Load Response of the Tarsal Bones in Patients with Flatfoot Deformity: 
In vivo 3D Kinematic Study

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Summary:
The aim of this study was to evaluate the bone rotation of each joint in the hindfoot and compare the load response between normal and flat feet with the reconstructive three dimensional (3D) CT image data during weightbearing. The method in this study was useful for the 3D evaluation of the load response dynamics of the foot. It could be applied to clinical analysis of foot disease and a tarsal kinetic analysis of feet pre-surgery and post-surgery.

Introduction:
Measuring the load response of tarsal bones is important for the evaluation of clinical conditions and staging of foot diseases. There have so far been no 3D studies that have evaluated the load response of tarsal bones in patients with flatfoot deformity using CT images.

The purpose of this study is to evaluate the bone rotation of each joint in the hindfoot and compare the load response between normal and flat feet with the reconstructive 3D CT image data during weightbearing.

Methods:
All patients provided written informed consent in the IRB approved study. CT scans of 21 normal feet (11 healthy volunteers) and 21 feet with flatfoot deformity (11 patients) were taken in non-load followed by full-body-weight bearing load. The images of the four bones (tibia, talus, navicular, and calcaneus) of the hindfoot were reconstructed into 3D models using CAD software. The volume merge method in three planes was used for calculating the rotation of the talus relative to the tibia in the tibiotalar joint; the navicular relative to the talus in talonavicular joint; the calcaneus relative to the talus in the talocalcaneal joint. The global x-y-z coordinate system was used to describe the orientation and position of bones. The data was analyzed using unpaired t-test.

Results:
The rotation of the talus under loading relative to the tibia at the tibiotalar joint was larger in the plantarflexed direction in flatfoot as compared to normal foot (flatfoot: -3.4 ± 3.3°, normal foot: -1.7 ± 1.3°, p = 0.031). In flatfoot, the navicular under loading relative to the talus at the talonavicular joint was more everted in the coronal plane as compared to the normal foot (flatfoot: 4.8 ± 2.6°, normal foot: 2.5 ± 2.3°, p =0.0034). The calcaneus in the flatfoot was more dorsiflexed in the sagittal plane (flatfoot: 2.0 ± 1.4°, normal foot: 0.9 ± 1.0°, p = 0.0060), more everted in the coronal plane (flatfoot: 3.4 ± 1.7°, normal foot: 1.7 ± 1.7°, p = 0.0018), relative to the talus at the talocalcaneal joint under loading as compared with the normal foot (figure).

Conclusion:
Joint instability occurred in the rear foot with load in patients with flatfoot. This method may be applied to clinical analysis of foot diseases and a tarsal kinetic analysis to evaluate the effects of foot surgery in the future.