ORIGINAL RESEARCH

The Incidence of and Demographic Disparities Among Fifth Metatarsal Fracture Nonunions

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Received on: 13 October 2022; *Accepted on:* 02 December 2022; *Published on:* 31 December 2022

Abstract

Aim: This study aimed to assess the incidence and demographics of fifth metatarsal (5MT) fractures, as well as the association of these factors with nonunion rates.

Materials and methods: A total of 1,000 adult patients with confirmed 5MT fractures were recruited retrospectively. Patients were screened for union vs nonunion, where nonunion was defined as failure to heal completely within 180 days of fracture diagnosis. Inclusion criteria were: (1) age of ≥ 18-year-old and (2) confirmation of 5MT fracture by experts based on examination and radiograph. Exclusion criteria were: (1) missing data on final healing status, (2) presence of another traumatic injury to the foot during the healing process of the primary 5MT fracture, (3) lack of radiologic proof of healing or nonhealing, and (4) missing demographic data or relevant clinical or operative notes. Data on demographics, fracture characteristics, and treatment methods (conservative vs operative) were also collected. One-way analysis of variance (ANOVA) and Chi-square analysis was used, and $p < 0.05$ was considered statistically significant.

Results: The overall nonunion rate was 22.4%, with zone 2 demonstrating the highest nonunion rate (28.1%). Weight and body mass index (BMI) were correlated with a higher nonunion rate ($p = 0.002$ and $p = 0.012$, respectively). Type of treatment (operative vs conservative) and displacement were not correlated with nonunion; however, stratification by both types of treatment and displacement revealed a difference in nonunion between the three fracture zones.

Clinical significance: 5MT fracture nonunion remains a prevalent problem. The association between nonunion and weight, BMI, and fracture characteristics can be used by clinicians in the decision-making process regarding treatment and management of 5MT fractures to reduce the incidence of nonunion, improve patient-reported outcomes, and reduce the healthcare burden.

Keywords: Fifth metatarsal, Metatarsal fracture, Nonunion.

Journal of Foot and Ankle Surgery (Asia-Pacific) (2023): 10.5005/jp-journals-10040-1275

Introduction

Metatarsal fractures are one of the most common foot injuries seen in foot and ankle clinics, demonstrating an estimated annual incidence of 6.7/10,000 people and accounting for approximately 35% of all foot fractures.[1,2] Approximately two-thirds of metatarsal fractures involve the Fifth metatarsal (5MT).[3] In the general population, there is a peak incidence of 5MT fractures between the ages of 20 and 50, with a greater incidence in older females.[3,4] A second peak incidence in a younger population is represented by athletes or military recruits, as a consequence of an acute injury or due to repetitive loading that results in stress fractures.[5]

Fifth metatarsal fractures are traditionally classified according to the anatomic zone of the fracture. One of the most commonly utilized classification systems is the Lawrence-Botte, which categorizes 5MT fractures into three zones.[6] Zone 1 involves the proximal aspect of the base of the 5MT, and fractures in this area are mostly tuberosity avulsion fractures. Zone 2 fractures, also known as Jones fractures, comprise the metaphyseal-diaphyseal junction. Lastly, zone 3 includes the most distal aspect of the base of the 5MT, occupying the diaphyseal region within 1.5 cm of the tuberosity.[6] Stress fractures are more common in zone 3.

Unfortunately, union deformities, such as nonunion and delayed union, are common in 5MT fractures.[5,7–9] Prior literature suggests these union deformities are related to the fracture zone and the type of treatment. Zone 1, followed by zone 3, fractures

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have demonstrated the lowest nonunion rate and quickest time to union of all the 5MT base fractures.[10] Zone 2 fractures are more commonly associated with delayed or nonunion, with reported delayed and nonunion rates ranging from 7 to 68%, based on current literature.[11–13]

Despite acknowledging the high rate of union deformities associated with 5MT fractures, determining the associated causes and risk factors has remained a challenge. This study aims to assess the incidence of nonunion of 5MT base fractures and the correlation of nonunion with fracture characteristics and patients' demographics. Our hypothesis was that some correlation would exist between patient characteristics, fracture zone and treatment method, and nonunion rates in 5MT fractures.

Materials and Methods

This is a retrospective case-control study of 1,000 patients with a confirmed diagnosis of 5MT fracture. The protocol of the study was approved by the Institutional Review Board under protocol no. 2015P000464. Patients with suspected 5MT fractures from 2004 to 2014 were recruited using the Research Patient Data Registry based upon International Classification of Disease (ICD9/10) codes. The initial cohort of patients was screened by two expert orthopedic researchers to confirm patient eligibility. Diagnosis of 5MT was confirmed using clinical notes in the electronic medical record and radiographs. Inclusion criteria were: (1) age of ≥18-year-old and (2) confirmation of 5MT fracture by experts based on examination and radiograph. Exclusion criteria were: (1) missing data on final healing status, (2) presence of another traumatic injury to the foot during the healing period of the primary 5MT fracture, (3) lack of radiologic proof of healing, and (4) missing demographic data or relevant clinical or operative notes. The final cohort of 1,000 patients was divided into two groups according to final osseous consolidation status: union ($n = 776$) and nonunion ($n = 224$).

For each patient, the electronic medical records were reviewed to obtain demographic data, fracture zone, fracture displacement, treatment method (conservative or operative), consolidation status, and if applicable, time to consolidation. Demographic data included age, height, weight, BMI, gender, race, smoking habits, and activity level (athlete/nonathlete). The fracture zone was characterized according to the previously discussed Lawrence-Botte classification system, and 5MT shaft fractures were included in zone 3 due to similar characteristics. For consolidation status, nonunion was defined as incomplete or no healing after 6 months from the date of fracture diagnosis. Consolidation time was defined as the time from the date of fracture diagnosis to the date of complete osseous consolidation of the fracture on a plain radiograph, interpreted by an expert orthopedic surgeon and a radiologist. Given this definition, consolidation time was only calculated for fractures that went on to union.

Statistical Analysis

Descriptive statistics [mean ± standard deviation, (SD)] were calculated for all quantitative variables and percent occurrence was calculated for all qualitative variables. The one-way ANOVA test was used to assess differences in continuous, quantitative variables between specific subsets of the populations. The chi-squared test was used to assess for significant differences in qualitative variables in the various subgroups of the population. The chi-squared test was also used to assess for correlation with nonunion rates of 5MT fractures. For all statistical analysis, a p-value of <0.05 was considered statistically significant.

How to cite this article: Flaherty A, Akhbari B, Ghaednia H, *et al*. The Incidence of and Demographic Disparities Among Fifth Metatarsal Fracture Nonunions. J Foot Ankle Surg (Asia-Pacific) 2023;10(1): 8–12.

Source of support: Nil

Conflict of interest: None

Results

Demographic and fracture characteristics of the patients in the study population are shown in Table 1. Overall, of all 5MT fractures included in the cohort, 42% were zone 1, 31% were zone 2, and 27% were zone 3 fractures (Table 1). An analysis of demographic data by fracture zones showed a significant difference in height ($p = 0.005$), weight ($p = 0.009$), gender ($p = 0.049$), and activity status ($p = 0.003$) between the three fracture zones (Table 1).

Of all the demographic variables included, only weight ($p = 0.002$) and BMI ($p = 0.012$) were found to have a correlation with nonunion rates based on one-way ANOVA test results. Increased weight and BMI were found to be associated with a higher rate of nonunion (Table 2). The fracture zone also showed a significant correlation with the incidence of nonunion ($p = 0.002$). Zone 2 fractures demonstrated the highest nonunion rate of 28%, followed by zone 1 fractures with a nonunion rate of 22%, and zone 3 fractures with a rate of 16% (Fig. 1). There was no correlation between the type of treatment and the rate of nonunion when the entire cohort was assessed as a whole nor when stratified by fracture zone. However, within the subgroup of patients treated conservatively, there was a significant correlation between the fracture zone and the nonunion rate (Table 3). Similarly, analysis of displacement and nonunion rate revealed no correlation, both for the overall cohort and for each individual fracture zone; however, when stratified by displaced ($p = 0.01$) and nondisplaced ($p = 0.01$), there was a significant difference in union rates among the fracture zones, with the highest rate of nonunion in zone 2 (Table 3).

Discussion

This study aimed to assess the demographics and fracture characteristics of patients with 5MT fractures. Moreover, finding associations, if any, between these factors and the rate of nonunion was a secondary aim of this investigation. It was found that BMI, weight independent of BMI, and fracture zone are correlated with increased rates of nonunion. Although this study cannot determine causal relationships, these correlations can be used to aid in deciding treatment plans, predicting patient prognosis, and improving patient outcomes.

Age and male-to-female ratio are two of the most commonly discussed factors in the literature on 5MT fracture.[3,4,14] Several prior studies report the peak incidence of 5MT fracture to occur between the second and 5th decades of life.[4,14,15] The average age of this cohort, 51.4 years, is slightly older than the upper range of this reported peak incidence but is consistent with a previous retrospective cohort study.[3] In terms of the male-to-female ratio, 75% of the fractures in this study occurred in female patients, which is consistent with prior literature stating that 5MT fractures are more common in women.[3,4]

Among clinicians and researchers, there remains controversy regarding the correlation of patient demographics, especially weight, BMI, and activity level with the incidence of 5MT nonunions.

Table 1: Demographic and fracture characteristics of patients diagnosed with 5MT fractures, overall and broken down by fracture zone, according to the Lawrence-Botte classification system

			Overall (n = 1,000)	*Zone 1 (n = 421)*	*Zone 2 (n = 308)*	*Zone 3 (n = 271)*	*p-value*
Demographic characteristics	Age (years)		51.4 ± 17.6	51.5 ± 17.6	51.0 ± 17.9	51.6 ± 17.5	0.900*
	Height (cm)		165.5 ± 9.3	165.2 ± 9.8	166.9 ± 10.6	164.3 ± 9.1	**0.005***
	Weight (kg)		76.0 ± 19.3	75.9 ± 19.5	78.3 ± 20.8	73.4 ± 16.8	**0.009***
	BMI		27.6 ± 6.2	27.8 ± 6.5	27.9 ± 6.2	27.1 ± 5.6	0.283*
	Gender	Female	75%	75%	70%	79%	**0.049†**
		Male	25%	25%	30%	21%	
	Race	White	85%	84%	86%	87%	0.548†
		African American	5%	5%	6%	3%	
		Hispanic	2%	2%	2%	2%	
		Asian	3%	4%	3%	3%	
		Other	4%	4%	4%	5%	
	Activity level	Regular	98%	99%	96%	100%	**0.003†**
		Athlete	2%	1%	4%	0%	
	Smoking	Never	64%	66%	61%	63%	0.293†
		Former	30%	30%	32%	29%	
		Current	6%	5%	7%	8%	
Fracture characteristics	Classification by zone		–	42%	31%	27%	–
	Displacement	Yes	44%	46%	28%	59%	**<0.001†**
		No	56%	54%	72%	41%	
	Treatment method	Conservative	91.1%	95%	82%	94%	**<0.001†**

*One-way ANOVA was used to compare fracture zones; $p < 0.05$ was considered significant; †Chi-squared test of independence used to compare fracture zones; $p < 0.05$ considered significant; Bold values signifies *p* values less than 0.05

Table 2: The correlation of nonunion and demographic factors in a patient with 5MT fractures. Within the 1,000-patient cohort, the overall rate of nonunion was 22.4%. Data is shown either as mean ± SD or as a percentage

Demographic factor		*Union (n = 776)*	*Nonunion (n = 224)*	*p-value*
Age		51.2 ± 17.6	52.1 ± 16.5	0.488*
Height (cm)		165.2 ± 9.7	166.4 ± 10.7	0.099*
Weight (kg)		74.9 ± 18.5	74.9 ± 21.4	**0.002***
BMI		27.4 ± 6.0	28.5 ± 6.7	**0.012***
Gender	Female	78%	22%	0.374†
	Male	76%	24%	
Race	White	77%	23%	>0.4†
	African American	76%	24%	
	Hispanic	95%	5%	
	Asian	69%	31%	
	Other	84%	16%	
Activity level	Regular	78%	22%	0.144†
	Athlete	62%	38%	
Smoking States	Current	75%	25%	0.429†
	Former	77%	23%	
	Never	78%	22%	

*One-way ANOVA was used to compare fracture zones; $p < 0.05$ was considered significant; †Chi-squared test of independence used to compare fracture zones; $p < 0.05$ considered significant; Bold values signifies *p* values less than 0.05

This study found a correlation between increased weight and BMI and higher rates of nonunion. Since weight is a non-normalized variable, it is rarely reported in the literature, which makes it difficult to find prior studies assessing this variable. Conversely, BMI is frequently reported with contradicting findings. In a retrospective study of 59 patients, Ruta et al. found a positive correlation between BMI and nonunion rate,[16] while Thorud et al., in a case-control study of 48 patients, showed no association between BMI and nonunion

Table 3: The correlation of nonunion and fracture characteristics in a patient with 5MT fractures. Within the 1,000-patient cohort, the nonunion rate by fracture zone is 22% in zone 1, 28% in zone 2, and 16% in zone 3. Data are shown as percentages

				Union (n = 776)	*Nonunion (n = 224)*	*p-value*
Treatment method	Overall	Conservative		78%	22%	0.279†
		Operative		73%	27%	
	Classification by zone	Conservative	Zone 1	78%	22%	**0.003**†
			Zone 2	72%	28%	
			Zone 3	84%	16%	
		Operative	Zone 1	74%	26%	0.974†
			Zone 2	72%	28%	
			Zone 3	75%	25%	
Fracture alignment	Overall	Displaced		76%	24%	0.159†
		Non displaced		79%	21%	
	Classification by zone	Displaced	Zone 1	74%	26%	**0.006**†
			Zone 2	66%	34%	
			Zone 3	83%	17%	
		Non displaced	Zone 1	82%	18%	**0.049**†
			Zone 2	74%	26%	
			Zone 3	85%	15%	

†Chi-squared test of independence used to compare fracture zones; $p < 0.05$ considered significant; Bold values signifies p values less than 0.05

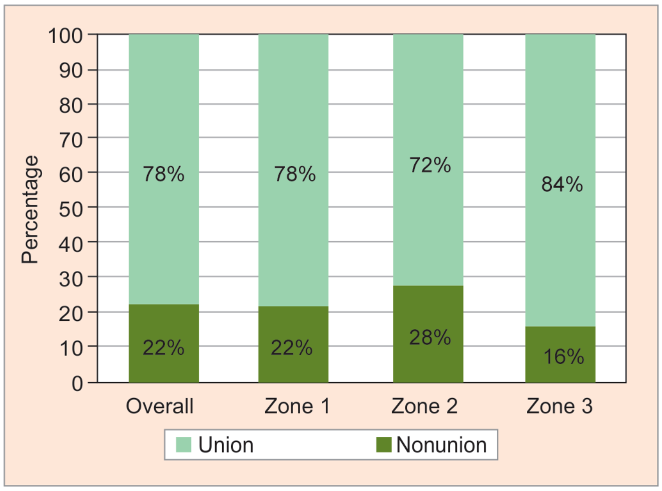

Fig. 1: Union and nonunion rates for the cohort, overall, and for each fracture zone, as defined by the Lawrence-Botte classification system

rates.[17] Unlike previous studies, we did not find a direct association between activity level and higher nonunion rate. Larson et al. reported a significantly higher nonunion rate and refractures in athletes than in nonathletes.[18] The lack of findings in this aspect of our study may be explained by the small population of athletes in the cohort.

The incidence of 5MT base fracture in this study, when classified by fracture zone, was higher in zone 1 (42%) compared to zone 2 (31%) and zone 3 (27%), which is consistent with previous literature.[16,19] Of all the zones, zone 3 fractures demonstrated a significantly higher rate of displacement (59%), followed by zone 1 fractures (46%) and zone 2 fractures (28%). The literature on the relative rates of displacement by fracture zone is sparse, and no specific data was found in prior publications. Most of the patients in this study were treated conservatively (91.1% conservative vs 8.9% operative), which was expected according to the literature.[19]

The overall union rate in this study was 77.6%, which agrees with prior reported results.[19] Fracture zone was the only fracture characteristic that was associated with nonunion rate ($p = 0.002$). Zone 2 fractures demonstrated a significantly increased rate of nonunion (28%) in comparison to zone 1 (22%) and zone 3 (16%) fractures. The finding of the increased rate of nonunions in zone 2 fractures is consistent with prior literature.[9,15] However, the nonunion rate for zone 3 fractures (16%) found in this study contrasts with several prior studies that have reported zone 3 fractures to have increased rates of nonunions.[9,15,20,21] The discrepancy may be explained by the inclusion of 5MT head and diaphyseal fractures in the zone 3 subgroups in this study. It could also be the result of other confounding factors, such as population characteristics or the mechanism of fracture. This study found no difference between operative and conservative treatment and nonunion rates for the 5MT fracture cohort as a whole nor for each individual fracture zone subgroup. However, the results demonstrate that if conservative treatment is chosen, zone 3 fractures are more likely to result in a union than zone 1 or zone 2 fractures. As mentioned previously, these findings contrast with prior literature reporting increased rates of nonunion for zone 3 fractures; therefore, these findings should be compared to future studies with larger populations. If corroborated in future studies, this result can help clinicians choose conservative treatment for zone 3 fractures with greater confidence.

This study has several limitations. Due to its retrospective nature, patient data, such as foot alignment, mechanism of injury, patient-reported outcomes, and patient compliance with treatment protocols were not available for the entire population. Additionally, the zone 3 fracture cohort in this study also included distal 5MT fractures, such as 5MT head and diaphyseal fractures. Another limitation of this study was the binary categorization of conservative vs operative treatment without a deeper subanalysis of factors that may influence healing, such as fixation method, immobilization, and the weight-bearing status during the recovery period. Lastly, both nonunion and delayed unions were combined into the general category of nonunion due to the small sample size.

In conclusion, weight, BMI, and fracture zone are three key factors found to be significantly correlated with 5MT fracture nonunions. The correlations established in this study may aid clinicians by highlighting specific characteristics that should raise concern for possible increased risk of 5MT fracture nonunion. Although future studies are needed to corroborate these results and to establish causality, these findings can be used as a foundation for both future research endeavors and the clinical management of 5MT fractures.

Clinical Significance

Fifth metatarsal (5MT) fractures are a common injury presenting to orthopedic clinics. This study and previous studies have demonstrated that nonunion of 5MT fractures remains a prevalent problem. The association between nonunion and the demographic and fracture characteristics demonstrated in this study provide a foundation to aid clinicians in the decision-making process regarding the treatment and management of 5MT fractures with the goal of minimizing 5MT fracture nonunion. Predicting and preventing nonunion would not only improve patient outcomes but also decrease the healthcare burden.

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