

# Hindfoot Kinematics during Simulated Level Walking after Combined Spring Ligament and Interosseous Talocalcaneal Ligament Repair

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**DISCLOSURES:** Jeffrey Hoffman (N); Cesar de Cesar Netto (2; Exactech Inc., Ossio, Stryker Inc., Extremity Medical, Zimmer Biomet. 3B; Curvebeam, Exactech Inc., Ossio, Stryker Inc, Zimmer Biomet. 4; Curvebeam, Tayco Brace LLC.. 8; Foot and Ankle Clinics, Journal of Foot and Ankle. 9; American Orthopedic Foot and Ankle Society.), Ricardo Villar (N), Scott Ellis (1; Nextremity. 3B; Paragon 28, Vilex, LLC, Wright Medical. 8; Foot and Ankle International, Foot Innovate, Wolters Kluwer. 9; American Orthopedic Foot and Ankle Society, Orthopaedic Foot Club, International Weightbearing CT Society.), Jonathan Deland (1; Arthrex Inc., Zimmer. 3B; Paragon28.), Brett D. Steineman (N)

**INTRODUCTION:** Peritalar subluxation (PTS) plays a crucial role in Progressive Collapsing Foot Deformity (PCFD), initially occurring through external rotation and dorsolateral subluxation, pivoting around the Interosseous Talocalcaneal Ligament (ITCL). Recent research has shown that improvements in PTS are associated with improvements in patient reported outcomes [1]. While traditional surgical techniques for PCFD can indirectly address PTS by repositioning the foot in three dimensions, a direct repair or reconstruction of the ITCL is often avoided due to technical difficulties [2]. Our goal was to evaluate a novel combined ITCL and spring ligament (SL) PCFD reconstruction surgical technique and analyze its impact on PTS and hindfoot movement during simulated walking. We hypothesized that ITCL-SL reconstruction would correct PTS and restore talonavicular and subtalar joint kinematics.

**METHODS:** 10 matched pairs (N=20) of cadaveric mid-tibia specimens (4 Male, 6 Female; 43.6 ± 16.3 years) were used in this study. Specimens underwent simulations of the stance phase of gait using a previously validated six-degree of freedom hexapod robot [3] (Figure 1B). A force plate attached to the robot is rotated around the foot in a manner that replicates the orientation of the floor relative to the tibia during level walking. Simultaneously, nine extrinsic tendons surrounding the foot are attached to linear actuators above the robot, which applied physiological muscle forces according to when they are active during the stance phase [4]. An iterative control process using fuzzy logic was used to adjust force plate trajectory and muscle forces to produce optimal inputs for reproducing in vivo ground reaction force profiles [5]. Each specimen was simulated using healthy level walking gait inputs at 1/6<sup>th</sup> of normal walking speed and ¼ bodyweight. Eight infrared cameras (Vicon Motion Systems Ltd.; Oxford, UK) surrounding the simulator tracked the motion of reflective markers attached to the tibia, talus, calcaneus, and navicular. Weightbearing computed tomography (WBCT) scans were collected after stance phase simulations for each condition. Kinematic and WBCT data was collected in four conditions: (1) prior to PCFD deformity (intact), after simulated PCFD deformity creation (sPCFD) [6], and (3) after performing the SL-ITCL repair (Tether). Specimens were randomly divided into two groups for simulating PCFD creation, which included spring ligament and medial talonavicular capsule initially sectioned: (1) ITCL intact (N=10) (ITCL<sub>i</sub>) and (2) ITCL additionally sectioned (ITCL<sub>s</sub>) (N=10). Rotations of the ankle, subtalar, and talonavicular joints were calculated as the average of three trials per condition. Additionally, foot and ankle offset (FAO) was calculated from the simulated WBCT scans of cadavers after each condition. Bias corrected 95% confidence intervals of the repeated measures difference between both the sPCFD and Tether conditions and the Intact condition were calculated for each joint to determine the differences from intact at each point in stance [7].

**RESULTS:** Subtalar and talonavicular joint kinematics in both the ITCL<sub>i</sub> and ITCL<sub>s</sub> group were partially corrected by the Tether conditions (Figures 1). Subtalar eversion was reduced relative to the sPCFD condition by a maximum of 2.8° (95% CI 0.3- 3.8) at 77% of stance in the ITCL<sub>i</sub> condition, and 3.0° (95% CI 0.1-7.0) at 93% of stance in the ITCL<sub>s</sub> group. Relative to the intact condition, the ITCL<sub>i</sub> condition was under corrected by up to 2.3° (95% CI: 0.6° - 4.6°) and 2.3° (95% CI: 1.5°, 4.3°) in the ITCL<sub>s</sub>. Similarly, talonavicular abduction decreased in the Tether condition by 3.8° (95% CI: 2.3°-5.3°) at 60% of stance in the ITCL<sub>i</sub> group, and 4.5° (95% CI: 0.6° - 9.8°) at 48% of stance in the ITCL<sub>s</sub> group. Both conditions remained under corrected to intact by up to 1.7° (95% CI: 0.6, 4.1) and 3.1° (95% CI: 2.0°, 4.1°) in the ITCL<sub>i</sub> and ITCL<sub>s</sub> conditions, respectively. FAO measurements improved on average by 1% ± 1.4% following ITCL-SL reconstruction.

**DISCUSSION:** The results of this study demonstrate that a novel combined ITCL and SL reconstruction technique for PCFD resulted in significant improvements in hindfoot joint kinematics during simulated walking. The ITCL-SL reconstruction reduced subtalar joint eversion and talonavicular joint abduction, improving hindfoot alignment which was also noticed in simulated WBCT scans. Repairing the ITCL and spring ligament can correct peritalar subluxation and restore near normal hindfoot movement in PCFD specimens even in the absence of traditional bony procedures such as calcaneal and Cotton osteotomies. Further clinical studies are needed to confirm the efficacy of this combined reconstruction technique in improving patient-reported outcomes and long-term function in PCFD patients.

**CLINICAL RELEVANCE:** The results from this study could be used to inform surgical decision making in the reconstruction of progressive collapsing foot deformity.

**REFERENCES:** 1. Brodell et al., 2019; 2. Lintz et al., 2025 3. Baxter et al., 2016; 4. Whittaker et al., 2012; 5. Aubin et al., 2010; 6. Henry et al., 2021; 7. Lenhoff et al., 1999

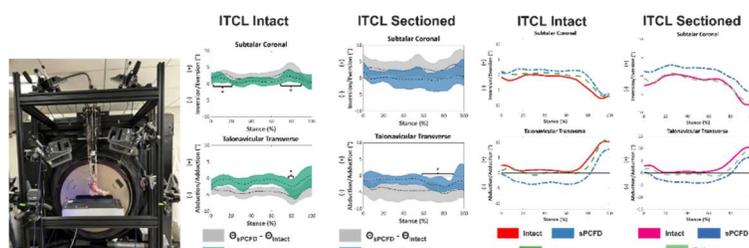


Figure 1: (Left) Six degree-of-freedom robot that simulated stance phase of gait. (Center) Bias corrected 95% confidence intervals of the repeated measures difference between both the Tether and sPCFD conditions and the intact condition for both the ITCL<sub>i</sub> and ITCL<sub>s</sub> conditions. \* denotes a period of significant difference between the tether condition and the intact condition. (Right) Mean kinematics of the subtalar and talonavicular joint in the coronal and transverse plane respectively for all three conditions.

