Joint Angle Differences in Patients with Varus Ankle Osteoarthritis

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Disclosures: None

INTRODUCTION: Ankle osteoarthritis (OA) may lead to limited physical function, severe pain, and a diminished quality of life in affected patients [1]. Varus ankle OA is observed in most ankle OA patients with approximately half of these patients presenting with peritalar compensation, where the subtalar joint is aligned valgus to compensate for a varus tibiotalar joint [2,3]. Weightbearing computed tomography (WBCT) enables comprehensive analyses to evaluate joint degeneration more accurately throughout the ankle while minimizing errors in bone orientation and superposition within 2D radiographic projections [4,5]. Anatomic coordinate systems (ACS) are commonly used to understand joint relationships including bone position and orientation for informed preoperative surgical planning. This study aims to investigate the differences in ACSs between patients diagnosed with varus ankle OA (neutral alignment/compensated versus varus alignment/non-compensated) and asymptomatic patients. We hypothesize that midtarsal joint angles would statistically differ between the asymptomatic and two OA ankle alignments and that these differences would affect midtarsal joint orientation.

METHODS: In this study, 44 patients with advanced varus ankle OA underwent WBCT scans (Planmed Verity; 0.4 x 0.4 x 0.4 mm voxels) with IRB approval. Additionally, 26 skeletally mature asymptomatic reference ankles (mean age: 50 years; range: 40-66 years; 7 males) with no history of ankle trauma, operative procedures, or chronic pain of the foot and ankle, were enrolled with IRB approval. An orthopedic surgeon screened for hindfoot compensation based on coronal talar tilt (TT) and hindfoot alignment angle (HAA) measurements, which classified OA patients into two groups (27 compensated and 17 non-compensated) [5]. OA patients had TT > 1.9°, compensated patients had HAA < 12.5°, and non-compensated patients had HAA >12.5°. DISIOR (v2, Bonelogic) was used to obtain radiographic measurements including coronal TT and HAA determined by the Saltzman 20° view. Bone segmentations of the talus and calcaneus were generated using DISIOR. Segmentations were verified and revised as needed using Mimics 24.0 (Materialise). An automatic anatomical foot and ankle coordinate toolbox (AAFACT) in MATLAB (R2023b, MathWorks) was used to automatically calculate all ACSs. The ACSs calculated include a calcaneal subtalar axis, talar subtalar axis, calcaneal calcaneocuboid axis, and talar talonavicular axis. Static joint angles were calculated for the subtalar joint (calcaneal subtalar axis and talar subtalar axis) and the midtarsal joint (calcaneal calcaneocuboid axis and talar talonavicular axis. Mean Euler angles with one standard deviation were calculated for each group. Statistical analyses were performed between groups to assess observed differences.

RESULTS: Statistical differences were found between the asymptomatic group and both advanced varus OA groups for all three joint angles in the midtarsal joint (Table 1). Specifically, both OA groups' midtarsal joints were significantly more inverted, externally rotated, and plantarflexed ($p < 0.05$). Additionally, while the OA groups were not significantly different from one another, the non-compensated group was trending towards more severe in all three angles. However, there were no significant angle differences found between the asymptomatic and the OA groups in the subtalar joints. We calculated the Cohen's d values for each statistically different joint angle between groups, yielding a range from 0.75 to 1.43, which indicates a large effect size.

DISCUSSION: Peritalar joint compensation may contribute to the preservation of the ankle joint and delay further degeneration in cases of asymmetric varus ankle osteoarthritis [3]. Our findings revealed variations in joint angles between the varus ankle osteoarthritis patients and the asymptomatic group. Notably, the varus group exhibited significant midtarsal joint variation, specifically more inversion, external rotation, and plantarflexion. These differences in anatomical alignment may result in altered joint mechanics during weight-bearing activities, potentially contributing to further cartilage degeneration and joint instability. Future work should calculate the static joint angles for other joints in the foot and ankle to more quantitatively highlight compensations that arise when varus OA is present. The identification of these anatomical differences offers valuable insights for clinicians in devising personalized treatment strategies for patients with varus ankle osteoarthritis. Our study highlights the importance of 3D analyses to comprehensively evaluate clinical presentations of varus ankle OA.

SIGNIFICANCE/CLINICAL RELEVANCE: The current study helps surgeons to better understand the underlining mechanism of peritalar compensation in two cases of varus ankle OA representing the majority of clinical presentation. Surgical planning and treatment of advanced varus ankle OA may need to be adapted in case of the presence/absence of peritalar compensation to address these specific anatomical differences and ensure neutral hindfoot alignment following operative treatment.

REFERENCES: [1] Glazebrook M, et al. *J Bone Joint Surg Am*. 2008;90(3):499-505. [2] Valderrabano V, et al. *Clin Orthop Relat Res*. 2009;467(7):1800-6. [3] K. Hayashi, et al. *Foot Ankle Int*, 29 (2008), p. 400. [4] Barg A, et al. *Foot Ankle Int*, 39 (2013), p. 376-386. [5] Kvarda P, et al. *Foot Ankle Int*. 2021;42(2):200-14.

ACKNOWLEDGEMENTS: Funding was provided by the National Institutes of Health (1K01AR080221, U24EB029011, R01AR076120).

	Asymptomatic	Compensated	Non-compensated
ST DoPl (Mean ± SD)	6.30 ± 3.32	6.15 ± 3.32	6.83 ± 2.81
ST InEv (Mean ± SD)	24.01 ± 2.57	23.97 ± 2.01	25.20 ± 3.64
ST ExInt (Mean ± SD)	24.36 ± 2.67	24.17 ± 1.97	25.29 ± 3.23
MT DoPl (Mean ± SD)	-8.9 ± 2.63	-12.16 ± 4.55*	-14.15 ± 4.46*
MT InEv (Mean ± SD)	4.66 ± 1.89	2.65 ± 2.77*	2.16 ± 3.01*
MT ExInt (Mean ± SD)	10.36 ± 2.89	13.41 ± 4.99*	15.40 ± 4.63*

Table 1: Mean and standard deviation values of joint angle differences. Values reported in degrees for the dorsiflexion/plantarflexion (DoPl), inversion/eversion (InEv), and external/internal (ExInt). An asterisk (*) denotes values that are statistically different ($p < 0.05$) than the asymptomatic values.

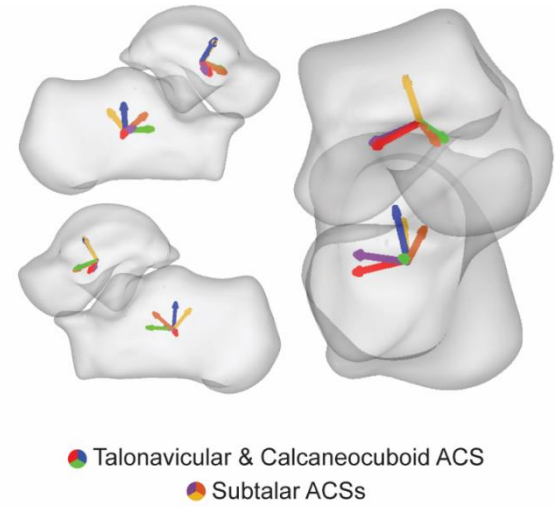

Figure 1. Representative patient visualizing the anatomical coordinate systems (ACS) for the talonavicular, calcaneocuboid, and subtalar joints on the talus and calcaneus.