Comparison of Transfer Sites for Flexor Digitorum Longus in Treatment of Posterior Tibialis Tendon Dysfunction
+1, 2Vaudreuil, N J; +1, 2Ledoux, W R; +1, 2Roush, G C; +1, 2Whittaker, E C; +1, 2Sangeorzan, B J
+1 VA Puget Sound, Seattle, WA, +1University of Washington, Seattle, WA
wrdoux@u.washington.edu

INTRODUCTION:
Dysfunction of the posterior tibialis tendon (PTTD) has been shown to cause adult acquired flatfoot deformity, a common etiology of foot and ankle pain. Stage 2 PTTD is an intermediate stage characterized by a torn or attenuated posterior tibial tendon (PTT) [1], and a patient usually presents with passively correctable forefoot abduction and hindfoot valgus. Common treatment of Stage 2 PTTD involves a bony realignment of the calcaneus and a flexor digitorum longus (FDL) tendon transfer to the insertion of the PTT. The purpose of the FDL transfer is to regain control over transverse tarsal joints and the inverting and plantar flexing abilities of the hindfoot [2]. An FDL transfer can be accomplished by attaching the tendon to the navicular, medial cuneiform, or distal residuum of the degraded PTT. Thus, the objective of this study was to assess the kinetic and kinematic outcomes of these three surgical procedures using cadaveric gait simulation.

METHODS:
In this IRB-approved study, eight fresh-frozen cadaveric lower limb specimens were obtained from the University of Washington; four have been tested and four are in preparation. Specimens were transected to include the distal leg, ankle joint, and foot, and specimens with pathological abnormalities, such as hallux valgus, were excluded. To induce a flatfoot deformity, the talocalcaneal interosseous, plantar first metatarsocuneiform, plantar naviculocuneiform, and anterior tibial part of the deltoid ligament were attenuated using several 1-2 cm parallel incisions. Additionally, the calcaneonavicular (spring) ligament and talonavicular capsule were transected. Each specimen was cycled from 10N to the donor’s body weight for 20,000 cycles at 2 Hz, with the load applied axially to the tibia with an MTS Mini Bionix 858 materials testing machine. Up to 15,000 additional cycles were required to achieve sufficient flattening for several feet. Pre-operative and post-operative radiographs were evaluated to verify the degree of flattening.

Following the flattening procedure, each specimen was tested on the robotic gait simulator (RGS) [3, 4] under the following four conditions: flatfoot (FF); and then in randomized order: FDL transfer to navicular (NAV); with FDL transfer to medial cuneiform (CUN); and with FDL transfer to the residuum of PTT (rPTT). The FDL transfer procedures were simulated by pulling on the transected FDL tendon with 1.8x its normal forces (rPTT) or by pulling on the transected FDL tendon with 1.8x its normal forces while it was attached with a custom tendon clamp and string to a hanger bolt in either the inferior-medial aspect of the navicular or medial cuneiform (NAV or CUN, respectively) (Figure 1). Instead of normal FDL force, 1.8x FDL force was used to simulate hypertrophy of the FDL muscle in response to posterior tibialis atrophy.

The stance phase of gait was simulated in 4.09 s at 50% of the donor’s body weight. The RGS was controlled as described by Aubin et al. [4]. A Novel emed sf platform measured pressure, and a six-camera Vicon system tracked the motion of ten bones using a previously described ten-segment foot model [3]. Peak plantar pressure was the primary outcome, and was assessed with a repeated measures ANOVA (in progress), while trends were observed in the kinematic data.

RESULTS:
Peak plantar pressure (kPa) decreased at the heel, first metatarsal, hallux, and lesser toes for each of the three surgeries as compared to the flatfoot model (Figure 2). Increases in pressure were noted for the lateral midfoot and second through fifth metatarsal regions.

DISCUSSION:
Treatment of Stage 2 PTTD generally includes an FDL transfer, despite some literature questioning its biomechanical rationale [2]. We hypothesized that all three transfer locations would result in a lateral shift in peak pressure and restore normal kinematics. The peak pressure analysis showed that each of the surgical procedures resulted in a lateral shift in peak pressure away from the hallux and first metatarsal. The CUN procedure had the most discernable trend towards increasing pressures at the third and fourth metatarsals, while the NAV procedure resulted in more balanced peak pressure increases across the second through fifth metatarsals. Our kinematic results showed that during stance phase, ROM and peak angle did not differ by more than 1.8 degrees at most (Table 1). These findings suggested that an FDL transfer alone might not be sufficient to correct flatfoot kinematics. Future work must be conducted to see if a concomitant calcaneal osteotomy would solve the underlying misalignment and allow for normal kinematics after an FDL transfer at each of the three locations.

SIGNIFICANCE:
The results of this study should supplement previous research efforts involving the FDL transfer procedure and the treatment of adult acquired flatfoot deformity. In quantifying the kinematic and kinetic differences associated with the three procedures, we hope to provide clinicians with a better understanding of biomechanical outcomes when selecting an FDL transfer location for future patients.

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REFERENCES:

Table 1: Average range of motion (ROM) [SD] and peak angle during stance phase for flatfoot and three surgical conditions for navicular with respect to talus (NAV_TAL); for peak angle, positive = dorsiflexion, eversion, abduction.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sagittal plane ROM</th>
<th>Frontal plane ROM</th>
<th>Transverse plane ROM</th>
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Figure 1: Cadaveric specimen with bony markers and FDL transfer to navicular (NAV) surgical model.

Figure 2: Averages changes in peak pressure (kPa) compared to FF for the CUN, NAV, and rPTT procedures.

Kinematic findings showed subtle differences between the surgical procedures and the flatfoot model. Few trends were discernable, however the navicular with respect to the talus showed subtle trending towards increased plantar flexion, inversion and adduction (Table 1). A statistical analysis will be conducted once the 4 additional feet are tested.