fractures with a confirmed atraumatic origin revealed statistically significant differences in all assessed radiographic variables, except for the calcaneal pitch angle, when compared to fractures of nontraumatic origin. The predominance of zone 3 fractures in this group (12 atraumatic fractures vs 2 in the zone 1 and 2 group) might explain this association. These findings highlight the role of foot malalignment in causing (repetitive) foot overload, potentially leading to atraumatic fractures.

The inconsistent classification and varied use of the term *Jones fracture*[15] present another apparent challenge in comparing our findings with prior studies.[27] The eponym Jones fracture has been widely adopted, but variably applied to both zone 2[20,25] and zone 3 fractures,[18,33,40] often leading to their combined description in the literature. We advocate for avoiding the *Jones* eponym in clinical practice and future research to prevent misinterpretation of fracture pathophysiology.

In recent years, several efforts have been made to adapt and refine the Lawrence and Botte classification. Some authors have proposed combining zone 2 and 3,[8,11] suggesting similar, operative treatment for injuries in both zones. However, recent large-scale studies have demonstrated good clinical outcomes and time to union with functional, nonoperative treatment of zone 2 fractures.[2,16,31] Therefore, we believe such a classification system may fail to effectively guide treatment and predict prognosis. Polzer et al[32] proposed another simplified classification into 2 zones: metaphyseal fractures (including Lawrence and Botte zone 1 and most of zone 2 fractures) and meta-diaphyseal fractures (encompassing zone 3 and the distal fourth-fifth intermetatarsal articulation) to better guide treatment and prognosis. In a survey conducted among members of the American Orthopaedic Foot and Ankle Society (AOFAS), this 2-zone grading system demonstrated better interrater reliability compared to the 3-zone system of Lawrence and Botte.[27]

For the current study, we opted to apply the traditional Lawrence and Botte classification system because of its familiarity and widespread adoption, despite criticism for its relatively low interrater reliability in studies relying on conventional radiographs.[6,27,29] We believe that CT scans improve the ability to differentiate between zone 2 and zone 3 compared with conventional radiographs. Based on our hypothesis and to account for the limited sample size, we decided to group zone 1 and zone 2 together, slightly deviating from the two-zone system used by Polzer et al.[32]

This study has several inherent limitations. It is retrospective and consists of patients treated by multiple surgeons. Because of differences in evaluation and surgical decision making, we did not evaluate treatment options or clinical outcomes and focused on objective radiographic assessments alone. Furthermore, WBCT was not consistently used for all proximal fifth metatarsal fractures in our institution, leading to a potential selection bias. The relatively high proportion of zone 3 fractures (49%) in our sample is greater than the 20% reported in larger cohort studies,[31] suggesting that patients with more severe deformities may have been preferentially selected for WBCT. Additionally, the significantly higher BMI observed in patients with zone 3 fractures could act as a confounding factor, as increased body weight may lead to overload and, in some cases, result in stress fractures.[21] Moreover, the sample size is relatively small, and no power analysis was performed.

Our study is the first to use WBCT for assessing foot alignment in proximal fifth metatarsal fractures. The significant association between both zone 3 fractures and fractures with atraumatic origin and alignment disorders with lateral column overload highlights the importance of both addressing foot alignment in treatment plans and with patient counseling and risk assessment for those with such foot and ankle deformities.

Conclusion

Our findings highlight the relationship between foot alignment and the development of proximal fifth metatarsal fractures, especially zone 3 fractures and fractures with atraumatic origin, which are strongly associated with hindfoot varus, metatarsus adductus, and a high transverse arch. In the future, systematic assessment of foot alignment should be incorporated into clinical practice for patients with zone 3 fractures and fractures of atraumatic origin to guide treatment and mitigate potential risks of lateral overload and related complications. This would be particularly meaningful in high-demand athletic populations where there is a critical need to reduce risk of refracture or contralateral injury.

Future research could explore approaches currently lacking robust data. For instance, investigating the effects of specific rehabilitation protocols or custom-made insoles on bone density distribution and the risk of stress fractures would be valuable.

Finally, we recommend avoiding the term *Jones fracture*, as it can lead to misinterpretation and incorrect grouping of zones 2 and 3, instead of zones 1 and 2. As a future direction, adopting a 2-zone classification could offer better guidance for treatment, provide clearer prognostic insights, and more effectively highlight underlying foot malalignment.

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Ethical Approval

Our Institutional review board (IRB) approved this study (IRB number Pro00113556).

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Emily Luo MD: Sana Biotechnology (shareholder). Antoine Acker MD: CurveBeamAI (shareholder). François Lintz MD, PhD: Paragon28 (consultant, shareholder), CurvebeamAI (consultant, shareholder), Newclip Technics (consultant, royalties), Podonov (consultant, royalties), LINNOV (founder, shareholder), Followinvest (shareholder), International WBCT Society (co-founder, past president). Cesar de Cesar Netto MD, PhD: Paragon28 (consultant, medical advisory board, royalties), CurvebeamAI (consultant, shareholder), Ossio (consultant), Zimmer (consultant), Stryker (consultant), International WBCT Society (co-founder, president), Exactech (consultant), Arthrex (consultant), Tayco Brace (shareholder), Extremity Medical (consultant), AOFAS committee member, *Foot Ankle Clinics* (editor in chief). Disclosure forms for all authors are available online.

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