

Charcot-Marie-Tooth Talar Morphology Analysis

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INTRODUCTION: Charcot-Marie-Tooth (CMT) disease is a commonly inherited peripheral neuropathy that often presents with cavovarus foot deformity. CMT often causes altered hindfoot alignment, ankle incongruity, and abnormal bone morphology [1]. However, these morphological abnormalities have been minimally studied throughout the foot and ankle [2]. For this study, we focused on the talar morphological variation between CMT-diagnosed patients and a healthy control group. Two analyses were performed: (1) a single-domain statistical shape model (SSM) of all the tali to identify bony regions of difference between the groups and (2) a talar neck measurement using an open-source coordinate toolbox to mathematically compare the talar body to the talar neck angle differences between groups. We hypothesize a larger angle difference between the talar neck and talar body exists in the CMT patients compared to the healthy patients.

METHODS: Our study contained 90 feet from 83 patients (age: 41.94 ± 14.76 ; 43 females) comprising 47 feet with diagnosed CMT and 43 feet from healthy controls. Among them, 15 patients had a CMT subtype 1 variant, 6 patients had a CMT subtype 2 variant, 1 patient had a CMT subtype 4 variant, and 15 patients had an unknown CMT variant. All patients had a weightbearing computed tomography (WBCT) scan which was automatically segmented using DISIOR (v2.1.1; Bonelogic) and manually verified using Mimics (v24.0; Materialise). A single bone SSM (v6.3.2; ShapeWorks) was performed for all tali in order to develop a healthy mean correspondence model and a CMT mean correspondence model. The bone surface differences between the mean shapes were compared using MATLAB (R2023a, MathWorks). The 3D angle between the talar body and talar neck was calculated on each talus using the talonavicular and tibiotalar anterior-posterior axis from an open-source automatic coordinate toolbox in MATLAB [3]. A two-sample t-test was used to determine if this 3D angle was significantly different between groups.

RESULTS: Both analyses identified talar neck variation between the healthy and CMT groups. The SSM-generated mean shape surface comparison highlighted that the mean CMT talar neck is more prominent medially compared to the healthy group (Figure 1). Additionally, the ridges along the superior talar body are less prominent compared to the healthy population. The coordinate angle calculation for the CMT group was significantly larger ($20.71^\circ \pm 3.06^\circ$) than the healthy group ($19.23^\circ \pm 3.06^\circ$) using the two-sample t-test ($P=0.025$). This study had a Cohen's d value of 0.48 which is of moderate significance.

DISCUSSION: Our study revealed significant talar morphological variability between the healthy and CMT groups. The SSM surface comparison showed medial talar neck prominence and a shallower talar dome compared to healthy. These variations in conjunction with a significantly larger 3D angle calculation between the talar neck and body seem to identify a significant morphological abnormality between these groups in the talar body and neck regions. Previous studies have used 2D angle calculations on 3D surfaces in three planes and found decreased talar neck sagittal declination (more horizontal talus) and less axial plane head abduction in their CMT group [1]. However, our study found an increased medial rotation of the talar head compared to the healthy group. These differences may be due to varying genetic subtypes within the CMT diagnosis as a whole. However, neither study has sufficient genetic information to properly compare these differences. Future work should include genetic subtypes as a variable to determine if there are morphological variations between subtypes. Understanding the presentation of these morphological variations could provide valuable clinical information when surgically correcting for CMT malformities.

SIGNIFICANCE/CLINICAL RELEVANCE: Historically, CMT assessment focused on 2D radiographs and malalignment, but these findings emphasize that talar morphology deformities may contribute to malalignment in CMT patients, impacting surgical correction for severe cavovarus deformities. Due to these significant morphology deformities, soft tissue tibiotalar and talonavicular alignment interventions may not allow achievement of full desired corrections.

REFERENCES: [1] Pfeffer, G. et al. JAAOS. 2023, [2] Michalski, MP. et al. Foot & Ankle Int. 2022; 43(4):576-581, [3] Peterson, A. et al. ISB. 2023

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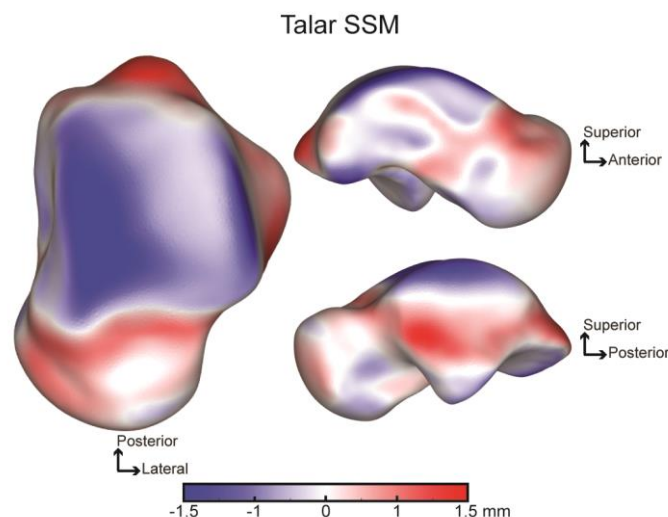


Figure 1. Surface distance comparison between CMT and healthy SSM mean shapes. Red indicates more prominent morphology of the CMT mean shape, blue indicates less prominent morphology.

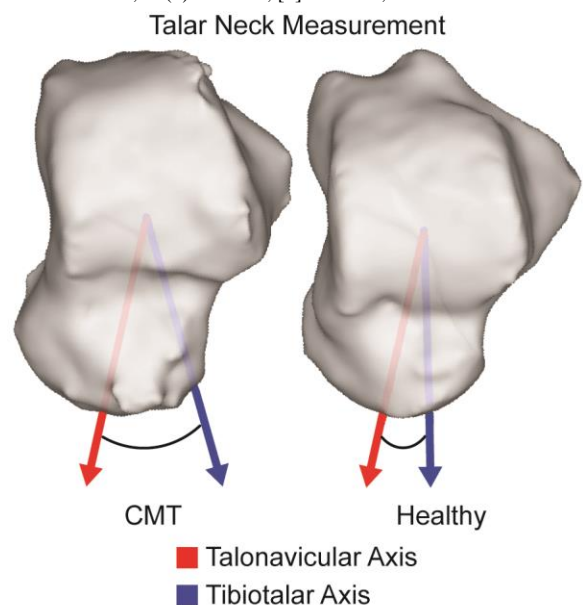


Figure 2. Representative patient from CMT and healthy group visualizing the angle difference calculation between the talonavicular and tibiotalar axis