Novel Reconstruction of the Medial Ligamentous Complex in a Flatfoot Model

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Abstract: The purpose of this investigation was to create a flatfoot model and reconstruct the deformity with a novel static medial ligamentous complex (MLC) and to evaluate its ability to correct talar head subluxation and the radiographic flatfoot deformity. Four pairs of matched cadaveric specimens were sectioned to create a severe flatfoot model. Cyclic preconditioning and axial loading was applied to the intact foot, the flatfoot, and the reconstructed MLC foot. AP and lateral views were taken at each stage. For each set of films, the following parameters were measured: on the lateral view; talar-first metatarsal angle, medial cuneiform height, talocalcaneal angle, and the calcaneal pitch angle; and on the anteroposterior view, the talar-first metatarsal angle. Compared with the intact foot, the flatfoot model showed a significant change in the AP talar-first metatarsal angle (p=0.001), the lateral talar-first metatarsal angle (p=0.002), the medial cuneiform height (p=0.007), the talocalcaneal angle (p=0.03) and the calcaneal pitch angle (p=0.018). After MLC reconstruction of the severe flatfoot model, the AP talar-first metatarsal angle, the lateral talar-first metatarsal angle and the medial cuneiform height were significantly different from the intact foot model and was not significantly different than the intact foot model. The talocalcaneal angle and the calcaneal pitch angle remained significantly undercorrected after static MLC reconstruction. Our results suggest that static MLC reconstruction is effective in correcting several key radiographic parameters in a flatfoot model and may be useful in the future as a new soft tissue reconstructive procedure for treating adult flatfoot.

Materials and Methods: Eight fresh-frozen cadaver specimens (four matched pairs) without gross evidence of pathologic changes or anatomical abnormalities at the foot were disarticulated at the level of the tibiotalar joint. All soft tissue attachments above the level of the talus were removed with the exception of the tibialis anterior tendon, which was harvested from the musculotendinous junction to its insertion at the medial cuneiform and first metatarsal in the intact lower extremity prior to disarticulation of the specimen. The initial testing of each specimen included preconditioning of the foot for five cycles at 180 N with each cycle lasting three seconds. After preconditioning, the foot was subjected to a 360 N load, simulating one-half body weight, and anteroposterior and lateral radiographs of the intact native foot were obtained.

Each specimen was then sectioned to create a severe flatfoot. The medial, superior and inferior talonavicular capsule was sectioned in addition to the spring ligament; short and long plantar ligaments; talocalcaneal intersosseous ligament; and the medial, superior and plantar naviculocuneiform capsule. The severe flatfoot model was then preconditioned and loaded as described for the initial native foot and radiographs were taken. The severe flatfoot model was then reconstructed with a split tibialis anterior graft that was harvested from the same cadaveric donor. The graft was preconditioned at ten pounds for ten minutes. Fixation points for the reconstruction were: the inferomedial talar neck and medial cuneiform. The tendon ends were secured to bone using 6.25mm x 15mm Bio-Tenodesis Screw (Arthrex, Naples, Florida). The reconstructed foot model was placed on the axial custom load-frame and preconditioned and loaded as the previous specimen and anteroposterior and lateral radiographs of the reconstructed foot were obtained.

The talar-first metatarsal angle, medial cuneiform height, talocalcaneal angle, and the calcaneal pitch angle were measured on the lateral radiograph and the AP talar-first metatarsal angle was measured on the anteroposterior radiograph. One examiner made all measurements. Changes in the measured radiographic parameters between the intact foot, the flatfoot model and the flatfoot model after reconstruction were calculated. Descriptive statistics were computed for all dependent variables. The effect of testing condition (intact, flatfoot, and reconstruction) on each dependent variable was assessed using a nonparametric repeated measures model based on the Friedman test. Significance was set at p=0.05. When main effects were detected, post-hoc tests were conducted to assess pair-wise differences between variables. The method used was based on the average ranks of each variable, and it controls the overall Type I error at the 0.05.

Results: Compared with the intact foot, the flatfoot model showed significant change in the AP talar-first metatarsal angle (p<0.001), the lateral talar-first metatarsal angle (p=0.002), the medial cuneiform height (p=0.007), the talocalcaneal angle (p=0.03) and the calcaneal pitch angle (p=0.018). After MLC reconstruction of the severe flatfoot model, there was a significant change in the AP talar-first metatarsal angle (p<0.001), the lateral talar-first metatarsal angle (p=0.002) and the medial cuneiform height (p=0.007) (Figure 1A-C) and was not significantly different from the values of the intact foot in these measurements. After this procedure, talocalcaneal angle and the calcaneal pitch angle did not significantly differ from the flatfoot state and remained undercorrected from the intact values.

Discussion: Our results suggest that reconstruction of a medial soft tissue ligament complex from the inferomedial talonar neck to the medial cuneiform is adequate in correcting key radiographic parameters in a severe flatfoot model. This non-anatomical reconstruction provided a static restraint to peritalar subluxation and provided a soft tissue sling for the talar head, reducing its position from the planatarflexed and adducted position in relation to the navicular. This technique does not violate the navicular, which would allow for concomitant or future reconstruction of the posterior tibial tendon via tendon transfer. It is currently unclear whether the spring ligament has the ability to heal if primary repair is performed. To date there has not been any data reporting primary repair of the spring ligament without additional augmentation of the nearby supporting structures. Historically, primary ligament repairs in the body have yielded poor results. This is consistent with the experience of ligament reconstruction, rather than repair, producing superior results in anterior cruciate ligament, ulnar collateral ligament, acromioclavicular ligament.

Previous reconstructive methods have been described in the literature including reconstruction with a superficial deltoid ligament bone block, peroneus longus reconstruction routed through the calcaneus and anterior tibial tendon graft routed from the navicular to the calcaneus, an anatomic reconstruction with peroneus longus tendon, a split anterior tibial tendon passed from the navicular and anchored into the sustenaculum tali as well as augmentation of the spring ligament using a stump from the posterior tibial tendon all with equivocal success. The current mainstay of flatfoot reconstruction is bony procedures and their success has been well documented. However there is data to show that bony procedures may increase stress on nearby joints or lead to arthrosis of these joints. We feel that by correcting the static restraint of the talus, which is the principal deformity that leads to the radiographic changes of flatfoot, we can directly reduce the talus to its correct position. We can use this reconstruction to augment bony procedures that realign the foot in relation to the navicular or possibly refrain from performing bony procedures especially in young adults.