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Radiographic Analysis of Diabetic Midfoot Charcot Neuroarthropathy With and Without Midfoot Ulceration

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Abstract

Background—The aim of this study was to evaluate weight-bearing radiographs in patients with and without foot ulcers diagnosed with midfoot Charcot neuroarthropathy (CN) secondary to diabetes mellitus.

Methods—One hundred fourteen patients with midfoot CN (50 with foot ulcers and 64 without ulcers) were identified and included in this study. Nine radiographic measurements were made (7 in the sagittal plane and 2 in the transverse plane).

Results—CN patients with foot ulcers had significantly greater deformity when assessing the lateral-talar first metatarsal angle, calcaneal pitch, cuboid height, medial column height, calcaneal-fifth metatarsal angle, talar declination, and lateral tibiotalar angle. Two measurements in the transverse plane (hindfoot-forefoot angle and AP talar first metatarsal angle) were not significantly different between the 2 groups. Of patients with foot ulcers, 24% had a lateral talar first metatarsal angle of less than -27 degrees and 80% had a negative cuboid height.

Conclusion—Sagittal plane deformities were more likely to be associated with foot ulceration in patients with CN than transverse plane deformities. Lateral column involvement was associated with a worse prognosis than medial column involvement, thus we believe progressive deformity of the lateral column should be monitored closely to prevent foot ulceration. Lateral column involvement could be identified by a decrease in the cuboid height, decreased calcaneal pitch, and decreased lateral calcaneal fifth metatarsal angle. This study can assist physicians in stratifying the risk for both ulceration and need for surgery in patients with CN based on reproducible radiographic measurements.

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Declaration of Conflicting Interests

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Level of Evidence—Level III, comparative series.

Keywords

Charcot neuroarthropathy; ulcers; diabetes; deformity

Charcot neuroarthropathy (CN) in patients with diabetes mellitus (DM) is associated with reduced quality of life, impaired lower extremity function and premature mortality.^{6,13} Midfoot CN is the most common anatomic location of involvement representing approximately 60% of CN cases.^{4,14,21} As the deformity progresses, the insensate plantar skin is subjected to increased pressure from plantar bony prominences that may result in foot ulceration. Once ulceration develops, the risk of infection and amputation rises dramatically. The amputation risk has been reported to be 12 times higher in CN patients with foot ulcers compared to CN patients without foot ulcers.^{15,19} Consequently, 1 of the major goals in the treatment of CN is to prevent foot ulceration. Schon et al¹⁶ reported that 3 reproducible radiographic angles (AP and lateral talar first metatarsal angles and lateral calcaneal fifth metatarsal angle) strongly correlated with severity of deformity. Bevan and Tomlinson¹ also reported on radiographic measures which predicted foot ulcer in diabetic patients with CN. Their study was limited to 19 patients with 24 radiographs and included only 6 patients with midfoot ulcers, 2 patients with forefoot ulcers and 2 patients with callus. Two radiographic measures were significantly associated with foot ulcers (the lateral talo-first metatarsal angle and the calcaneal fifth metatarsal angle) and 2 other angles demonstrated a trend toward significance (the lateral tibiotalar angle [$P = .09$] and the calcaneal pitch [$P = .054$]). Bevan and Tomlinson¹ also reported that no patient with a lateral talo-first metatarsal angle (Meary's) of less than 27 degrees was associated with foot ulceration. The aim of this study was to expand on the work by Bevan and Tomlinson by evaluating weight bearing radiographs in patients with midfoot CN secondary to DM, comparing patients with and without foot ulcers. An additional goal of this study was to compare these radiographic findings in patients with CN and patients with diabetic neuropathy who did not have CN.

Methods

After institutional review board approval was obtained, inpatient and outpatient medical records were searched for diabetic patients with CN from 2009 to 2014. Two hundred ninety patients with diabetic CN were identified in our database. Patients included in the study had midfoot diabetic CN who had not undergone previous midfoot, hindfoot, or ankle surgery. Patients who had previously undergone isolated forefoot surgery (lessor toe amputations or hammertoe surgery) were included, although amputation of the great toe, any ray resection or multiple toe amputations were criteria for exclusion. For the purposes of this study, only patients with midfoot ulcers were included (ie, forefoot and heel ulcers were excluded). One hundred fourteen patients were identified who met these criteria. These patients were divided into 2 groups. Group 1 ($n = 64$) included patients with CN and no ulceration. Group 2 ($n = 50$) comprised patients with CN and ulceration. A control group (Group 3) of diabetic patients ($n = 46$) with peripheral neuropathy without ulceration was also included. These patients presented for other foot and ankle problems (not related to CN). Charcot neuropathy was excluded in our diabetic neuropathy group (Group 3) based on radiographic evaluation.

Peripheral neuropathy was clinically diagnosed using the Michigan Neuropathy Screening Index on each patient in all 3 groups (score ≥ 2.5).²⁰ This validated instrument relies on Semmes-Weinstein monofilament, vibration testing with the 128-Hz tuning fork, assessment of Achilles reflex, presence or absence of ulceration, and the presence or absence of deformity (claw toes, CN). Diabetic neuropathy was confirmed in patients by a quantitative neurological examination coupled with nerve conduction studies in the original study.⁵ Four plantar sites (the first and fifth metatarsal heads, plantar hallux, and heel) were tested with the 5.07 Semmes Weinstein monofilament. These 4 sites represented a slight modification from the original description of the Michigan Neuropathy Screening Index. Patients who could sense all 4 sites with their eyes closed received a score of zero for each foot. Patients who were unable to sense the monofilament in 1 of the 4 sites received a score of 0.5 per foot. Patients who were unable to sense 2 or more of the 4 sites received a score of 1.0 per foot. Vibratory sensation was evaluated with the 128-Hz tuning fork at the dorsal hallux. If the patients could feel the vibration consistent with the duration that the examiner felt while holding the tuning fork, a score of zero was given for each foot. Those patients who initially felt the vibration but were unable to sense it after 5 seconds of dampening received a score of 0.5 for each foot. Those patients who were unable to sense the tuning fork at all or noted absence within 5 seconds were given a score of 1.0 for each foot. Achilles reflexes were evaluated in a standard musculoskeletal manner.^{2,3} An intact reflex without reinforcement was scored as zero, a reflex that was present with reinforcement was scored as 0.5 and absent reflex as 1.0. If a foot ulcer was present, a score of 1.0 was given and a zero was scored if no ulcer was present. For the purposes of this study, we defined neuropathic deformity as multiple clawtoes involving both feet and or the presence of CN. Clawtoes and CN were evaluated both clinically and radiographically. The presence of a deformity was scored as 1.0 and the absence of deformity as zero. The maximum score per foot was 5 and the combined maximum total score of both feet was 10.

CN was diagnosed according to previously published guidelines and the anatomic location was classified according the Sanders/Frykberg classifications.¹⁴ This classification divided the foot and ankle into 5 anatomic patterns of destructions for CN. Type 1 involves the forefoot and represents 15% of cases. Type 2 involves the tarsometatarsal joints and represents 40% of CN. Type 3 involves the naviculocuneiform, talonavicular, and calcaneocuboid joints and comprises 30% of CN cases. Type 4 involves the ankle and/or subtalar joints and represents 10% of CN cases. Type 5 involves the calcaneus and involves 5% of CN cases. Only patients with inactive CN (Eichenholtz stage 3) with anatomic involvement of the midfoot were included (Sanders/Frykberg Types 2 and 3). Inactive CN was determined clinically by the absence of inflammatory signs (warmth, edema and erythema) and radiographic findings of consolidation and evidence of bone healing.¹⁴ Peripheral artery disease (PAD) was defined as the absence of 2 of the 4 pedal pulses or an ankle brachial index (ABI) less than 0.9. Nine different radiographic measures were performed utilizing digital radiographs including the lateral and anteroposterior talo-first metatarsal angle, calcaneal pitch, cuboid height, medial column height, hindfoot-forefoot angle and the lateral tibiotalar angle, lateral calcaneal fifth metatarsal angle, and talar declination angle.^{1,10} All measurements were recorded from weight-bearing radiographs (see Figures 1A, 1B, and 2).

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Calcaneal pitch and the lateral tibiotalar angle are radiographic measures of ankle/hindfoot equinus. Transverse plane deformity such as midfoot abduction and adduction was assessed with the AP talar first metatarsal angle and the hindfoot-forefoot angle.^{10,17} Medial column arch integrity was assessed with lateral talar first metatarsal angle and medial column height. Lateral column involvement was manifested by a decrease in the cuboid height, decreased calcaneal pitch, and decreased lateral calcaneal fifth metatarsal angle.¹⁷

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Cuboid height was measured as the perpendicular distance from the plantar aspect of the cuboid to a line drawn from the plantar aspect of the calcaneal tuberosity to the plantar aspect of the fifth metatarsal head (Figure 1A, measurement G).¹⁰ This distance was measured in millimeters and was positive if the plantar cuboid remained dorsal to the reference line (Figure 1A, line AB) and negative if the plantar cuboid was plantar to this line. Medial column height was measured as the perpendicular distance from the plantar aspect of the first tarsometatarsal joint to reference line AB (Figure 1B, measurement I). This distance was measured in millimeters and was positive if the plantar aspect of the joint remained dorsal to the reference line and negative if the plantar joint was plantar to this line. Calcaneal pitch was measured as the angle between the reference line from the plantar aspect of the calcaneal tuberosity to the plantar aspect of the fifth metatarsal head and a line extending from the most plantar aspect of the calcaneal tuberosity to the most plantar aspect of the anterior process of the calcaneus (Figure 1A, angle E). The lateral talar first metatarsal angle was measured as the angle formed from a line bisecting the talar body and neck and a line bisecting the first metatarsal (Figure 1A, angle D). Apex plantar angulation was considered a negative angle. The lateral tibiotalar angle was measured as the angle formed from a line bisecting the distal tibia and a line bisecting the talar body and neck (Figure 1A, angle C). The talar declination angle was formed as the angle between a line bisecting the talar body and neck and the reference line from the plantar aspect of the calcaneal tuberosity to the plantar aspect of the fifth metatarsal head (Figure 1A, angle F). The lateral calcaneal fifth metatarsal angle was measured between a line bisecting the fifth metatarsal and a line extending from the most plantar aspect of the calcaneal tuberosity to the most plantar aspect of the anterior process of the calcaneus (Figure 1B, angle H). Two radiographic measurements were made from the AP radiograph. The hindfoot-forefoot angle was measured between a line that bisected the AP talocalcaneal angle (Figure 2, line C) and a line through the longitudinal axis of the second metatarsal (Figure 2, angle D).^{9,10} The AP talar first metatarsal angle was measured as the angle formed from a line bisecting the talar body and neck and a line bisecting the first metatarsal (Figure 2, angle D).^{9,10} For both of the AP measurements, apex medial angulation (abduction) was considered a positive angle and apex lateral angulation (adduction) was considered a negative angle. Three fellowship trained foot and ankle surgeons measured each of the 9 angles and the average angle was recorded.

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In addition to the radiographic analysis, demographic data was also compared between the 3 groups. This included age, gender, type of DM (1 vs 2), use of insulin, duration of DM, presence of active infection, Charcot pattern/stage, presence of peripheral arterial disease, and body mass index.

Descriptive statistics were summarized as frequencies (percentages, %) or as mean $\pm$ standard deviation (SD), as appropriate. Examination of normal distribution assumption for continuous data was determined by q-q plots and histograms. Analysis of variance (ANOVA) or Kruskal–Wallis test was performed to determine differences between groups for normally or nonnormally distributed continuous data, respectively. Post hoc comparisons for the nonnormally distributed continuous data were performed using the Mann–Whitney test and adjustment for multiple comparisons was performed using the Dunn–Sidak adjustment method. Pearson’s chi-square or Fisher’s exact test, as appropriate, were used to compare the frequency distribution of categorical variables between groups. Post hoc comparisons for categorical data were performed using Pearson’s chi-square or Fisher’s exact test on subtables and adjustment for multiple comparisons was performed using the Sidak adjustment method. A multivariate analysis of variance (MANOVA) model with all 9 angles being the outcome and group as the predictor was fit to the data. The MANOVA analysis was conducted to determine the effect of the 3 groups (Charcot without ulcer, Charcot with ulcer, and control diabetic neuropathy) on 9 dependent variables (9 angles). The MANOVA *P* value represents the test that the vectors of angle means are equal among the 3 groups. Pillai’s trace is reported as the test statistic for the MANOVA analysis because it is the most robust statistical measure (ie, least sensitive to departures from assumptions) when there is unequal cell size.⁷ Univariate analyses of variance (ANOVAs) for each dependent variable were conducted as follow-up tests to the MANOVA. The Sidak method for controlling type I error rates for multiple comparisons was used for each ANOVA. Post hoc analysis for the significant ANOVAs consisted of conducting pairwise comparisons to determine which group affected the angles most strongly. Each pairwise comparison was tested using Sidak correction. The correlation (*r*) between the angles was also obtained as part of the MANOVA analysis and the corresponding test of statistical significance is presented. All analyses were conducted using SAS version 9.3 statistical software (SAS Institute Inc, Cary, NC).

Results

The demographic and radiographic data for each group are summarized in Tables 1 and 2, respectively. There were no significant differences among the 3 groups for age, gender, duration of diabetes, prevalence of PAD, body mass index, or obesity. Charcot patients with foot ulcers were more likely to use insulin, had higher rates of active infection, and had a higher Michigan Neuropathy Screening Index than the control group. In addition, Charcot patients with foot ulcers had higher rates of infection and a higher Michigan neuropathy screening index than CN patients without ulcer. There was no significant difference in duration of follow-up or anatomic involvement (Sanders/Frykberg types 2 and 3) between CN patients with and without foot ulcers.

Table 2 summarizes the means and standard deviations of the dependent variables (ie, angles) for the 3 groups. The results of the MANOVA showed that there is an overall difference between the angles from different groups (Pillai’s trace = 0.73), $F(18, 300) = 9.65$, $P < .0001$. Given the significance of the overall test from MANOVA, we examined the univariate ANOVA results. After correction for multiple comparisons, using the method of Sidak, statistically significant ANOVA results were found for the angles lateral talar-first

metatarsal angle, $F(2, 157) = 71.84, P = .0009$, calcaneal pitch, $F(2, 157) = 60.43, P = .0009$, cuboid height, $F(2, 157) = 101.88, P = .0009$, calcaneal-fifth metatarsal angle, $F(2, 157) = 44.23, P = .0009$, talar declination angle, $F(2, 157) = 53.41, P = .0009$, medial column height, $F(2, 157) = 20.74, P = .0009$, and lateral tibiotalar angle, $F(2, 157) = 16.23, P = .0009$, while the nonsignificant ANOVAs were found for AP talar-first metatarsal angle, $F(2, 157) = 4.05, P = .1609$, and hindfoot-forefoot angle, $F(2, 157) = 5.12, P = .0613$. Post hoc analysis for the significant ANOVAs revealed significant differences across the 3 groups for lateral talar first metatarsal angle, calcaneal pitch, cuboid height, calcaneal fifth metatarsal angle, talar declination angle, and lateral tibiotalar angle. For the medial column height, significant differences were found between each Charcot group and the control diabetic neuropathy group. The results also indicated a strong correlation between calcaneal pitch and lateral calcaneal-fifth metatarsal angle ($r = .76, P < .0001$). Other angles that showed high correlation were calcaneal pitch and cuboid height ($r = .65, P < .0001$) and lateral calcaneal-fifth metatarsal and cuboid height ($r = .63, P < .0001$).

Charcot patients with foot ulcers had significantly greater deformity than CN patients without ulcers when measuring lateral talar-first metatarsal angle, calcaneal pitch, cuboid height, lateral calcaneal-fifth metatarsal angle, talar declination angle, and lateral tibiotalar angle. Measurement of medial column height, AP talar-first metatarsal angle, and hindfoot-forefoot angle were not significantly different between those CN patients with and without ulcers. Diabetic foot infections occurred in 20 of the 50 CN patients (40%) with foot ulcers; however, no infections were observed in CN patients without foot ulcers. Twelve of 50 patients (24%) with CN and foot ulcers had a lateral talar-first metatarsal angle of less than 27 degrees and a negative cuboid height was observed in 40 of the 50 patients (80%) with CN and foot ulcers. We identified a foot ulcer in a patient with a lateral talar-first metatarsal angle of -17 degrees, and an additional 11 ulcers in deformities ranging from -20 to -26 degrees.

Discussion

This study demonstrated that sagittal plane deformities were more likely to be associated with foot ulceration in patients with CN than transverse plane deformities. Our findings are consistent with those of Bevan and Tomlinson¹ with regard to the lateral talar-first metatarsal angle, however we also found significant differences in measurement of calcaneal pitch, cuboid height, talar declination angle, lateral calcaneal-fifth metatarsal angle, and lateral tibiotalar angle in CN patients with and without ulceration. Radiographic abnormalities in the transverse plane, as measured with the hindfoot-forefoot angle and dorsoplantar talo-first metatarsal angle, were not significantly associated with midfoot ulceration. Bevan and Tomlinson's study¹ also reported that transverse plane deformity was not associated with foot ulceration.

Sinacore et al¹⁸ demonstrated that an increasing talar declination angle (negative correlation) and decreasing calcaneal inclination angle (positive correlation) were associated with a decrease in ankle plantarflexion (50%) and subtalar inversion (30%) when CN patients were compared to healthy controls. The loss of plantarflexion and inversion potentially impairs function during walking leading to increase stress in the midfoot.¹⁸ Traditionally, loss of

ankle dorsiflexion secondary to a tight Achilles tendon has been implicated in foot ulceration.¹¹ An increasing talar declination angle may also result in posterior ankle impingement further affecting walking. As midfoot deformity increases, further plantarflexion of the talus may not be possible resulting in compensatory motion in the midfoot. Talar declination angles greater than 30 degrees are typically associated with talonavicular joint subluxation/dislocation and resultant medial column deformity.^{1,16,18} Conversely, calcaneal pitch less than 10 degrees is associated with calcaneocuboid subluxation/dislocation and lateral column malalignment.¹⁷ A paradoxical finding in CN patients with CN and foot ulcers was an increase in medial column height. This is most likely due to the collapse of the lateral column, resulting in supination of the forefoot and elevation of the medial column.

Hastings et al⁹ found that radiographic worsening of alignment of midfoot CN occurred over time despite a standardized treatment program. This finding is important since it demonstrates that further deterioration can occur after the active phase of CN has resolved. In the Hastings et al study, the lateral talar-first metatarsal angle changed most during the first 6 months of treatment while the cuboid height deteriorated most after the first 6 months. Calcaneal pitch demonstrated a gradual decline throughout the study period. Lateral column involvement is associated with a worse prognosis than medial column involvement, and progressive deformity of the lateral column may warrant operative intervention to prevent ulceration.¹⁷ This concept was originally introduced by Harris and Brand,⁸ as they noted that breakdown of the lateral arch was particularly malignant in the insensate foot. Schon et al¹⁷ suggested that earlier intervention may be indicated in patients with lateral column involvement because of the high risk of ulceration and subsequent infection. In 2004, Pinzur¹² reported that 60% of patients with midfoot CN could achieve the desired endpoint with nonoperative treatment after a minimum follow-up of 1 year. Given the recent findings of Hastings et al⁹ noting that deformity may continue to progress after the first year, longer vigilance may identify additional patients who ultimately require surgery.

This study also demonstrated that CN patients with and without foot ulceration had significantly greater radiologic abnormalities in all sagittal measurements when compared to patients with diabetic neuropathy who did not have CN. Our 2 CN study groups were similar with regard to age, gender, duration of diabetes, and anatomic location of the deformity. None of the CN patients without ulcers developed an infection while 40% (20 of 50 patients) of CN patients with ulcers experienced a foot infection during the treatment. Because no patients without foot ulcers experienced an infection, we are unable to do a statistical comparison between these difference rates of infection.

This study has limitations that must be acknowledged. The most obvious weakness is the retrospective design and the accuracy of the demographic relies on the recorded information. We utilized electronic inpatient and outpatient records to retrieve our data. Another limitation is the potential for error in radiographic measurement, particularly in patients with destructive CN. Our software program permitted us to measure angles within 1-degree increments and height within 0.1 millimeter increments. The use of a control group of diabetic neuropathy patients without CN also permitted us to gain experience in these measurements in patients without significant alterations in the osseous architecture. We

averaged the findings of 3 fellowship trained foot and ankle surgeons in an effort to minimize errors in radiographic measurement.

There is some debate among surgeons who treat CN regarding the indications for surgery, particularly in patients with a closed soft tissue envelope. It is generally agreed that patients with recurrent infections and ulcers associated with deformity most likely will need some type of operative intervention. Based on our radiographic study, we feel that operative reconstruction should be considered in patients with progressive deformity in the sagittal plane, particularly when lateral column involvement becomes pronounced. A negative cuboid height indicates a lateral bony prominence that is likely to cause ulceration. When bone projects below the normal plantar weight-bearing surface, offloading becomes more difficult. Intervention prior to formation of the ulcer may prevent osteomyelitis and the subsequent need for amputation. This type of recommendation should be assessed in a future study designed to establish the indications for operative intervention in this complicated group of patients.

Conclusion

This study demonstrated that radiographic measurements in the sagittal plane differed significantly when comparing CN patients with and without foot ulcers. The goal of treatment is to prevent foot ulceration, and heightened awareness should be entertained in patients with progressive deformity in the sagittal plane. When reconstructive CN surgery is necessary, our goal is to reestablish the anatomy by attempting to address these radiographic abnormalities. Although it is not usually possible to normalize these angles, improvement in alignment typically results in a plantigrade foot and healing of the ulcer. In contrast to the study of Bevan and Tomlinson,¹ our study demonstrated that 24% (12 of 50) of the patients with foot ulcers had a lateral talar first metatarsal angle of less than -27 degrees and 80% (40 of 50) of patients with foot ulcers had a negative cuboid height.

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Figure 1.

Lateral weight-bearing radiograph of the foot in a patient with Charcot neuroarthropathy and a lateral plantar ulcer. Line A B, from the plantar aspect of the calcaneus to the plantar aspect of the fifth metatarsal head; C, lateral tibiotalar angle measuring 135 degrees; D, lateral talar-first metatarsal angle measuring -29 degrees; E, calcaneal pitch angle measuring 10 degrees; F, talar declination angle measuring 42 degrees; G, cuboid height measuring minus 3.5 mm; H, lateral calcaneal-fifth metatarsal angle measuring 19 degrees; I, medial column height measuring 8.4 mm.

Figure 2.

Anteroposterior weight-bearing radiograph of the foot in a patient with Charcot neuroarthropathy and a lateral plantar ulcer. A, line drawn along the longitudinal axis of the lateral border of the calcaneus; B, line drawn along the longitudinal axis of the talus; C, line bisecting the long axis of the talus and lateral border of the calcaneus; D, hindfoot-forefoot angle measuring minus 7 degrees; E, anteroposterior talar-first metatarsal angle measuring 4 degrees.

Table 1

Patients Demographic Data.

	Group 1, Charcot Without Ulcer (n = 64)	Group 2, Charcot With Ulcer (n = 50)	Group 3, Control Diabetic Neuropathy (n = 46)	P Value (Overall Test)	Post Hoc Comparisons (Adjusted P Values) 1 vs 2 2 vs 3 1 vs 3
Age (years)	57 ± 9	59 ± 11	58 ± 11	.4337	
Gender, n males (%)	36 (56)	32 (64)	30 (65)	.5659	
Type of diabetes, number with type 2 (%)	27 (42)	29 (58)	32 (70)	.0152	.2558 .5602 .0134
Insulin use, n (%)	42 (67)	39 (78)	23 (51)	.0231 [*]	.4569 .0179 .2795
Duration of diabetes (years)	16.2 ± 11.0	16.0 ± 11.1	16.5 ± 12.6	.9780	
Active infection, n (%)	0 (0)	20 (40)	0 (0)	<.0001	
Charcot pattern, n Sanders/Frykberg pattern 2 (%)	29 (45)	25 (52)	N/A	.4779	
MNSI, median (interquartile range)	7 (1)	8 (2)	7 (2)	.0002 [^]	.0018 .0018 .7537
Peripheral artery disease, n (%)	5 (8)	8 (16)	5 (11)	.3879	
Average body mass index (units)	34.6 ± 6.4	34.1 ± 6.4	32.2 ± 6.6	.1467	
Obese, n (%) BMI >	49 (77)	37 (74)	32 (70)	.7120	
Duration of follow-up (weeks)	131.4 ± 90.7	141.7 ± 113.7	N/A	.5969 [#]	
Patients ultimately undergoing surgery	31 (48)	36 (72)	N/A	.0112	

Mean ± standard deviation or frequency (percent) are presented otherwise noted. MNSI, Michigan Neuropathy Screening Index; N/A, not applicable.

^{*} Fisher's exact test.[^] Kruskal–Wallis test.[#] t test.

Table 2

Patients Radiographic Data.

Angles	Group 1, Charcot Without Ulcer (n = 64)	Group 2, Charcot With Ulcer (n = 50)	Group 3, Control Diabetic Neuropathy (n = 46)	P Value	Adjusted P Value
MANOVA					
Overall test				<.0001	
ANOVA					
Lateral talar-first metatarsal angle (Meary's) (degrees)	-24.6 (11.9)	-32.9 (8.3)	-8.1 (9.8)	<.0001	.0009
Calcaneal pitch (degrees)	10.2 (6.8)	6.3 (6.7)	20.7 (6.4)	<.0001	.0009
Cuboid height (mm)	0.7 (6.1)	-5.1 (5.4)	10.8 (4.7)	<.0001	.0009
Calcaneal fifth metatarsal angle (degrees)	19.2 (9.8)	14.4 (8.5)	30.7 (7.2)	<.0001	.0009
Talar declination (degrees)	39.9 (8.9)	45.2 (7.0)	29.5 (5.8)	<.0001	.0009
AP Meary's (degrees)	8.2 (12.9)	10.8 (15.0)	3.8 (6.0)	.0193	.1609
Hindfoot-forefoot angle (degrees)	6.7 (12.7)	7.3 (16.3)	-0.1 (6.8)	.0070	.0613
Medial column height (mm)	3.4 (8.6)	4.5 (10.7)	13.8 (7.0)	<.0001	.0009
Lateral tibiotalar angle (degrees)	127.6 (11.4)	134.6 (10.1)	19.7	<.0001	.0009

ANOVA, analysis of variance; MANOVA, multivariate analysis of variance; mm = millimeters.