Passive Eversion Assessment for Progressive Collapsing Foot Deformity after Lateral Column Lengthening: A Cadaveric Biomechanical Study

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INTRODUCTION: Lateral column lengthening (LCL) is an established procedure for correcting abduction deformity in patients with progressive collapsing foot deformity (PCFD). Although functional improvements are frequently reported following LCL, postoperative lateral foot pain and stiffness remain the major concerns. Studies have suggested that decreased subtalar eversion motion after LCL may indicate an increase in foot stiffness and lateral plantar pressure, resulting in lateral foot pain (Ellis et al., 2010). The key to the LCL procedure may be determining the amount of lengthening that preserves subtalar eversion motion while also providing adequate abduction correction. Given this, some surgeons have attempted to use a manual assessment of subtalar eversion to help titrate the amount of correction needed (Ellis et al., 2020). However, it is unknown whether this subjective assessment of passive eversion is associated with objective postoperative measurements of foot stiffness, such as plantar pressure. Our goal was to quantify the relationship between eversion during a passive assessment and plantar pressures during simulations of level walking. We hypothesized that a strong relationship exists between the location of plantar pressure and the eversion measured with passive manipulation.

METHODS:

Ten mid-tibia cadaveric specimens (6 Male; Age range: 35-72 years) were utilized in this study. Each specimen underwent stance phase simulation using a validated robotic gait simulator (Baxter et al., 2016). Briefly, the simulator recreates in vivo ground reaction forces by rotating a force plate around a stationary tibia while applying in vivo muscle forces to extrinsic tendons through linear actuators (Whittaker et al., 2012). In vivo ground reaction forces for a specified population are then replicated by adjusting the force plate trajectory around the specimen and the muscle forces applied to the extrinsic tendons through an iterative learning algorithm. Following stance phase simulations, a fellowship-trained orthopaedic surgeon manually assessed the eversion motion present in the subtalar joint by applying an everting force to the calcaneus, while holding the foot in a neutral position (Thoradson et al., 2020). Reflective marker clusters were attached to the tibia, talus, calcaneus, navicular, and 1st metatarsal and tracked by an 8-camera motion capture system during stance phase simulations and eversion assessments. Additionally, a plantar pressure mat attached to the simulator was used to track the pressure distribution in each condition. Kinematic data were collected during five conditions for each specimen: before PCFD creation (Intact), after PCFD creation (PCFD), and after insertion of three different sizes of lateral column lengthening wedges (4mm LCL, 6mm LCL, and 8mm LCL). The model of PCFD was created through sectioning of the spring ligament complex, superficial deltoid ligament, and interosseous talocalcaneal ligament. After sectioning, the specimen was cyclically loaded for up to 800 cycles at 800 N to produce a deformity that achieved 5° of additional talonavicular abduction (Henry, In Review). A fellowship-trained orthopaedic surgeon performed LCL procedures in a randomized order using a 4mm, 6mm, and 8mm wedge. Outcome measures for each condition included the lateral-to-medial forefoot plantar pressure ratio (LM ratio) during level walking simulations and the maximum amount of subtalar eversion motion achieved during the assessment for each condition. Pearson correlation coefficients were calculated to determine the relationship between the maximum amount of eversion during the assessment and the lateral-to-medial plantar pressure ratio during walking simulations. Additionally, a linear mixed-effects model was used to determine the relationship between the LM ratio and the size of the LCL wedge used. All statistical analysis was conducted using same statistical computing language.

RESULTS:

The LM ratio strongly correlated with the maximum subtalar eversion achieved during the assessment (Figure 1). In this case, a decrease in the amount of eversion motion present within the subtalar joint was strongly correlated ($p<0.001$) with a lateral shift in plantar pressure during stance phase simulations. The LM ratio was also significantly correlated ($p<0.001$) with the size of the LCL wedge inserted into the foot. This result indicates that a lateral shift in plantar pressure is strongly correlated with the size of the LCL wedge used in the procedure. A similar relationship was present between the maximum subtalar eversion achieved during the assessment and the size of the wedge, as a larger wedge size was correlated to a decrease in the maximum amount of subtalar eversion present.

DISCUSSION AND CONCLUSION: The results of this study confirmed our hypothesis that reduced subtalar eversion following LCL is associated with increased lateral plantar pressure. This finding is consistent with reported stiffness in the lateral foot coupled with decreased subtalar eversion motion following LCL surgery (Conti et al., 2015). Our results suggest that a passive eversion assessment could be used to help predict functional outcomes of the LCL procedure. Also, the size of the wedge used in each foot greatly affected the functionality of the foot after surgery. For example, insertion of the 8-mm wedge resulted in a large increase in lateral foot stiffness during the assessment. Conversely, the 4-mm wedge resulted in adequate correction to intact as measured by plantar pressure and subtalar eversion assessment.

Therefore, it is strongly recommended to minimize the amount of lengthening performed to avoid complications associated with LCL.

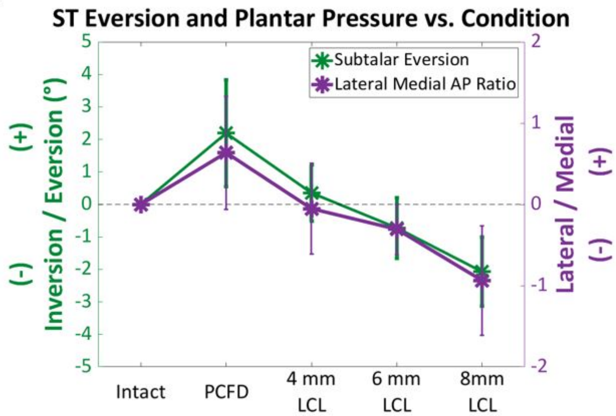

Figure 1: Lateral-to-Medial Average plantar pressure ratio during level walking and maximum subtalar eversion during the assessment during each condition. All values were normalized to the intact value for each condition. {*} denotes a significant difference from the intact condition.