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Sequential Dissection for Exposure of the Second Metatarsophalangeal Joint

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ABSTRACT

Background: **Instability of the second metatarsophalangeal (MTP) joint is relatively common, and although the anatomy of the joint has been well described and plantar plate pathology has been identified, little has been written about its exposure and repair. The goal of this study was to elucidate the necessary dissection to expose and potentially repair the lesions of the plantar plate through a dorsal approach.** ***Materials and Methods:*** **Sequential dorsal dissection of the second MTP joint was carried out in eight cadaveric specimens. After each step, measurements were obtained using fluoroscopic imaging and digital photography to determine the amount of exposure of the plantar plate gained by each step.** ***Results:*** **Dorsal capsulotomy of the second MTP joint with collateral ligament release off of the proximal phalanx base, then combined with a subcapital oblique metatarsal osteotomy provided on average 8 and 8.5 mm of exposure of the plantar plate as measured by digital photography and fluoroscopy, respectively. Minimal exposure was gained by releasing the collateral ligaments from the metatarsal head or elevating the plantar plate off of the plantar metatarsal head.** ***Conclusion:*** **Exposure of the plantar plate can be obtained by releasing the collateral ligaments off of the proximal phalanx and performing a subcapital oblique osteotomy.** ***Clinical Relevance:*** **Minimizing the risk of disrupting the blood supply to the metatarsal head may be possible by avoiding collateral ligament or plantar plate release.**

Key Words: Metatarsophalangeal Joint; Crossover Toe; Plantar Plate

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INTRODUCTION

Instability of the second toe at the metatarsophalangeal (MTP) joint is a common occurrence.[5,8,13] Several etiologies have been described for such pathology and include trauma,[4,6,10] synovitis or inflammatory conditions.[10,22,23,26] With chronic synovitis, deterioration of the collateral ligaments and joint capsule may lead to instability.[7] High fashion footwear may lead to chronic hyperextension of the MTP joint, causing elongation or attenuation of the plantar plate, destabilizing the joint.[7] Brunet and Tubin reported on traumatic lesser toe MTP joint injuries and found that in all cases the plantar plate and capsule of the joint had been damaged.[6] Cases of plantar capsule attenuation with subsequent dislocation following intra-articular steroid injection have been described as well.[4,30] Most commonly, instability occurs in older individuals with no history of trauma or steroid injection.[10]

Pathology in the plantar plate has been observed in cases of second MTP joint instability,[3,4,12,15,17,29,33] and in the majority of these reports, pathology has been observed near the attachment distally to the base of the proximal phalanx.[3,12,15,17,29,33] Chronic capsular microtrauma and synovitis may be exacerbated by a long second toe creating increased stress during walking.[7,19] Ultimately, this can result in attenuation or rupture of the plantar plate.

Numerous surgical techniques have been developed to treat instability of the second MTP joint, most of which indirectly treat the capsular pathology. These include soft tissue joint arthroplasty with capsular releases and reefing of the elongated collateral ligaments, extensor tenotomy or lengthening, flexor tendon transfer, extensor tendon transfer, and osseous decompression with proximal phalangectomy, arthroplasty of the metatarsal head or shortening osteotomy of the metatarsal.[1,7,9,10,8,15,16,18,32] There are few reports of procedures that directly address plantar pathology by direct repair.[3,4,15,17,29]

Of the reports of MTP plantar plate repair, to our knowledge only Gregg et al.[17] have published a technique performed through a dorsal approach. The aim of our study was to examine the dorsal exposure and identify the access

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gained to the plantar plate through sequential sectioning of the restraining structures. Additionally, we wished to identify whether or not performing a oblique osteotomy[32] of the distal metatarsal provided additional exposure of the plantar plate that would facilitate repair through a dorsal exposure. Ideally, this study would allow us to determine the minimal amount of sectioning required to expose the plantar plate through a dorsal approach to allow for repair.

MATERIALS AND METHODS

Eight fresh frozen below the knee amputated cadaveric specimens were obtained from an accredited tissue bank (LifeLegacy Foundation, Tuscon, AZ). The specimens were examined for restricted range of motion or deformity at the second MTP joint, and all were found to be grossly normal, and none had malalignment of the second MTP joint. Immediately after thawing, dissections were performed on the second MTP joint. In all cases, a dorsal approach was carried out through a 4-cm incision centered over the joint. Extensor tenotomy was performed to expose the dorsal capsule, which was then incised to provide access to the joint. At this point the feet were divided into four groups of two for differential sectioning of structures, with or without a Weil metatarsal osteotomy (Figure 1). In group A ($n = 2$), the collateral ligaments were released from the base of the proximal phalanx, followed by elevation of the plantar plate off of the distal metatarsal using a McGlamry elevator and Weil osteotomy. Group B ($n = 2$) was similar to group A, with the exception that no elevation of the plantar plate from the metatarsal was performed. In group C ($n = 2$), the same procedures were carried out in an identical fashion to group A, except that the collateral ligaments were released from the metatarsal head rather than the base of the proximal phalanx. Lastly, the feet in group D ($n = 2$) underwent the same procedures as C without the elevation of the plantar plate from the metatarsal prior to osteotomy. In cases where a metatarsal osteotomy was performed, the metatarsal head was shifted 4 to 5 mm proximally and the site was temporarily fixed with a 0.045 Kirschner wire.

After each step–extensor tenotomy and dorsal capsular release, collateral ligament release, elevation of the plantar plate from the metatarsal, and Weil osteotomy–the joint was distracted using a modified lamina spreader that had barrels for Kirschner wires, which were placed in the base of the proximal phalanx and distal metatarsal (Figure 2). Each joint was maximally distracted to the point that further pressure from the lamina spreader caused the Kirschner wires to bend rather than cause further joint distraction. The plantar plate was then inspected and the amount of exposure was determined in two fashions. A digital photograph was taken

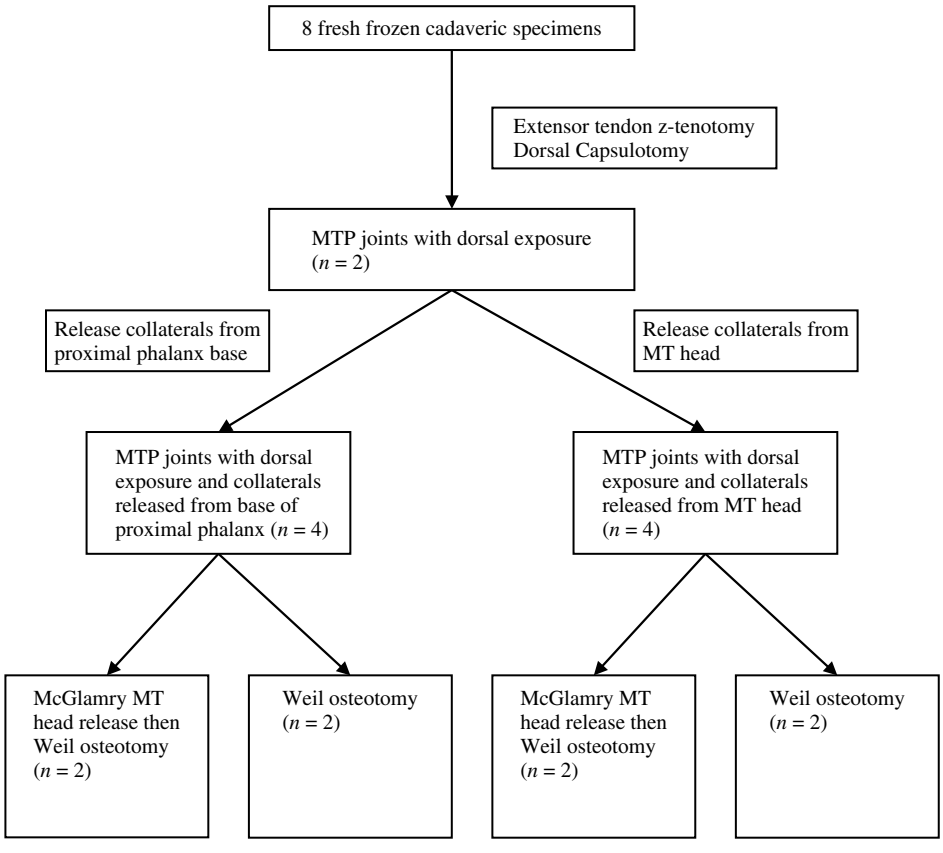

Fig. 1: Flowsheet demonstrating sequential sectioning for exposure of the plantar plate among the four groups of feet.

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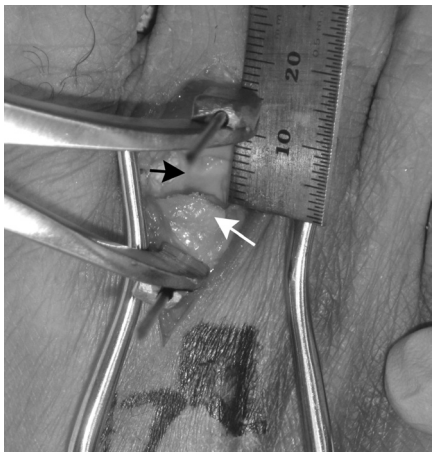

Fig. 2: Digital photograph demonstrating distraction of the second MTP joint with a modified lamina spreader. Depicted here is specimen #2 following release of the collateral ligaments off the proximal phalanx, plantar plate elevation and metatarsal osteotomy. (white arrow – metatarsal head, dark arrow – plantar plate).

with a ruler positioned to allow review and measurement of the dorsal visualization of the plantar plate. Second, a fluoroscopic image was obtained with a standardized radio-opaque marker in place to measure the direct distraction between the base of the proximal phalanx and the metatarsal head (Figure 3). Each foot was placed in a consistent plantigrade position on the image intensifier with the second MTP joint in the center of the field. The images were printed and gap between the metatarsal head and proximal phalanx was measured with a digital slide caliper (catalog # 721 A-6/150; L.S. Starett, Athol, MA), which has a measurement error of 0.03 mm. The known value of the marker was then used to standardize each measurement to reflect actual distraction.

RESULTS

The distraction of the second MTP joint measured both by direct visualization and fluoroscopy increased after each release with one exception. We used digital photography to create a permanent record, which furthermore allowed us to measure the actual visualization of the plantar plate. In foot six, there was a 0.3-mm decrease in measurement of joint space after elevation of the plantar plate from the metatarsal head.

Measurements of distraction obtained using fluoroscopic imaging and digital photograph are listed in Tables 1A and 1B, respectively. Total mean distraction measured fluoroscopically was 9.5 mm for group A, 8.5 mm for group B, 11.2 mm for group C, and 9.0 mm for group D. Total mean distraction as measured by digital photography was 7.5 mm for group A, 8 mm for group B, 9.5 mm for group C, and 7 mm for group D. In general, joint distraction as measured by direct visualization (digital photography) was routinely

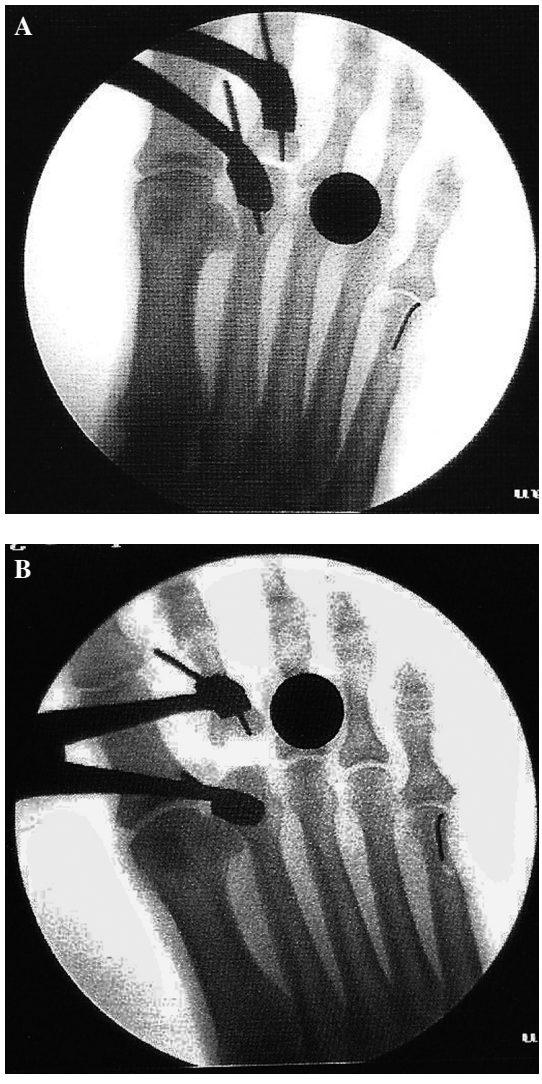

Fig. 3: Fluoroscopic image with calibrated marker in place demonstrating distraction at the MTP joint. A) Specimen #2 after only extensor tenotomy and dorsal capsulotomy. B) Specimen #2 after collateral ligaments released from the proximal phalanx.

less than the distraction demonstrated fluorscopically, likely due to the fact that the thickness of the articular cartilage is not appreciated fluoroscopically.

DISCUSSION

Multiple studies have demonstrated the role of the plantar plate in conjunction with the collateral ligaments in maintaining the stability of the second metatarsophalangeal joint.[2,11,12,15,19,33] The plantar plate functions to resist tensile loads in the longitudinal direction (particularly in dorsiflexion of the joint) as well as to cushion the joint and weightbearing forces.[11,19] It is firmly attached to the base of the proximal phalanx and more loosely attached to the metatarsal neck with a synovial-like appearance.[11,19] However, the plate does maintain stout fibrous proximal attachments to the collateral

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Table 1A: Fluorscopic Measurement of Total Distraction Between Metatarsal Head and Proximal Phalanx Base After Each Step of Exposure (in mm)

Group A			
	Foot 1	**Foot 2**	**Mean**
Dorsal capsulotomy/ET	4.4	2.5	3.5
Collaterals released from prox phalanx	4.6	3.3	4.0
Plantar plate elevation from MT head	6.6	7	6.8
Weil Osteotomy	9.4	9.6	9.5
Group B			
	Foot 3	**Foot 4**	**Mean**
Dorsal capsulotomy/ET	5.1	4.4	4.8
Collaterals released from prox phalanx	5.7	6.4	6.1
Weil Osteotomy	9	7.9	8.5
Group C			
	Foot 5	**Foot 6**	**Mean**
Dorsal capsulotomy/ET	3.8	4.1	4.0
Collaterals released from MT head	6.9	6.3	6.6
Plantar plate elevation from MT head	8.4	6.0	7.2
Weil Osteotomy	13.7	8.6	11.2
Group D			
	Foot 7	**Foot 8**	**Mean**
Dorsal capsulotomy/ET	3.7	5.0	4.4
Collaterals released from MT head	5.4	6.4	5.9
Weil Osteotomy	8.3	9.7	9.0

Table 1B: Measurement of Plantar Plate Exposure After Each Step as Obtained by Digital Photograph

Group A			
	Foot 1	**Foot 2**	**Mean**
Dorsal capsulotomy/ET	3	2	2.5
Collaterals released from prox phalanx	5	3	4.0
Plantar plate elevation from MT head	6	5	5.5
Weil Osteotomy	9	6	7.5
Group B			
	Foot 3	**Foot 4**	**Mean**
Dorsal capsulotomy/ET	3	3	3
Collaterals released from prox phalanx	5	5	5
Weil Osteotomy	7	9	8
Group C			
	Foot 5	**Foot 6**	**Mean**
Dorsal capsulotomy/ET	3	2.5	2.8
Collaterals released from MT head	6	3	4.5
Plantar plate elevation from MT head	7	4	5.5
Weil Osteotomy	10	9	9.5
Group D			
	Foot 7	**Foot 8**	**Mean**
Dorsal capsulotomy/ET	2	2.5	2.3
Collaterals released from MT head	3	4	3.5
Weil Osteotomy	7	7	7

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ligaments and plantar fascia.[11] The lateral sided anatomic structures have been shown to be thicker than those on the medial aspect.[11,19] In addition to resisting tensile loads and cushioning the joint, the plantar plate functions as the central stabilizing structure of the MTP joint through its attachments to multiple ligaments, the plantar fascia and the flexor mechanism.[11]

Although plantar plate pathology has been well described in instability of the second metatarsophalangeal joint,[2–4,11,12,15,17,19,29,33] few reports exist describing procedures that directly address this pathology.[3,4,15,17,29] It is possible to access the plantar plate through a plantar approach by dissecting through the flexor tendon sheath,[3,4,15,29] however, if other pathology in the joint is to be addressed or a metatarsal osteotomy is to be carried out, a second dorsal approach must be performed.

In a cadaveric study, Ford et al.[15] reported that there was a significant increase in dorsal displacement of the toe at the second MTP joint after transecting the plantar plate but that the stability was restored following plantar plate repair, flexor tendon transfer or a combination of the two, with no statistical difference between the repair groups. A similar combined plantar plate repair and flexor tendon transfer was evaluated by Bouche and Heit[4] in a retrospective clinical study of fifteen patients with 16 cases of MTP joint instability. The plantar plate repair was performed through a plantar incision, and the tendon transfer was done through a separate dorsal incision. They reported that in fifteen of sixteen toes, the plantar plate was torn transversely in its midsubstance, with only one case demonstrating a tear near its insertion.

Gregg et al.[17] reported on their results of plantar plate repair in lesser MTP joints with sagittal plane instability, primarily extension deformity. Their dorsal exposure of the plantar plate included extensor tenotomy, collateral ligament release in an unspecified fashion and Weil osteotomy. They did not specify the exact pathology encountered in the plate but suggest that it was either attenuated near the insertion on the proximal phalanx or torn transversely near this insertion. Repair was performed by excising diseased tissue and advancing the plantar plate, securing it to the proximal phalanx base with suture through drill holes.

While the present study is a small cadaveric study lacking sufficient numbers to prove statistical significance, through sequential sectioning of the restraining structures of the second MTP joint, we were able to consistently obtain access to the plantar plate through a dorsal approach. Extensor tenotomy or lengthening and incision of the dorsal capsule are frequently performed in association with dorsal exposure of the MTP joint. We found that after performing these, little access to the plantar plate was gained. Proceeding in a systematic fashion, the next restraining structures are the collateral ligaments.[11,19,31] While osteonecrosis of the first metatarsal head after distal osteotomy in hallux valgus surgery has been reported,[14,20,21,24,25,28] in our own experience, it has been found quite uncommon in the lesser metatarsal heads following surgical intervention. Nonetheless, we do have concern for the vascularity of the metatarsal head when extensive soft tissue dissection is performed in conjunction with an osteotomy and one goal should be to minimize the risk. Petersen[27] found the blood supply to the metatarsal head to arise from branches of the dorsal and plantar metatarsal arteries, with the primary nutrient arteries to the head traversing the cortex of the metaphysis near the capsular insertion. It was noted that these arteries have a close relationship with the origins of the medial and lateral collateral ligaments.

Release of the collateral ligaments offered some improvement in exposure of the plantar plate over merely dorsal release of the joint, but we did not find any difference in the access whether they were released from the metatarsal head or the proximal phalanx. Although Petersen et al.[27] found little plantar contribution to the blood supply of the metatarsal head, the use of a McGlamry elevator to release the plantar plate off of the metatarsal head may also disrupt some of the medial and lateral blood supply. In these dissections, we found little improvement of visualization of the plantar plate after use of the McGlamry elevator for plantar release. Lastly, in each foot a Weil osteotomy was performed, the metatarsal head was displaced proximally and temporarily pinned in place prior to distraction. This increased the exposure in all cases, regardless of what releases had been previously performed.

While plantar plate pathology in second toe instability has been demonstrated,[2–4,11,12,15,17,29,33] the exact nature of the pathology has not been consistently reported. This may be due to a broad spectrum of deformities that can exist including medial or lateral deviation, extension deformity and complete dislocation. We suspect that the precise pathology present is directly related to the deformity (i.e., located more laterally in medial deviation or directly plantar in toes that are hyperextended). Further study is planned to further elucidate the pathology in the plantar plate as well as to examine repair techniques. However with this current study, we feel that we have demonstrated the ability to adequately expose the plantar plate through a dorsal transarticular approach to the second MTP joint and have shown that this can be done while limiting dissection around the metatarsal head as much as possible. While it is currently unknown exactly how much exposure is required to repair the plantar plate, we feel that a dorsal approach that includes standard dorsal exposure, collateral ligament release from the proximal phalanx base and Weil osteotomy provides necessary exposure of the plantar plate to accommodate direct examination and potential repair of capsular pathology. In instances where a distal metatarsal osteotomy is not otherwise indicated, a dorsal soft tissue approach in isolation does not offer the same exposure of the plantar plate, and other methods of repair should be considered.

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