The Effects of First Ray Instability on Midfoot Joint Forces and the Forefoot Force Distribution: A Cadaveric Study

Foot & Ankle Category: Midfoot / Forefoot

Author(s):
John C. Tanner, MD
Cameron G. Patthanacharoenphon, MD
Travis Burgers, PhD
Donald R. Bohay, MD
John G. Anderson, MD

Introduction
The motivation for this study is the clinical observation that patients with first ray instability develop arthritis in a predictable pattern in the midfoot. Cartilage wear is typically seen in the dorsal and medial in the 1st naviculocuneiform (NC) joint and dorsally in the 2nd tarsometatarsal (TMT) joint. It is the senior author’s belief that intercuneiform instability plays an important roll in the development of this pattern. This study is an attempt to quantify that effect of intercuneiform and 1st ray instability in a cadaveric model.

Methods
Seven fresh frozen human cadaver leg specimens were tested. All specimens were sectioned at the mid tibia level and muscle tendons were dissected out and tensioned with a weight and pulley system to simulate muscle forces. The specimens were mounted in a dynamic compression testing machine (Test Resources) and cyclical compressive forces applied. A foot sensor (TekScan) recorded the ground reaction forces and paddle sensors (TekScan) measured joint forces in the 1st NC joint and the 2nd TMT joint. The sequential transection of ligaments around the medial cuneiform was performed to destabilize the first ray, with data collected after each dissection. Specifically, the dorsal intercuneiform ligament was transected, followed by the plantar intercuneiform ligament, followed by the intermetatarsal ligaments and the plantar NC ligament. Foot sensor data was collected as force applied to the 1st ray forefoot and lateral forefoot. This was analyzed both as total force, and percentage of forefoot force. The joint sensor data was collected as the maximum force measured in a four-pixel area (~2mm x 2mm). Data from all seven specimens was averaged for our results.

Results
Transection of the ligaments around the medial cuneiform decreased the force transmitted to the medial forefoot in 6 out of 7 test samples. On average, the first ray forefoot forces decreased by 18% while the force transmitted to the lateral forefoot was unchanged. This was a 6% shift in forefoot force from medial to lateral. The measured peak force in the 1st NC joint increased with sequential sectioning of ligaments and reached a maximum average increase of 49% with the plantar NC ligament intact. The measured peak force in the 2nd TMT joint had reached a maximum average increase of 31% with the intercuneiform ligaments sectioned.

Conclusion
In a cadaveric model, destabilization of the first ray shifts forefoot force lateral while increasing peak forces in the 1st NC joint.