BIOMECHANICAL EFFECTS OF GRAFT SHAPE FOR LATERAL COLUMN LENGTHENING

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INTRODUCTION:
Lateral column lengthening procedure is commonly used to augment tendon transfer for symptomatic pes planus deformity. This technique has been shown to re-establish bony alignment of the forefoot, recreate the medial arch and preserve motion of the midfoot and hindfoot. However, the biomechanical alteration resulting from lateral column lengthening is poorly understood. Therefore, the objective of this study was to quantify the biomechanical effects of lateral column lengthening using different shaped bone grafts in a cadaveric flat foot model.

METHODS:
Six fresh frozen cadaver below-the-knee specimens were used and examined clinically after dissection to exclude deformity or arthritis. The specimens were dissected so that three reproducible bony landmarks could be placed on the tibia, first and second metatarsals, talus, navicular, calcaneus and cuboid. The positions of these bones were quantified by digitizing the three markers in each bone using the Microscribe 3DLX (Immersion Corp, San Jose, CA) as the specimen was loaded on a MTS machine at axial loads of 200N, 400N, 600N, 800N, 1000N (Figure 1). A point on the distal sustentaculum tali and the plantar surface of the navicular were used to track the relative length of the spring ligament. A Tekscan (Tekscan Inc, South Boston, MA) pressure sensor was used to measure contact pressure in the subtalar joint at each axial load for each condition.

A flatfoot was created by a method described by McCormack et al.1 We attenuated the spring ligament and medial capsule of the talonavicular joint and loaded the specimen to 10,000 cycles at a load between 700 and 1200N at a frequency no greater than 0.5Hz. The interosseous ligament between the talus and calcaneus was also attenuated. Once a flatfoot was created, testing was repeated for each axial load described above.

A calcaneal osteotomy was then performed 1 cm proximal to the calcaneocuboid joint with a thin oscillating saw between the anterior and middle facets medially. A one centimeter rectangular bone graft was then placed and fixed to the calcaneus using a plate and screws. The Microscribe was used to record the positions of the marked bones at the axial loads. This step was repeated for 1 cm wedged bone grafts placed laterally, dorsally and plantarily.

RESULTS:
The flatfoot deformity had progressive changes in the lateral talo-first metatarsal angle and calcaneal pitch. The lateral talo-first metatarsal angle changed (talus rotating plantarly) on average 11.3 degrees at 200N, 12.2 at 400N, 12.7 at 600N, 13.3 at 800N and 13.4 at 1000N (Figure 2) (400N, p = 0.0001). The calcaneal pitch for the specimens also changed the most for the flatfoot subgroup. At 200N, the calcaneal pitch angle decreased (plantarly) by 5.2 degrees. At 1000N the change in angle was 5.9 degrees (400N, p = 0.0002). As expected after attenuating the spring ligament to create a flatfoot, the length of the spring ligament increased between 3.2 to 3.7mm at all axial loads. Again, the length increased as expected with the bone grafts. The lateral wedge graft created the smallest increase in length by 4.2mm at 600N, and the plantar graft had the largest increase at all loads with 8.4mm at 600N.

The rectangular graft best reestablished the lateral talo-first metatarsal angle within 3 degrees of normal at all axial loads as well as restoring calcaneal pitch (400N, p = 0.97 rect vs. normal). The next shape that best restored this angle was the dorsal wedge. However, there was still a change in the lateral talo-first metatarsal angle of 3.8 degrees at 200N to 6.1 degrees at 1000N (400N, p = 0.05, dorsal vs. normal). The dorsal graft was also able to reestablish the pitch by 3 degrees at all axial loads (400N, p = 0.61, dorsal vs. normal). The lateral wedge had a change of 4.1 degrees at 200N and 7.1 degrees at 1000N (400N, p = 0.02 lateral vs. normal). The plantar wedge was unable to correct the change in the lateral talo-first metatarsal angle (400N, p = 0.0001 plantar vs. normal). These grafts did not correct calcaneal pitch as well as the rectangular or dorsal wedge graft (400N, p = 0.0001 plantar vs. normal).

The peak pressure of the subtalar joint for the normal specimen was 1.9 MPa at 200N, 2.6 MPa at 400N, 3.5 MPa at 600N, 4.2 MPa at 800N and 4.9 MPa at 1000N. As expected, the peak pressure in the flatfoot model was increased except at 1000N, where the peak pressure was decreased by 0.2 MPa, however this was not statistically significant. After the lateral column lengthening procedure, the peak pressure in the subtalar joint was significantly less than the flatfoot for the dorsal, lateral and plantar wedge groups (p < 0.007). The pressure in the subtalar joint was closer to the measured pressure in the normal specimen with the rectangular graft.

DISCUSSION:
The lateral column lengthening procedure is used to restore alignment and function of hindfoot, midfoot and forefoot. The findings from this study suggest that a rectangular bone graft is the best at correcting the deformity in terms of the lateral talo-first metatarsal angle and calcaneal pitch. If a surgeon were to use a wedge graft, it is shown that a dorsal wedge is better as the longer end is in the plane of the talonavicular joint (when compared to the lateral or plantar wedges) and gives a better correction of the deformity.

REFERENCES:

ACKNOWLEDGEMENTS:
VA Rehab R&D and Medical Research

Figure 1: Testing setup with Microscribe and Tekscan.

Figure 2: Lateral talo-first metatarsal angle with each testing condition.

Figure 3: Average subtalar peak pressure for each testing condition.