The Role of Passive Plantar Flexion in Floating Toes Following Weil Osteotomy

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Floating toes are a common complication following Weil osteotomy. The toes are passively plantarflexed via the windlass mechanism, which may play a role in floating toe. Five cadaver lower limb specimens were loaded on a custom frame and 3 different interventions were tested, including control group, Weil osteotomy group, and Weil osteotomy plus plantar plate-shortening group. The extensor tendon to the second toe was loaded with 20 Newtons of tension during the trials, and non–weight-bearing and simulated weight-bearing radiographs were taken to measure the metatarsophalangeal joint extension angle. The extension angle passively plantarflexed 11.20° ± 3.43° in the control group, 0.40° ± 0.89° in the Weil osteotomy group, and 8.00° ± 1.41° in the Weil osteotomy plus plantar plate–shortening group. Comparison of the amount of passive plantarflexion between the groups revealed statistically significant changes between the control and Weil osteotomy groups (P = .0001), and the Weil osteotomy compared with the Weil osteotomy plus plantar plate-shortening (P < .0001); whereas no statistically significant difference was observed between the control and Weil osteotomy plus plantar plate–shortening groups (P = .0893). These results support the idea that the toes undergo passive plantar flexion due to the windlass mechanism, which is dampened by the Weil osteotomy. Dampening of the windlass mechanism may be responsible for floating toe following a Weil osteotomy. Level of Clinical Evidence: 5 (The Journal of Foot & Ankle Surgery 47(6):520–526, 2008)

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The plantar plate and collateral ligaments are commonly considered the primary stabilizers of the lesser metatarsophalangeal (MTP) joints (1–4). Although the plantar plate has been statistically shown to significantly restrain dorsal dislocation of the second MTP joint (2, 3), its role as a dynamic stabilizer of the toe is not commonly addressed. Because plantar plate rupture may lead to an extension deformity of the MTP joint as seen in claw, hammer, and floating toes (5–9), it is hypothesized that sectioning the plate will have a similar effect.

The distal attachment of the plantar plate is onto the proximal phalanx and most of its proximal attachment is to a slip of plantar fascia forming a plantar fascia/plate complex. There is only a tenuous connection to the metatarsal in the form of a synovial fold (5, 6), suggesting that the plantar plate cannot act as a ligament and thus there must be an alternative method by which the MTP joint is stabilized. Given the anatomic connection between the toes and the plantar plate, it is the belief of the authors that the plantar fascia plays a considerable role in the function of the toes.

Weil osteotomies have demonstrated effectiveness in treating lesser metatarsal overload by off-loading the lesser MTP joints (10–15). There is, however, a consistently high prevalence of floating toe following Weil osteotomy, and published reports describe the range to be 20% to 68% (10–13). It should be noted that the Weil osteotomy, even when resulting in the development of a floating toe, consistently relieves metatarsalgia and other digital and metatarsal symptoms (10–13). In fact, the Weil osteotomy is considered by many to be a proven procedure that is effective in relieving pain, has fewer complications than a Helal osteotomy, and rarely results in a metatarsal nonunion (12, 14–16). Interestingly, the development of a transfer lesion following this procedure is less common than is floating toe (10, 11, 13, 15, 16).

Some theories on the etiology of floating toe following a Weil osteotomy concentrate on excessive dorsiflexion of the MTP joint (16). However, the authors, as well as others (17), consider floating toe to result from a lack of plantarflexion with weight bearing, rather than excessive dorsiflexion. Hicks (18) proposed that the toes are actively plantarflexed in late midstance by the flexors and passively by the windlass mechanism. McGlamry (17) stated, ". . . floating toe is caused by a failure of the flexor mechanism. This usually involves a slip of the plantar fascia that fails to load with weight bearing." It is generally understood that tension

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in the plantar fascia is critical to the function of the plantar fascia (windlass mechanism). As such, shortening the metatarsal could reduce tension in the plantar fascia and possibly cause a dampening of the windlass mechanism. Laxity in the plantar fascia, or dampening of the windlass mechanism, may be responsible for the development of a floating toe following Weil osteotomy.

The purpose of this study was to determine if the passive plantarflexory mechanism of the toe was dampened by a Weil osteotomy. It was further hypothesized that if the loss of tension in the plantar fascia were observed to be responsible for the development of a floating toe, then restoration of tension, by means of shortening the plantar plate, would result in a measurable degree of passive MTP joint plantarflexion.

Materials and Methods

Specimen Acquisition and Preparation

Five fresh-frozen cadaveric lower limb specimens, ranging from 62 to 73 years of age at the time of death, were obtained from the Department of Biological Services at the University of Washington. All of the specimens had intact foot and ankle joints and were without visible deformity. The specimens were preserved by wet towel wrappings and deep frozen to –20°C. Before testing, each specimen was completely thawed to room temperature, and dissection of the second ray was carried down to the MTP joint, with care being paid to preserve the long extensor tendon. The metatarsal was exposed at a level approximately 1 cm proximal to the MTP joint, and the collateral ligaments of the MTP joint were released to gain access to the metatarsal head. The base of the proximal phalanx, just distal to the MTP joint, was also exposed. A plantar intermetatarsal incision was then made lateral to the second metatarsal, and dissection was carried down to the level of the long flexor sheath. The sheath was incised in a linear fashion to allow retraction of the tendons and gain full exposure to the plantar plate. Proximally, the Achilles and extensor digitorum longus tendons were isolated and a Dacron (DuPont, Wilmington, DE) cord was used to trap them in order to apply tensile loads, allowing manipulation at the ankle and second toe by means of a pneumatic actuator.

Marker Placement

Radiopaque markers were placed in the proximal phalanx and metatarsal head, using a 0.062-inch Kirschner wire (K-wire) to drill a canal in the metatarsal approximately 15 mm proximal to the MTP joint, and in the proximal phalanx approximately 5 mm distal to the joint. Care was taken to orient the canals perpendicular to the long axis of each bone, and the plantar cortex was preserved at each site. A 0.054-inch K-wire was then manually inserted into each canal and cut flush to the dorsal cortex, thereby leaving a 3- to 5-mm linear marker for radiographic identification of MTP joint movement.

Loading Frame

All of the specimens were mounted and tested on a custom loading frame designed by BioConcepts, Inc., Seattle, Washington, and fabricated by Advanced Biomedical, Inc., Oakland, California. The frame was designed so that an axial load could be applied through a polycarbonate rod to the tibia and fibula via a central actuator that allowed for near physiologic loading. Smaller actuators surrounded the central actuator, and these were used to apply tensile loads through the extrinsic tendons. The testing platform was covered with a nonskid surface to prevent specimen slippage during mechanical loading.

Testing Trials

A total of 3 trials were run for each of the 5 specimens, including a control, a Weil osteotomy, and a Weil osteotomy combined with shortening of the plantar plate. In the control group, non–weight-bearing and weight-bearing lateral radiographs were taken for each trial. The non–weight-bearing radiographs were taken with the foot at 90° to the leg, under no axial load and without tension in the Achilles tendon, while 20 Newtons of tension was placed on the long extensor tendon in order to reorient the foot in the same alignment as in the weight-bearing views. Weight-bearing radiographs were taken with loads of 400 Newtons placed axially down the tibia and 250 Newtons on the Achilles tendon.

A Weil osteotomy was then performed on the second metatarsal, approximately 1 mm from the dorsal edge of the cartilage. Care was taken to ensure that the saw blade was parallel to the weight-bearing surface of the foot. The capital fragment was then translated proximally for a distance of 5 mm, after which the fragment was fixated with two 0.054-inch threaded K-wires. The dorsal overhang, caused by the proximal translation of the capital fragment, was removed. Non–weight-bearing and weight-bearing lateral radiographs were then taken in the fashion previously described for the control model.

Following testing of the Weil osteotomy model, a #15 scalpel blade was used to remove a 3-mm wedge of tissue from the plantar plate. The proximal and distal margins of the plantar plate were then reapproximated using 2-0 nylon sutures, thereby shortening it. In a fashion similar to that described for the control and Weil osteotomy models, the plantar plate–shortening model was then tested and the lateral radiographs were obtained.