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Ligament Balancing for Total Ankle Arthroplasty. An In Vitro Evaluation of the Elongation of the Hind- and Midfoot Ligaments
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Summary: Guidelines for ligament balancing in total ankle arthroplasty are not well established. This study documented the changes in length of the hindfoot ligaments in response to alterations in ankle and subtalar joint orientation under physiologic load in cadaver limbs. The findings may facilitate optimizing alignment and range of motion through selective ligament release.

Introduction: The results of total ankle arthroplasties are enhanced by correct alignment of the hindfoot and balancing of the ankle joint ligaments. History has demonstrated that total knee arthroplasties are best balanced by selective ligament release based on the knowledge of the ligament bundles that elongate with flexion or extension of the knee. However, there has not been a comprehensive study of the length changes in the hindfoot ligaments under simulated weight bearing. The study described here was designed to provide this information.

Methods: Eight fresh-frozen lower limbs were mounted in a neutral anatomic position in a servohydraulic materials testing machine. Acrylic cubes were rigidly attached to the tibia, talus, calcaneus, navicular, and cuboid, and the limb was placed under a 700N tibiotalar load. The planes of three facets of each cube were established with a digitizing stylus to define the initial position of each bone. The hindfoot was then sequentially repositioned into ten degrees of dorsiflexion, ten degrees of plantarflexion, fifteen degrees of inversion, and five degrees of eversion. Tibiotalar loading and bone position digitizing were repeated for each hindfoot orientation.

Each specimen was then dissected, the perimeters of the insertion sites of each hindfoot ligament were digitized, and the cube surfaces were again digitized to establish the spatial relationship between each bone and its associated ligament insertions. Solid modeling software was used to calculate the distance between the insertion site centroids of each ligament for each ankle position. Ligament length increases between the various hindfoot position were identified using ANOVA, followed by a Student-Newman-Keuls (SNK) post-hoc test (p<0.05).

Results: In eversion, the tibiocalcaneal (deltoid) [11% +/- 4%, mean +/- std dev], calcaneofibular [6% +/- 4%], posterior talofibular [7% +/- 4%], posterolateral talocalcaneal [21% +/- 9%], posteromedial talocalcaneal [33% +/- 45%] and calcaneonavicular (bifurcate) [8% +/- 7%] ligaments were elongated relative to their lengths in inversion. In inversion, the anterior capsular (talocalcaneal) [5% +/- 3%] and the plantar cuboidnavicular [5% +/- 6%] ligaments were elongated relative to their everted lengths. In dorsiflexion, the superficial [26% +/- 8%] and deep posterior tibiotalar [30% +/- 13%] (deltoid), calcaneofibular [8% +/- 4%], tibiocalcaneal [4% +/- 2%] and lateral talocalcaneal (cervical) [2% +/- 1%] ligaments were elongated. In plantarflexion, the tibionavicular (deltoid) [26% +/- 5%] and the anterior talofibular [7% +/- 4%] ligaments were lengthened.

No statistically significant elongation was documented in any ankle position for the anterior tibiotalar (deltoid), talocalcaneal interosseous, plantar calcaneocuboid, calcaneocuboid (bifurcate), all components of the spring ligament, and the dorsal cuboidnavicular ligaments.

Conclusion: This comprehensive study documented a broad array of ligament length changes related to hindfoot position. Components of the deltoid ligament complex elongated largest at the ankle joint with any hindfoot movement but inversion. Therefore, selective release of components of the deltoid ligament complex may provide a means for achieving optimal ligament balancing in total ankle arthroplasty.
Specifically, release of the superficial and deep posterior tibiotalar (deltoid) ligament may improve range of motion in total ankle arthroplasties, whereas the release of the tibiocalcaneal (deltoid) ligament may correct a varus talar tilt.