Locked Versus Nonlocked Plate Fixation for First MTP Arthrodesis: A Biomechanical Investigation

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Summary
We simulated fusion of the first metatarsophalangeal (MTP) joint with a compression screw and either a nonlocked or locked dorsal plate in nine paired cadaveric specimens. All underwent cyclical fatigue endurance testing and load to failure testing. Locked plates demonstrated higher stiffness values during the load to failure testing and less plantar gapping during fatigue endurance testing. Locked plates provide a more rigid construct for first MTP arthrodesis, which may impact fusion rates.

Introduction
First metatarsophalangeal (MTP) arthrodesis is a common procedure for various painful conditions of the great toe. Dorsal plate fixation is among the most popular treatment methods for this indication. Recently, locking plates have been used for this and other procedures in the foot with varying success rates. The biomechanical advantages and disadvantages of these plates are currently unknown. The purpose of this study is to compare the fatigue strength and load to failure of locked and nonlocked plates used for hallux MTP fusion.

Methods
The first ray was dissected from nine matched pairs of fresh frozen cadaveric feet, preserving ligamentous attachments. The MTP joint of each specimen was prepared with cup and cone reamers, and then fixed with a lag screw. One specimen from each pair was instrumented with a locked stainless steel dorsal plate, and the other with a nonlocked stainless steel dorsal plate, assigned randomly. Each specimen was loaded in a cantilever fashion to 90N at a rate of 3 Hz for a total of 250,000 cycles (this approximates six weeks of post operative weight bearing in a hard sole shoe). The amount of plantar MTP gap was recorded at one, ten, 100, 1,000, 10,000, 100,000, 200,000, and 250,000 cycles using a calibrated extensometer. Testing was terminated early if the plantar MTP gap reached 5mm. Load to failure testing was performed for all specimens that endured the entire cyclical loading. Stiffness (N/mm) was calculated from the final load to failure test. Bone Mineral Density (BMD) was determined for all specimens using dual-energy x-ray absorptiometry (DEXA). Anteroposterior and lateral radiographs were obtained pre- and post-testing to evaluate for hardware failure or loss of fixation. Paired t–test and Wilcoxon Signed Rank Test were used for group comparisons.
Results
Mean stiffness was significantly greater in the locked plate group compared to nonlocked plate group (70.32±11.55 N/mm vs. 43.07±5.53 N/mm, respectively; p = 0.02). The locked plate group demonstrated significantly less plantar gapping during fatigue endurance testing from 10,000 cycles through 250,000 cycles compared to nonlocked plates (p<0.05).

Conclusions
Our results suggest that, compared to nonlocked plates, locked hallux MTP arthrodesis plates exhibit significantly greater stiffness in load to failure testing and significantly less plantar gapping after 10,000 cycles of fatigue endurance testing. Low BMD is associated with early failure. We previously reported a trend toward a higher nonunion rate in patients treated with titanium locked plates compared to stainless steel nonlocked plates for hallux MTP fusion. It is possible that the stiffness of locked plates may produce insufficient interfragmentary motion that could be detrimental to bony healing if there is inadequate bony contact when the locked implant is applied. The optimal dorsal plate construct would allow adequate interfragmentary compression and bony contact, while providing sufficient stiffness to allow early protected weight-bearing without compromising fixation. As the use of locked plate technology is becoming increasingly common for arthrodesis and fracture fixation in the foot, an understanding of the biomechanical characteristics of these implants is paramount to directing their indications and clinical use.

![Fatigue Endurance Testing](image)

*Figure 1. Plantar gapping at MTP joint during fatigue testing. * = statistically significant to p<0.05*