Geometric Comparison of Second Metatarsal Shortening Osteotomy Variations Using 3D Printed Patient-Specific Models

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Introduction/Purpose: Second metatarsal shortening osteotomy is frequently used in the treatment of metatarsalgia and aims to decrease metatarsophalangeal joint and plantar pressures. Although various proximal, midshaft, and distal metatarsal osteotomy methods have been described for surgical treatment of metatarsalgia, to our knowledge no studies quantitatively compared their resulting geometric corrections. The purpose of our study was to investigate how much each osteotomy variation changed the length of the metatarsal as well as the height and relative location of the metatarsal head (MH) itself.

Methods: Following Institutional Review Board approval, three-dimensional computer models of second metatarsals of 5 deidentified clinic patients were extracted from CT scans using Mimics software. Fixed points were plotted on the printed models and a 3D coordinate digitizing arm (Microscribe) was used for precisely determining the 3D (x-y-z) coordinates of each point before and after the osteotomies. Six variations of second metatarsal osteotomies were performed using microsagittal saw and fixed using a 2.4 mm cannulated screw. The following osteotomy variations were performed with 3 and 5 mm translation or wedge resection for each patient model: (1) Classic Weil osteotomy performed at 15° and 25° to the plantar surface; (2) Classic Weil osteotomy performed at 15° and 25° using a double saw blade technique; (3) Classic Weil osteotomy performed at 25° and then a parallel block of 3 or 5mm was removed; (4) Distal closing wedge osteotomy of the MH at 25°; (5) Proximal closing wedge osteotomy of the MH made at 45° removing a 3 and 5mm wedge; (6) 45 degree oblique, midshaft, metatarsal osteotomy with 3 and 5mm of translation. The change in the length of the metatarsal, and vertical and medio-lateral translation of the metatarsal head was calculated then normalized by the osteotomy translation distance. A general linear model with correlated errors and Bonferroni correction was used to assess differences between osteotomies.

Results: The maximum metatarsal length shortening per millimeter translation was observed in osteotomy 3- 5mm block (2.6mm STD=2.1), while osteotomy 1- 15° caused the least (1.1mm STD=0.6). Maximum dorsiflexion of the MH occurred with osteotomy 1- 5mm wedge, 13.2mm (STD= 4.9mm) and minimum with osteotomy 1 - 25°, 0.5mm (STD= 1.4mm). No MH plantarflexion was noted with any of the osteotomies. The oblique midshaft osteotomies caused lateral translation of the metatarsal head significantly different from the controls (P <0.05) although not statistically different from one another (2.4mm vs 4.3mm).

Conclusion: Discussion: Our data shows maximal change in length/millimeter translation by performing a classic Weil osteotomy at 25° to the plantar surface of the foot, 5mm block resection and then translating 4mm. This osteotomy also caused the most effective dorsal translation of the MH, thereby making it the most effective osteotomy in terms of affecting both length and MH vertical orientation. Should dorsiflexion of the MH be the surgeon’s only goal, then the proximal closing wedge osteotomy had the greatest impact while minimally changing overall length. With this knowledge, surgeons can tailor operations based on the direction and degree of correction needed to be achieved.
Table 1 – Charts showing metatarsal shortening per mm. shift and metatarsal head dorsal translation achieved with each osteotomy variation.