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8:45 – 9:40 am

SYMPOSIUM 4:

FOREFOOT

The Dislocated 2

nd MTP Joint:

Is There a Reliable Reconstruction that the Patient and I Both Like?

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The Crossover Toe: Use of Extensor Tendons in Transfer Techniques

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Introduction:

Sagittal or horizontal plane instability of the second toe defines a crossover toe deformity. This entity is separate from clawtoe or hammertoe deformities, the latter being uniplanar. To confuse the issue, a crossover toe may have a hammer or clawtoe component. However, it is critical for the clinician to appreciate the crossover component to the mal-aligned toe, for those treated as routine clawtoes will often result in recurrence of the deformity.

A number of theories as to the etiology of this instability have been proposed; most involve rupture or attenuation of the collateral ligaments and volar plate of the metatarsophalangeal (MP) joint. Deland (1) performed a dissection on cadaveric foot with a true crossover toe in order to better define the pathology. He noted that the plantar plate had subluxed in a dorsal-medial direction, with plate attenuation located at both the proximal phalanx insertion and within the substance of the ligament. The plate was over 50% thinner laterally on the afflicted digit when compared to the 2

nd digit on the opposite extremity. Deland also noted a 20% contracture of the medial collateral ligament on the affected 2

nd toe versus the opposite 2

nd digit. The lateral collateral ligament demonstrated near complete rupture, with only a few bands of the accessory collateral left intact. Finally, the flexor tendons were medially displaced 4mm versus the opposite foot, with dorsal displacement incorporated into this shift. Thus, a rotary component was manifest through the alteration of the tendon axis.

Events leading to destruction of this tissue may be trauma, synovitis secondary to rheumatoid arthritis and other arthritides, constriction from narrow toe box shoes, a long second metatarsal, or hallux valgus deformity. An imbalance between the intrinsic and extrinsic musculature is probably a result of dorsal instability (sagittal plane only), leading to attenuation of the volar plate (2).

Modern pedobarographic studies (3) have shown that the lesser toes play an important role in walking. They exert a pressure equivalent to that of the metatarsal heads. By expanding the weight-
bearing surface, they can relieve pressure under the metatarsal heads and lessen shear forces (4). In addition, the bulky deformity of a crossover toe makes shoe-fitting difficult and uncomfortable. Multiple procedures have been created to attempt to reduce and stabilize the MP joint. These range from soft-tissue reconstructions of the lateral collateral ligaments with the interosseous tendon (5), to tendon transfers from a variety of sources, most commonly the flexor digitorum longus (FDL). Simple soft tissue reconstruction procedures are generally ineffectual in isolation, as compromised or poorly aligned tissues are insufficient to combat the underlying deforming force following repair (Deland, FAI). Such procedures do not involve direct repair of the plantar plate, and thus this attenuated structure remains, allowing recurrence. Tendon transfer techniques attempt to supplement for the deficient plantar plate, while counter-balancing the tendon deformation. For some time, the flexor digitorum longus tendon transfer (Girdlestone-Taylor) was considered the best available option to provide this stabilization. The rigidity of the construct provided absolute stabilization in the plane of the compromised plantar plate, limiting recurrence. However, multiple studies document a persistent significant patient dissatisfaction rate due to stiffness and persistent pain. Most recently, Myerson (8) evaluated 64 feet at an average follow-up of 45 months. Granted, this study was not pure in the sense that variables were introduced with respect to multiple surgical procedures performed on the cohort. However, this is common in many patients with underlying crossover toe deformities, and thus the data must be considered. Following reconstruction, 78% of the involved feet had stability about the surgical digit at the metatarsophalangeal joint. Twenty complications (31%) were sustained in 64 feet. More important, only 45% were very satisfied with the outcome, and 31% had either major reservations or were very unhappy following the procedure. Finally, 37% of patients had a residual dorsiflexion contracture of the metatarsophalangeal joint, and 32% had persistent medial or lateral subluxation of the digit.

Supporting this supposition, Thompson and Deland (9) evaluated the flexor-to-extensor tendon transfer in 13 feet. They employed the vertical stress test as a mechanism to detect instability, with all patients in their study group strongly positive (grade 2 or 3). All patients experienced substantial pain relief, although five had persistent toe pain. Interestingly, postoperative range of motion was strongly correlated to persistent pain. Those patients with an average of 30° of dorsiflexion experienced complete relief, whereas patients with an average of 15° of dorsiflexion had residual pain. One patient had an unsatisfactory result, was dissatisfied, and stated that the procedure would not be undergone again. This patient experienced the greatest amount of stiffness.

In contrast, Boyer (10) suggests that poor patient satisfaction can be combated by achieving successful fusion of the proximal interphalangeal (PIP) joint as a component to the flexor-to-extensor tendon transfer. Their series of 79 toes undergoing FDL tendon transfer found 89% of their patients were satisfied with the procedure and would undergo it again. By leaving their Kirschner wire in place for at least 4 weeks (allowing a fusion of the PIP joint), no toes were elevated at an average of 33 months follow-up. The authors reviewed Myerson’s data, and combining it with their own, found persistent toe elevation lead to patient dissatisfaction, and this elevation was compounded by a non-fused PIP joint. These authors did not support that concept that stiffness of the digit led to increased patient dissatisfaction, though their study does not specifically measure range-of-motion of the digits pre- and post-operatively.

Thus, as an alternative to the flexor digitorum longus tendon transfer procedure, we introduced a transfer technique that utilizes the extensor digitorum brevis (EDB) tendon (11). Our primary goal in describing this procedure was to create an operation that stabilizes the attenuated plantar plate and lateral collateral ligament, while allowing a satisfactory range-of-motion of the digit that enhanced patient satisfaction. This investigation provided a direct comparison of the EDB tendon transfer procedure versus the FDL tendon transfer, though the latter was based on retrospective data. Our hypothesis that the EDB technique would lessen postoperative stiffness proved true, as patients receiving this tendon transfer has an average of 16° greater motion at the MTP joint (highly statistically significant, p = 0.001). Subjectively, the three patients complaining of severe stiffness all had the FDL transfer, and eight other FDL patients complained of mild stiffness, whereas six patients in the EDB group complained of mild stiffness.

The decreased stiffness with the EDB technique may be a concession for decreased stability at the joint. Two of our patients undergoing the EDB transfer had complete dislocation of the MTP joint with crossover of the 2nd to upon the great toe. Both patients developed recurrence of deformity, leading to specific guidelines suggesting limitations of the EDB tendon transfer with this level of deformity. In addition, over the course of the study, the technique was modified to become and end-to-end anastomosis of the brevis tendon, after revision surgery revealed that the prior technique of anchoring the
tendon through a drill-hole into the bone failed with pull-out. It is this technique that will be described shortly.

Similar to Thompson and Deland’s (7) work, we found persistent pain in a number of our patients. Although 22 were pain-free, 8 stated that pain occurred occasionally, and one patient stated that pain was frequent. Patients with FDL transfers had more residual pain in the toe than those undergoing EDB tendon transfer; this difference was statistically significant (p = 0.036). Thompson and Deland related persistent pain to residual lack of motion at the MP joint. This correlates with our results, as patients with the FDL tendon transfer had more pain and less motion than those with the EDB tendon transfer. However, the fact that pain was still present in both populations illustrated the fact that no corrective procedure for this disorder is perfect, and that further modifications may be necessary to develop a more standardized method. One such modification has been recently described in the literature, and that technique provides answers for many of the limitations of the EDB tendon transfer as we initially described it. Thus, we will conclude with the description of the modified technique.

Surgical Technique: EDB tendon transfer

1) A dorsal surgical approach begins just distal to the proximal interphalangeal joint, with a gentle curve at the level of the metatarsophalangeal joint along the lateral border of the metatarsal shaft. This incision extends 5cm proximal to the metatarsophalangeal joint.

2) The dorsal digital nerves are dissected free and avoided to preserve post-operative sensation.

3) The extensor digitorum brevis is defined to the musculotendinous junction proximally, and two stay sutures (3.0 Ethibond) are placed on either side of the proposed sectioning of the tendon. Note that this is a proximal sectioning, near the musculotendinous junction.

4) The tendon is then sectioned.

5) The tendon is defined distally to its insertion. It must be freed to the capsular aponeurosis (extensor hood) proximal to the transverse metatarsal ligament.

6) The medial collateral ligament and dorsal capsule of the metatarsophalangeal joint is sectioned completely. The medial sectioning must extend deep, but must not violate the plantar plate.

7) A McGlamry elevator or gouge is used to strip the volar plate at its origin. This will allow the plate to scar to the metatarsal proximal to its current insertion, assisting with stability.

8) The lateral collateral ligament is examined for rupture. If attenuation is present, redundant tissue is excised at this time. In either case, permanent sutures are placed to repair the lateral collateral ligament (figure of eight) but not tied at this time.

9) Procedures at the proximal interphalangeal joint (minimal resection of the distal condyles and proximal condyles to stimulate a PIP fusion) are performed if a hammertoe is present.

10) The distal EDB tendon is sutured to the plantar-lateral base of the proximal phalanx with permanent suture, to eliminate a rotary force on the toe following transfer.
11) The transverse metatarsal ligament between the 2\textsuperscript{nd} and 3\textsuperscript{rd} metatarsal heads is defined. It is critical not to mistake the more dorsal fascia for the transverse metatarsal ligament, as it does not have the integrity of this structure. A lamina spreader is used to place tension on this ligament.

12) A mixture clamp is placed from proximal to distal deep to the transverse metatarsal ligament.

13) The extensor digitorum brevis tendon is passed from distal to proximal deep to the transverse metatarsal ligament by grasping the stay suture previously placed.

14) The sutures repairing the lateral collateral ligament are tied at this time.

15) The toe is pinned with a 0.062-inch Kirschner across the metatarsophalangeal joint, holding this joint reduced. This pinning is performed to take the tension off the lateral collateral ligament repair by placing the toe in some valgus and plantarflexion.

16) The tendon transfer is now tied end-to-end, completing the anastomosis.

17) The tourniquet is decompressed to assess vascularity of the digit prior to incision closure.

18) The skin is approximated with a layered closure, using 4-0 Monocryl and 4-0 nylon.

19) The pin is removed at 6 weeks post-operatively, and the toe taped into slight valgus for 6 additional weeks.

In addition to the information mentioned above, additional data is available through our initial investigation. The average overall AOFAS score was 84.7 ± 12 (range, 54 to 100 points). The average overall AOFAS score for those undergoing the flexor-to-extensor tendon transfer was 84.85 ± 2.10 (SE), and that for patients undergoing the EDB transfer was 88.22 ± 2.4. The AOFAS score results were then broken down according to preoperative staging in an attempt to determine if this variable created influence. Patients with stage 1 deformity averaged 83.25 ± 6.6, those with stage 2 averaged 84.82 ± 3.2, those with stage 3 averaged 84.5 ± 2.2, and the one patient with stage 4 had a score of 90.00. There were no statistically significant differences among the groups.

Postoperative range of motion at the MP joint was compared for both procedures. Stiffness was greater for the flexor-to-extensor group, with an average of 62.22 ± 2.8 of combined dorsiflexion and plantarflexion. For the EDB transfer group, combined motion averaged 78.44 ± 3.6. This difference was highly significant (p = 0.001).
Following description of this procedure in 1999, it became accepted as an alternative to the flexor-to-extensor tendon transfer for crossover toe correction. Like any procedure, however, technical complaints from surgeons performing the procedure were noted. Most commonly, surgeons found difficulty in performing and end-to-end anastomosis with the extensor digitorum brevis tendon due to the tension created by the increased distance required by the rerouting. In addition, surgeon dissatisfaction with the rotary force created by the anatomic dorsal insertion of the extensor digitorum brevis tendon created supination of the toe in the post-operative period. As noted in point 10 above, I have modified the initial description of the technique by suturing the distal portion of the tendon inferiorly (to the plantar-lateral portion of the capsule of the proximal phalanx) which changes the axis of pull and eliminates the supination force. However, this does not address the tendon on the anastomosis, which remains present.

Lui (12) has described a modification of the extensor digitorum brevis tendon transfer technique that appropriately addresses surgeon criticisms. This technique incorporates the extensor digitorum longus tendon into the transfer, which allows the required length to perform a side-to-side anastomosis, and creates a better route for the transfer by passing the tendon through a drill-hole in the base of the proximal phalanx. Finally, there is little concern for adding the extensor digitorum longus into the transfer, as this tendon is normally lengthened as a portion of any crossover toe correction procedure due to its inherent contracture.

**Surgical Technique: EDB/EDL tendon transfer**

1) The surgical approach is similar. The authors describe a lazy-S incision laterally based and extending 5cm proximal to the metatarsophalangeal joint.

2) The extensor digitorum longus tendon is lengthened in a standard Z-lengthening technique, though the lengthening is done through very long limbs.

3) The extensor digitorum brevis tendon is sectioned at the distal metatarsal level.
4) The metatarsophalangeal joint is addressed identically to that described above (points 6, 7, 8).

5) A transverse bone tunnel is made through the base of the proximal phalanx, just inferior to the midline separating the longitudinal axis of the phalanx. This tunnel should not be placed completely plantar, as that placement will result in a hyperextension deformity of the MTP joint. As is obvious, if the tunnel is placed dorsal to the midline, a supination deformity will result. The diameter of the tunnel is 2.5mm. (*Haddad modification:* if a Kirschner wire is to be used for the pinning (recommended), place the K-wire to the base of the proximal phalanx prior to drilling the tunnel. This will prevent the K-wire from penetrating the tunnel and violating the transferred tendon).

6) The distal limb of the EDL tendon is passed from medial-to-lateral through the tunnel. A tendon passer may be used, facilitated by a Krakow suture placed through the distal limb.

7) The EDL tendon is then passed from distal-to-proximal deep to the transverse metatarsal ligament.
8) The Kirschner wire is then advanced across the metatarsophalangeal joint, with the toe held in a reduced position.

9) The distal stump of the extensor digitorum longus tendon is then easily sutured to the proximal stump of the extensor digitorum brevis tendon, facilitated by the long limb initially created through the Z-lengthening procedure.

10) The EDL proximal limb is then sutured to the EDB distal stump, re-establishing the extension power of the digit. Again, sufficient tendon is present to complete this second transfer by the long limbs of the EDL initially created.

As this article was presented as a technique tip, no follow-up data was presented. However, I now utilize this modification in all circumstances requiring the EDB tendon transfer for a crossover toe, and it lives up to its promise of facilitating the operation. A clinical follow-up series is in progress, and the data will be presented when available.

Complications of all lesser toe procedures involve necrosis of the digit, especially in circumstances where the pre-operative deformity is severe and long-standing. The surgeon must perform careful dissection to avoid vascular violation, and release the tourniquet well in advance of incision closure to ensure adequate vascular supply to the digit. Similarly, digital numbness can be avoided by careful dissection and soft tissue handling.

References:
8) Myerson MS, Jung HG. The role of toe flexor-to-extensor transfer in correcting metatarsophalangeal joint instability of the second toe. Foot Ankle Int. 2005 Sep;26(9):675-9.

MTP Plantar Plate Direct Reparation

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The Plantar Plate is a rectangular fibrous structure that provides a cushion to the MTP joint. The distal attachment of the plantar plate to the proximal phalanx appears to be its strongest insertion directly to the bone. Although the synovial attachment to the metatarsal head is thin the plantar plate is connected to the longitudinal bands of the plantar fascia. The collateral ligaments insert directly into the medial and lateral sides of the plantar plate helping to maintain the stability of the joint. The intermetatarsal ligament fibers insert in the plate in the plantar portion adding lateral stability to the conjunct.

The weight-bearing nature of the foot as well as the chronic hyperextension malpositioning of the MTP joint can predispose the plantar plate to attenuation or different degrees of rupture leading to instability.

There is no consensus in the literature about the best treatment for this condition. The flexor tendon transfer has been reported as the most consistently successful treatment, eliminating pain and restoring the stability of the joint. The primary repair of the MTP plantar plate has been compared with other procedures and has proven to be a promising option to address this problem.

Based on these observations we are convinced that the best way to treat the different stages of the plantar plates can be by the direct action over the attenuated or torn tissue. We always start the procedure with an MTP arthroscopy to confirm the type and extent of the plantar plate lesion. At this time of the procedure we can remove the hypertrophic (inflammatory or fibrotic) synovial tissue.

The open part of the surgery starts with a dorsal italic “S” shape incision over the MTP joint. The EDL tendon is lengthened in a “Z” manner and the dorsal MTP articular capsule is opened with a “T” shape incision, exposing the metatarsal head. In the sequence, a distal Weil metatarsal osteotomy is performed retracting the metatarsal head proximally, creating room to see and touch the plantar plate and its lesion (A).