Impact of First Metatarsal Hyperpronation on First Ray Alignment: A Cadaveric Study
Matthieu Lalevée, MD; Kevin N. Dibbern, PhD; Nacime SB Mansur, MD; Hee Young Lee, MD; Jennifer S. Walt, MD; Jean-Yves Coillard; Charles L. Saltzman, MD; Cesar de Cesar Netto, MD, PhD

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Introduction/Purpose: Hyperpronation of the first metatarsal (M1) is present in Hallux Valgus (HV) but its impact is still unknown. A previous biomechanical study showed that an increase in hallucal pronation might lead to a medial soft tissue failure of the first metatarsophalangeal joint (MTP1). Conversely, an increase in supination and adduction of the first ray when weight-bearing is present in case of HV. The objective of our study was to sequentially answer the following questions: (1) Does an increase in M1 pronation cause an increase in hallucal pronation? (2) Can a combination of intrinsic M1 hyperpronation and MTP1 medial soft tissue failure induce a supination motion of the first ray during weight-bearing? (3) Can a first ray supination motion during weight-bearing be accompanied by an increase in IMA and HVA?

Methods: A cadaveric model allowing a simulated standing position was developed and secured with a radiolucent frame (Figure 1). A midshaft osteotomy of M1 was performed allowing either 0° or 30° in pronation. MTP1 medial soft tissue release was performed to simulate failure. Twelve specimens underwent 6 Weight-Bearing CT acquisitions under different conditions listed below. The first 3 acquisitions had 0° pronation of M1: 1. Simulated non-weight-bearing condition (Figure 2a) 2. Simulated weight-bearing condition (Figure 2b) 3. Simulated weight-bearing condition with medial soft tissue failure (Figure 2c). The next 3 WBCT acquisitions followed the same sequence but with 30° pronation of M1 (Figure 2d to 2f). On each WBCT acquisition, the HVA, IMA, Metatarsal Pronation Angle (MPA, M1 head pronation relative to the ground) and the hallucal pronation (HP) were measured (Figure 3). Motions were indirectly calculated from the differential values of these angular measurements produced by these 6 different conditions.

Results: 1. The increase in MPA and HP induced by the 30° pronation osteotomy of M1 in simulated non weight-bearing conditions were respectively 27.6+/-.4.1 and 25.5+/-.5.6 degrees (p=0.202). 2. The first ray motion induced by weight-bearing without pronation osteotomy combined with a MTP1 medial soft tissue failure was 3.7+/-.3.6 degrees pronation (differential value on MRA between Figure 2a and 2c) compared to 11+/-.7.5 degrees supination after the 30 degrees pronation osteotomy of M1 combined with a MTP1 medial soft tissue failure (p<0.01) (differential value on MPA between Figure 2d and 2f). 3. Regarding the static angular measurements, the HVA and the IMA presented fair positive linear correlations with the MPA (respectively ρ=0.2 and ρ=0.22). Considering the motions, the increase of the HVA and the IMA during weight-bearing presented respectively a very strong negative (p=-0.82) and a strong negative (p=-0.77) linear correlations with the pronation motion of the first ray during weight-bearing.

Conclusion: The combination of M1 intrinsic hyperpronation and MTP1 medial soft tissue failure led to an HV deformity in our cadaveric study. The static measurement of M1 head pronation relative to the ground (MPA) does not reflect the real intrinsic pronation of the first ray and foot and ankle specialists should be careful when interpreting these measures. HV is a dynamic condition, and the deformity could be more correlated with motions when WB than with plain static measurements. The first ray supination motion compensating a M1 intrinsic hyperpronation might be an important factor in the HV pathogenesis.
