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Biomechanical analysis of endobutton versus screw fixation after Lisfranc ligament complex sectioning

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ABSTRACT

Background: Our goal was to compare diastasis after endobutton and screw fixation after Lisfranc ligament complex sectioning.
Methods: Twenty-four (12 pairs) fresh-frozen cadaveric feet were assigned to endobutton or screw fixation and loaded to 343 N. Displacement (first–second metatarsal bases) was measured in intact feet and after ligament sectioning (Lisfranc, medial–intermediate cuneiform ligaments), fixation, and 10,000 cycles.
Results: The mean change in diastasis for endobutton and screw fixation under initial loading was 1.0 mm (95% CI, 0.2–1.9 mm) and 0.0 mm (95% CI, −0.4 to 0.4 mm), respectively ($p = 0.017$). After cyclic loading, diastasis decreased (mean, −0.7 mm, 95% CI, −1.2 to −0.1 mm) in the endobutton group but was unchanged in the screw group ($p = 0.035$).
Conclusions: Diastasis after endobutton fixation was significantly greater than after screw fixation under initial loading but did not increase further after cyclic loading.

1. Introduction

Lisfranc injuries are relatively uncommon, accounting for approximately 0.2% of all limb injuries [1] and occurring at an approximate rate of one per 55,000 people per year in the United States [2–4]. Diastasis at the Lisfranc joint is poorly tolerated, especially if diagnosis and treatment are delayed [5–10]. Most authors currently advocate accurate anatomical open reduction and internal fixation [1,3,8–17]. Purely ligamentous Lisfranc injuries have a worse prognosis than do fracture-dislocations [9,14,18], leading some authors to advocate primary fusion over open reduction and internal fixation [19].

Recently, endobutton fixation has become available [20] for the treatment of a Lisfranc ligament injury [21], with the potential advantage of not requiring later removal. This device may also allow a small amount of motion at the tarsometatarsal joint, which according to animal studies provides a more optimal environment for ligament healing [22–24]. The early clinical results of using the endobutton for isolated Lisfranc ligament rupture are promising [25].

One biomechanical study simulating isolated Lisfranc ligament rupture found no significant difference in diastasis under static loading between single-screw fixation and single-endobutton fixation [26]. In contrast, another biomechanical study reported significant diastasis at the bases of the first and second metatarsals after endobutton fixation compared with screw fixation [27]. In both studies, the Lisfranc ligament was sectioned in isolation. To our knowledge, no studies have simulated Lisfranc ligament injuries with additional ligament rupture at the medial–intermediate cuneiforms joint, which has been recognized in clinical reports [10,28], nor has the effect of cyclic loading on Lisfranc ligament fixations been tested.

Our goal was to measure and compare diastasis under initial loading and after cyclic loading in a cadaveric model after endobutton and screw fixation following Lisfranc ligament complex sectioning. The hypotheses were that screw fixation would result in significantly less diastasis than would endobutton fixation under initial and after cyclic loads, and that for endobutton fixation, diastasis at the bases of the first and second metatarsals would significantly increase after cycling.

2. Materials and methods

Twenty-four fresh-frozen matched cadaveric feet (12 pairs; donors, nine males and three females; mean donor age at death, 70.5 years; range, 63–83 years) were acquired from the Maryland

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State Anatomy Board. Data from two pair were lost because the motion analysis markers were later discovered to be collinear. Power analysis (assuming significance of 0.05 and power of 80%) was used to calculate sample size based on data from a previous biomechanical study [26]. All specimens had undergone dual-energy X-ray absorptiometry scanning of the distal radius to ensure that none were osteoporotic (t score < -2.5).

Each specimen was sectioned just distal to the metaphysis of the proximal tibia and fibula using a saw. For consistency, all specimens were prepared by the first author. The ankle was placed in approximately 45° of plantigrade flexion using a goniometer to reference foot position relative to the tibial shaft. A plumb line was used to position the midfoot directly under the loading point of the proximal tibia. The tibiotalar and subtalar joints were subsequently fixed in position by inserting an antegrade 9-mm-diameter intramedullary nail via the tibia, through the talus and the most posterior aspect of the heel. This foot position simulated the end of the stance phase of the gait cycle, which would be expected to induce the greatest diastasis at the Lisfranc joint. Previous biomechanical models simulating Lisfranc ligament injuries have also used a plantarflexed foot position [26,29]. Two additional Steinmann pins were inserted to add stability to the ankle and subtalar joints and facilitate specimen loading. The proximal 10 cm of the tibia and fibula were stripped of soft tissues and embedded in commercially available dental cement (Fastray, Harry J. Bosworth Co., Skokie, IL, USA) for later mounting to an MTS 858 Bionix material testing machine (MTS, Eden Prairie, MN, USA).

The dorsal skin over the medial and intermediate cuneiforms and first and second metatarsals was excised. We inserted 3.5-mm cortical screws into each of the medial and intermediate cuneiforms and the first and second metatarsals; they served as mounting posts for the marker triads used to track kinematic data from the motion capture system (eMotion, Padua, Italy) (Fig. 1).

2.1. Testing protocol

Ghost points (virtual markers) were created at the base of the first metatarsal and at a corresponding point on the second metatarsal base at the metaphyseal flare. Ghost points were also marked at the midpoint of the medial and intermediate cuneiforms to allow measurement of any diastasis at the cuneiforms (Fig. 2).

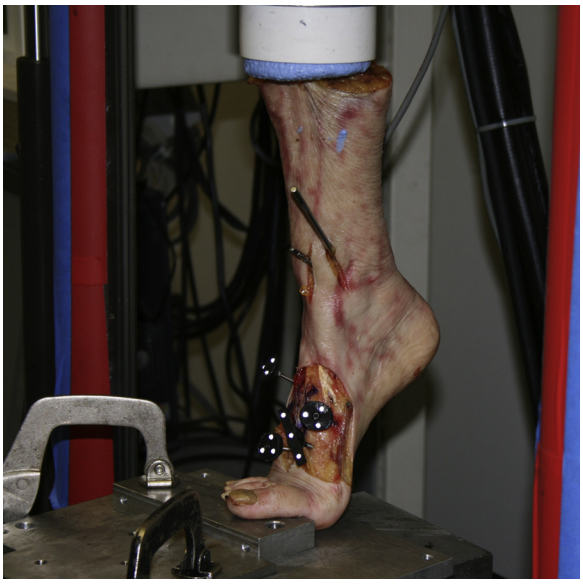

Fig. 1. A right foot specimen mounted onto the MTS machine. The ankle and subtalar joint have been fused with the foot in equinus. Steinmann pins used to strengthen the fusion are visible.

Ghost points were marked using a pointer and then digitized by a motion capture system (SMART Capture System, eMotion, Padua, Italy) that locates the ghost points relative to their respective marker triads inserted into the cuneiforms and metatarsals. The motion capture system has an accuracy of 0.1 mm of displacement. During testing, motion of the rigid bodies tracked by the motion capture system can be related to the points of interest identified by the ghost points. Using this method, the 3-dimensional displacements between the base of the first and second metatarsal bases and between the medial and intermediate cuneiforms was calculated. These displacements were measured in the laboratory (global) reference frame, which does not coincide with the anatomical reference frame. For this reason, we report resultant displacements, the dominant component of which was usually in the medial–lateral direction.

Each specimen was mounted to the MTS testing machine in a loading frame with the distal metatarsals resting on a platform (Fig. 1). The great toe and second toe were placed on a small block to prevent the foot sliding excessively during loading. A simulated axial weightbearing load of 343 N was applied through the tibia to model approximately 50% partial weightbearing [30] and held for 30 s before motion capture to allow the soft tissues to creep. Similar loads were used in a previous similar cadaveric biomechanical study [31].

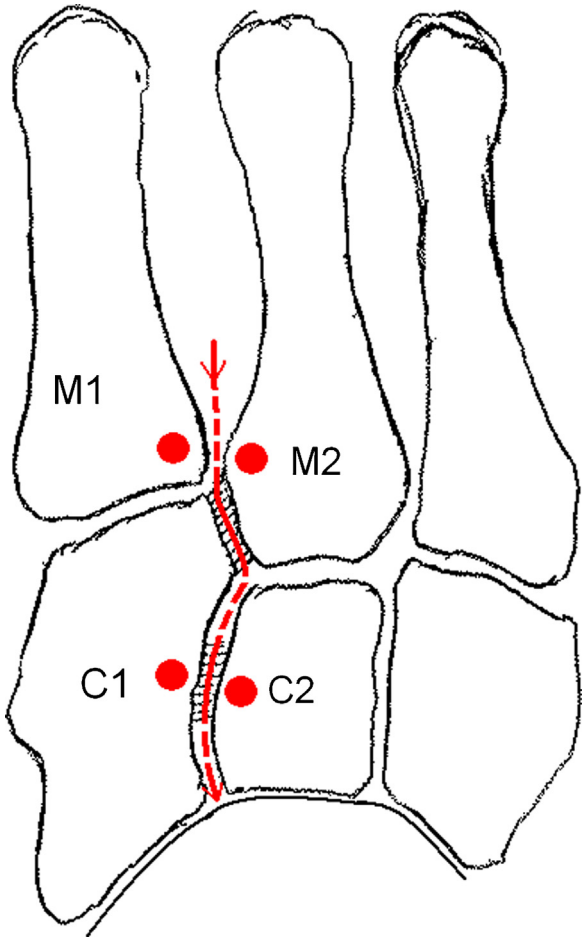

Fig. 2. Diagram to show the midfoot. The red line represents the ligaments sectioned (Lisfranc and medial–intermediate cuneiform ligaments) after testing of each specimen in the intact state. The dots on the metatarsal bases and medial–intermediate cuneiforms represent the position of the ghost markers that allowed diastasis to be recorded at these joints using motion capture. M1, metatarsal 1; M2, metatarsal 2; C1, medial cuneiform; C2, intermediate cuneiform. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)