# Adjunct Sesamoid Fixation to Strengthen First Metatarsophalangeal Joint Arthrodesis

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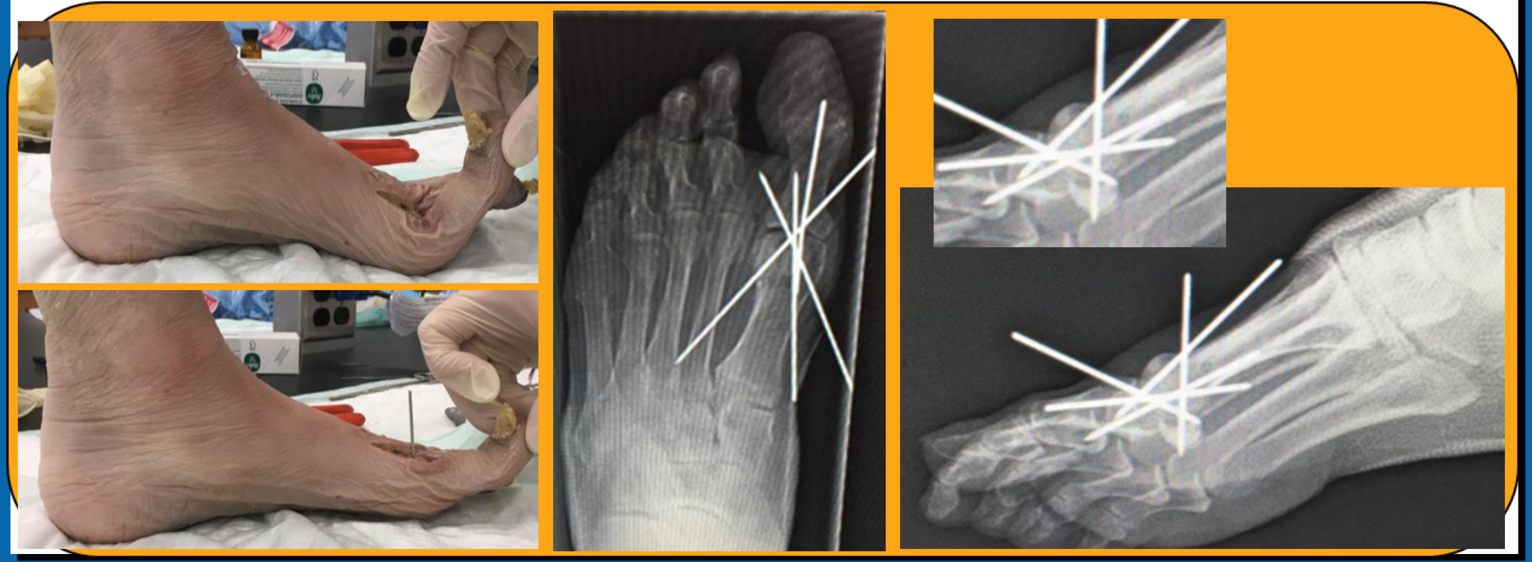
## Abstract

The nonunion rate following 1st MTP arthrodesis regardless of fixation has been found to be, on average, less than 6%. Stronger constructs have been utilized to help decrease the risk of non-unions and has allowed for early weight bearing with many patient benefits. Early weight bearing increases patient compliance, lessens adjacent joint stiffness, and decreases the risk of deep vein thrombosis. The purpose of our study was to investigate the effect of sesamoid fixation during 1st MPJ arthrodesis. The sesamoids serve as a fulcrum for the flexor hallucis brevis muscle, providing a greater force of motion in the toe-off stance of the gait cycle. Excision of a sesamoid has proven to reduce this force. The addition of a K-wire to fixate the tibial sesamoid theoretically creates a static fulcrum for the FHB muscle/tendon unit, thereby acting as a force to resist dorsiflexion of the great toe during 1st MPJ arthrodesis procedures.

Overall, this study has found that there is a correlation between the use of an additional K-wire to fixate the tibial sesamoid and an increased amount of force that the joint could withstand. This could provide a cost effective option for arthrodesis while improving patient outcomes by allowing earlier weight bearing.

## Introduction

Hallux rigidus describes a degenerative condition of the first metatarsophalangeal (MTP) joint that results in a progressive loss of cartilage between the metatarsal and proximal phalanx. Arthritis of 1st MTP joint causes pain, swelling, and can even alter normal ambulation. The use of arthrodesis for definitive treatment of degenerative joint disease offers patients a stable, predictable procedure to relieve their painful symptoms (1). Regardless of fixation method, the procedure carries a low incidence of nonunion (2). However, with the increased availability of dorsally applied locking plates and screws, surgeons have chosen to increase fixation strength in a race for early weight bearing postoperatively (3). The known benefits of early ambulation include lessened adjacent joint stiffness, decreased risk of venous thromboembolism as well as increased patient compliance and satisfaction. Nonetheless, the increased strength of fixation is not without consequence (4). The added costs of specially designed locking plates and screws, typically used in osteoporotic bone, can pile on to the already exorbitant amount of healthcare costs (5,6). Common joint fixation techniques ignore the body's own inherent mechanical advantage. Both the tibial and fibular sesamoids are embedded in the flexor halluces brevis (FHB) tendon, which resists dorsiflexion of the great toe, thereby increasing fixation strength. This anatomic design allows the joint to propel the foot off the ground in the last instances of the "push off" phase of gait. This is analogous to the patella assisted dorsiflexion at the knee but on a smaller scale. To our knowledge, no study has examined the enhanced strength that tibial sesamoid fixation provided the surgical construct by simply neutralizing the lever arm of the FHB.



## Rationale

Augmented strength to the 1st MTP construct has the potential to reduce nonunion rates, reduce surgical costs, and allow early weight bearing in the appropriate patients. Our study aim was to investigate the added strength of sesamoid fixation compared to commonly used arthrodesis methods in the 1st MTP.

## Materials and Methods

In order to determine the fixation strength required for early ambulation, fifteen fresh frozen cadaveric limbs were selected as models for the 1st MTP joint after they were properly dissected and the joints were fixated with their respective devices. A single surgeon, the senior author (AB), performed arthrodesis fixation of all the joints to reduce procedure variability among the study groups. The limbs were equally divided into three groups (A, B, and C) with five limbs per group. The following describes the experimental groups:

**Group A:** Four Kirschner wires placed across the joint in a locking position (n=5)
**Group B:** Four Kirschner wires places across the joint in a locking position, with an additional K-wire placed perpendicular from dorsal to plantar bisecting the tibial sesamoid (n=5)
**Group C:** Interfragmentary screw and locking plate fixation (n=5)

Following the placement, the fixation position was verified by utilizing plain film radiographs both standard anterior-posterior as well as lateral views. The first ray was then dissected through the 1st intermetatarsal space to the level of the 1st metatarsal cuneiform joint. Care was taken to maintain the pertinent soft tissue structures including the FHB. The limbs were then embedded into a PVC pipe construct using Bondo adhesive to allow biomechanical testing.

The limbs were then axially loaded at the great toe joint using the MTS® 858 Mini Bionix (MTS Systems, Eden Prairie, MN). Loading of the limbs occurred at a rate 90 Newtons at a rate of 5 Hz, focusing on loading the hallux distal to the MTP joint on the load cell to simulate propulsion until clinical failure was reached. Clinical failure was defined as failure of the limb, failure of the hardware, or the maximum load of the cell achieved when gapping of the joint fixation occurred. The load at clinical failure was recorded to compare the relative strengths among the groups.

**Figure 1.** Group A arthrodesis – 4 K-wires used in a locking position
**Figure 2.** Group B arthrodesis – 4 K-wires used in a locking position with an additional K-wire bisecting the tibial sesamoid
**Figure 3.** Group C arthrodesis – Interfragmentary screw and locking plate

## Results

Descriptive and inferential statistics were performed using a one-way ANOVA with a significance point established at $p<0.05$. Statistical analysis was performed using SPSS Statistics version 22 (IBM, Armonk, NY)
The average maximum loads at the point of clinical failure are demonstrated in Figures 4, with the exact values as follows:

| Group | Average maximum load | Standard deviation |
|---|---|---|
| A | 72.9 N | 9.5 N |
| B | 101.7 N | 18.4 N |
| C | 153.5 N | 18.9 N |

In our study, there was no statistical significance among group A and group B. The mean maximum load before failure was 72.9 Netwons (N) in group A and 101.7 N in group B. There was a mean increase of 28.8 N for fixation strength with the addition of one single Kirschner wire inserted into the tibial sesamoid. The mean maximal load to failure for the locking plate was 153.5 N which was significant ($p=0.004$) when compared to groups A and B. The locking plate was the strongest of the three fixation methods tested.

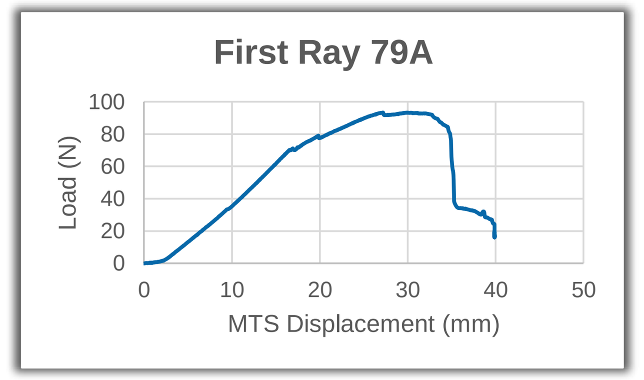



**Figure 4.** Point of failure determined for limb in Group A

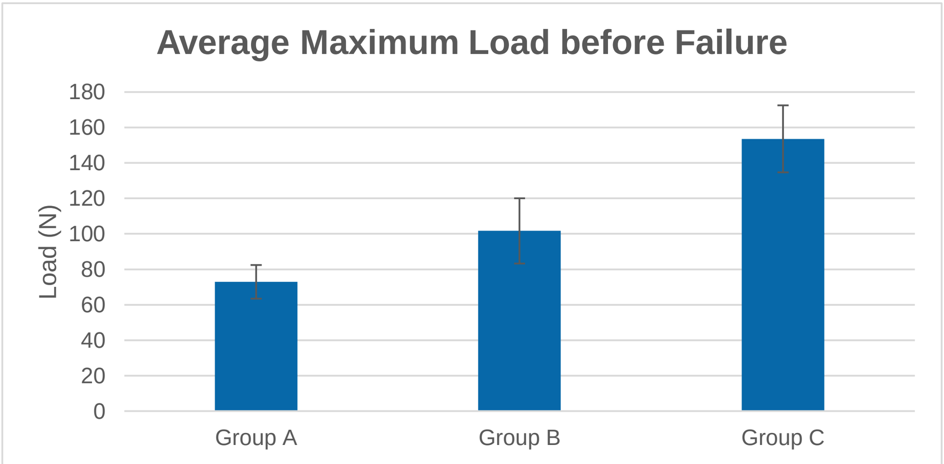



**Figure 5.** Group A = Four Kirschner Wire Fixation
Group B = Five Kirschner Wire Fixation
Group C = Plate and Screw Fixation

**Due to its large size, the data from one limb from Group A was excluded. The limb could not be properly assessed because the 1st MTP joint could not be properly loaded. In addition, one specimen from Group B and one from Group C were excluded due to multiple data points on the MTS load displacement curve and no obvious corresponding visual failure point.*

## Discussion

This study demonstrated the addition of a single Kirschner wire inserted into the tibial sesamoid can provide enhanced strength to the 1st MTP joint arthrodesis construct. Storts and Camasta, concurrently proposed the question of sesamoid fixation in 1st MTP arthrodesis publication due to the adherent increase in stability (7). By neutralizing the lever arm of the FHB by simple sesamoid fixation, our study showed a 28.8 N increase in load to failure. According to Campbell et al., approximately 25% of an individual's body weight can be supported at the 1st MTP joint (8). This simple technique addition will allow patients to withstand a greater force to allow early postoperative weightbearing (9). Our study also demonstrates the further benefit of augment fixation strength in the overall cost savings of the different methods.

Limitations of this study are inherent in cadaveric studies. The joint was focally loaded to failure without simulating true weight bearing. The testing construct was prone to failure at the bondo-cadaver ray interface. The motion at the adhesive demonstrates that the load to failure of each surgical fixation method may be viewed as minimums for future studies. Also in future studies, we recommended that direct screw fixation to the cadaveric bone be utilized for the test model. Two samples that had multiple date points on the load displacement curve and no obvious corresponding visual failure point had to be removed which effected the data. One sample ray was too large to be tested uniformly at the same point as the rest of the study group. Overall this study had a small sample size that could have not truly represented a surgical fixation model.

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