In Vivo Three-Dimensional Analysis of Hindfoot Kinematics with Posterior Tibial Tendon Dysfunction Stages II and III

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Summary: This study evaluated the kinematics of the mid-hindfoot with the progression of PTTD by quantitatively evaluating the three-dimensional mid-hindfoot bone motion in patients with flat foot, stage II and III of PTTD, with those with normal feet in dorsiflexion and plantarflexion. Plantarflexion of the tibiotalar joint decreased, and the adduction of the talocalcaneal and talonavicular joint increased in the maximal plantarflexion of the ankle joint in stage II in comparison to normal. Plantarflexion and adduction of the tibiotal joint were decreased, and those of the talocalcaneal joint and the talonavicular joint increased in stage III in comparison to stage II. A quantitative evaluation of the 3D kinematics of many cases of flatfoot can provide valuable information for determining the timing and methods of surgical treatment.

Background: Flat foot is defined as the foot which met the clinical stages of posterior tibial tendon dysfunction (PTTD), pain or tenderness of PTTD, and weakness of single heel rise in the single heel rise test. The divergence between stage II of PTTD and III is presence of mobility of the hindfoot. However, no study has previously addressed the exacerbation of the three-dimensional kinematics of the mid-hindfoot with the progression to stage II. This study evaluated the kinematics of the mid-hindfoot with the progression of PTTD by quantitatively evaluating the three-dimensional mid-hindfoot bone motion in patients with flat foot, stage II and III of PTTD, with those with normal feet in dorsiflexion and plantarflexion.

Materials and Methods: CT scans of 26 normal and 32 flat feet were used to construct a model of mid-hindfoot bones (tibia, talus, navicular, and calcaneus). The scans were performed using a custom-made device that held the foot in neutral position, dorsiflexion, or plantarflexion, respectively. The hindfoot bones were segmented based on the threshold level. The volume merge method in three planes was used for calculating the rotation and translation of the talus relative to the tibia in the tibiotalar joint; the navicular bone relative to the talus in talonavicular joint; the calcaneus relative to the talus in the tibiotalar joint. Three major axes of rotation - plantarflexion/dorsiflexion, abduction/adduction, and eversion/inversion - were examined for each bone to determine the Euler angles. The three-dimensional motion was compared between three groups (normal foot, stage II, and III of PTTD). The Bonferroni/Dunn method was used for post hoc tests after one-way ANOVA.

Results: The talus relative to the tibia with the foot in maximal plantarflexion was less plantarflexed (normal foot: -41.2°, stage II: -33.5°, stage III: -25.3°), and less adducted (normal foot: -13.9°, stage II: -10.7°, stage III: -5.6°) as the stage progressed.

The calcaneus relative to the talus in Stage III was more plantarflexed (normal foot: -0.8°, stage II: -3.0°, stage III: -8.7°), and more adducted (normal foot: -0.3°, stage II: -4.7°, stage III: -10.3°) as the stage progressed.

The navicular relative to the talus in Stage III was less inverted (normal foot: -3.9°, stage II: -7.2°, stage III: -7.6°, stage III: -14.9°), and more adducted (normal foot: 1.0°, stage II: -7.3°, stage III: -17.9°) as the stage progressed.

Discussions: Plantarflexion of the tibiotal joint decreased, and the adduction of the talocalcaneal and the talonavicular joint increased in the maximal plantarflexion of the ankle joint in stage II in comparison to normal.

Plantarflexion and adduction of the tibiotal joint were decreased, and those of the talocalcaneal joint and the talonavicular joint increased in stage III in comparison to stage II.

A quantitative evaluation of the 3D kinematics of many cases of flatfoot can provide valuable information for determining the timing and methods of surgical treatment.