# Pull-Out Technique for Plantar Plate Repair of the Metatarsophalangeal Joint

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**KEYWORDS**

• Crossover toe • Plantar plate • Second metatarsophalangeal joint • Instability

**KEY POINTS**

- The plantar plate provides cushion to the metatarsal head, and is the most important structure for stability of the metatarsophalangeal joint (MTPJ).
- Plantar plate rupture is a common cause of forefoot pain, multiplanar malalignment, subluxation, or dislocation of the MTPJ.
- A group of factors seems to be associated to the development of the lesion known as crossover, which features sagittal and horizontal plane instability.
- Inflammatory arthritis, such as rheumatoid arthritis, or trauma, may also precipitate MTPJ destabilization of the lesser toes.

## INTRODUCTION

The plantar plate provides cushion to the metatarsal head, and is the most important structure for stability of the metatarsophalangeal joint (MTPJ). Plantar plate rupture is a common cause of forefoot pain, multiplanar malalignment, subluxation, or dislocation of the MTPJ. A group of factors such as sagittal and horizontal plane instability, seems to be associated to the development of the lesion. The lesion is most commonly seen at the second ray, especially in the presence of index minus, and is often associated with hallux valgus or hallux rigidus.[1] Inflammatory arthritis, such as rheumatoid arthritis, or trauma, may also precipitate metatarsophalangeal joint destabilization of the lesser toes.

## ANATOMY AND BIOMECHANICS

At the dorsal aspect of the MTPJ, the extensor digitorum longus (EDL) tendon is centrally located, splitting into 3 portions over the proximal phalanx: the central portion

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attaches to the base of the middle phalanx, and the 2 adjacent portions blend over the dorsal aspect of that phalanx and attach to the base of the distal phalanx. A fibroaponeurotic apparatus extends from the MTPJ plantar region and proximal phalanx base to the dorsal region, surrounding and centrally stabilizing the EDL. The EDL does not have any proximal phalanx attachment, but acts through that fibroaponeurotic apparatus. The proximal phalanx is literally suspended (dorsiflexed) by the action of EDL over it. Besides MTPJ dorsiflexion, the EDL tendon may cause extension of the proximal (PIPJ) and distal (DIPJ) interphalangeal joints, as long as the proximal phalanx is in either neutral or plantar flexion position. Dorsiflexion of the proximal phalanx assures that EDL excursion is insufficient to exert tension onto the middle and distal phalanges. This concept is important in understanding the detrimental effect of high heels, which keep the proximal phalanx dorsiflexed, thus reducing or even nullifying the action of EDL onto the interphalangeal joints.[2–5]

Underneath, the MTPJ is stabilized by the joint capsule and the plantar aponeurosis, together forming the plantar plate. This structure is made of longitudinally oriented fibrocartilage that resists tensional stresses, and by transversally oriented fibers, which resist the compressive stresses from the metatarsal head. It has a roughly rectangular form, being 2 to 5 mm thick. The mean length is 19 mm; the average width is 11 mm at the proximal region and 9 mm at the distal region of the second ray. Regarding biochemical structure, the plantar plate shows 75% of type I collagen and 21% of type II collagen. Collagen types III and V complete the content. The structure of the plantar plate is similar to that of the knee meniscus and the spinal annulus fibrosus, which are designed for load bearing. Besides its stabilizing and shock-absorbing functions, the plantar plate offers a gliding surface for the metatarsal head and flexor tendons. It has a strong, distal osseous attachment at the proximal phalanx plantar surface, and a thin proximal plantar attachment at the metatarsal neck. Medially and laterally, the plantar plate gives off expansions for intermetatarsal and collateral ligaments. The latter are mainly responsible for horizontal stability at MTPJ level, and are also regarded as being the most important MTPJ static vertical stabilizers.[2–5]

The tendon of the flexor digitorum longus (FDL) is attached at the base of the distal phalanx and promotes DIPJ flexion, whereas the flexor digitorum brevis (FDB) is attached at the base of the middle phalanx and promotes PIPJ flexion. There is no flexor insertion at the proximal phalanx and, as such, the plantar flexion at MTPJ level occurs because of the action of interossei and lumbricales that run beneath the axis of MTPJ. However, if the toe assumes an extended (dorsiflexed) position at the MTPJ level, those muscles become superiorly situated with regard to MTPJ level and, in this new position, lose their original flexor capability and start acting as MTPJ extensors, perpetuating the extension that pushes off inferiorly the first metatarsal head, thus increasing the pressure over the plantar plate.[6,7]

## PATHOGENESIS

The exact cause of second-ray MTPJ instability is not known, but a handful of possibly predisposing factors can be seen in most cases. Plantar plate rupture usually occurs on the second ray, and the reasons possibly associated with the lesion occurring at this location include:

1. Excessive second metatarsal length with regard to the first metatarsal
2. The absence of plantar interossei and the presence of 2 dorsal interossei muscles, which may render local muscle imbalance

3. There is only one lumbrical muscle that is medially attached at the extensor apparatus at the second ray, which may also produce local muscle imbalance and create the characteristic medial deviation of the crossover deformity
4. The hallux valgus that is often associated to the lesion pushes the second toe laterally, which may lead to further instability and subluxation
5. Hypermobility with first-ray insufficiency, and lateral overload under the second ray

## PATIENT HISTORY AND PHYSICAL EXAMINATION

The complaint of insidious pain associated with inadequate shoe wear is common. It is usually located at the dorsal MTPJ aspect, and/or at the plantar region at the metatarsal head.

Various grades of toe clawing (usually the second toe) are observed during standing examination. The hallux usually shows valgus deviation, lying under the second toe. The callus at the dorsal region of the PIPJ represents the friction of that region against the shoe, and at the metatarsal head the plantar region represents ray hyperpressure against the floor.

Having the patient seated, MTPJ stability is tested by the Lachman test, as described by Thompson and Hamilton.[8] The test can be graded in terms of how much proximal phalanx can vertically translate. In stage 0, there is no laxity to dorsal translation. In stage 1, the proximal phalangeal base can be subluxated, but not dislocated. In stage 2, the phalangeal base can be dislocated but also manually reduced. In stage 3, the phalangeal base is fixed in a dislocated position because of the tightness of extensor tendons, and cannot be reduced manually. The patient's pain is typically reproduced with dorsoplantar stress, and in cases of dislocation it is sometimes difficult to achieve joint reduction.

Reduction of interphalangeal joint clawing, if present, should be tested through passive mobilization.

## IMAGING EXAMINATIONS

Severity of deformity is assessed by anteroposterior and lateral, standing radiograph films, and oblique views of the compromised foot. Joint congruity, metatarsal parabole, the presence of arthritic changes, and severity of deformity are all observed on radiographs. Widening of the MTPJ space can be present in early stages of joint synovitis, but the MTPJ clear space is usually reduced as the base of the proximal phalanx dorsally subluxates over the metatarsal head (**Fig. 1**).

The plantar plate itself can be studied by ultrasonography, arthrography, and magnetic resonance imaging (MRI); the latter is the examination of choice, because of its noninvasive character and its ability to show the earliest structural changes. The normal plantar plate appearance on MRI is of a smooth, curved, low-signal structure located under the metatarsal head, attaching to the base of the proximal phalanx. MRI demonstrates, especially in sagittal plane images, the lack of plate continuity at its distal attachment in the presence of a lesion.

## TREATMENT OPTIONS

The treatments that have been described for MTPJ instability of lesser toes include amputation, lengthening and/or tendon transfer, periarticular soft-tissue release (capsule, collateral ligaments, and plantar plate), collateral ligament reconstruction, metatarsal shortening osteotomy, and suture of plantar plate lesion.[9–22] The

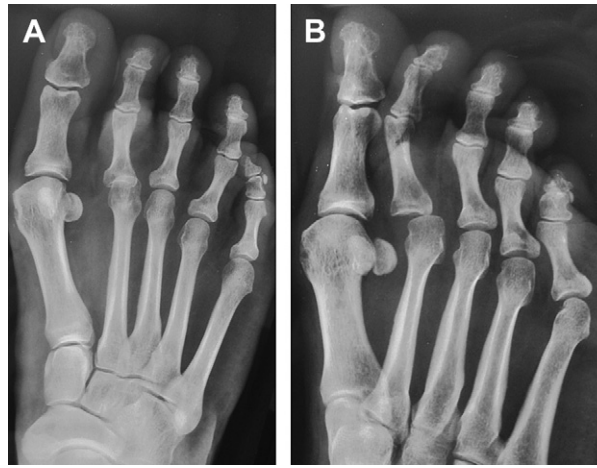


**Fig. 1.** (*A, B*) Anteroposterior and oblique views of the right foot, with plantar plate lesion of the second ray with joint subluxation.

combination of more than one of these procedures is often needed in the approach to treating such complex deformity.

VanderWilde and Campbell[23] reported on the results of second-toe amputations performed for chronic painful deformity, and 68% of the patients were satisfied with their results. Gallentine and DeOrio[24] published their results on removal of the second toe for severe hammertoe deformity. The study included 12 patients (17 amputations). For 11 patients the procedure met their expectation, but 8 patients observed that their hallux became more valgus after surgery. The indication for second-toe amputation is restricted to older patients with severe deformity and those who do not care about the resulting cosmetic component.

Tendon transfers do yield satisfactory results, but joint rigidity is common and often jeopardizes the final result. The most commonly used tendon transfer to stabilize MTPJ and avoid its extension is the tendon of the FDL to the extensor apparatus. Coughlin[1] recommends a flexor-to-extensor tendon transfer, performed in such a manner that the lateral limb of the FDL tendon is preferentially tightened, thus correcting the transverse malalignment. Haddad and colleagues[25] recommend extensor brevis tendon transfer for early cases of MTPJ synovitis and subluxation, and flexor-to-extensor tendon transfer for cases of toe overlap and MTPJ dislocation. In their study, 31 patients were assessed over 51.6 months of follow-up. Twenty-four patients were completely satisfied, 6 were partially satisfied, and 1 was not satisfied. Myerson and Jung[26] retrospectively assessed 59 patients who had undergone a flexor-to-extensor tendon transfer to correct MTPJ instability, with a minimum follow-up of 16 months. Weil osteotomy, PIPJ resection arthroplasty, and PIPJ fusion were the procedures additionally performed in 45%, 34%, and 13% of cases, respectively. Twenty-five patients (29 feet) were very satisfied, 15 satisfied with minor hesitancy, 6 satisfied with major hesitancy, and 14 not satisfied.[26]

A shortening osteotomy is useful for decompressing a long ray, and eventually is paramount for joint congruity reduction. Although the shortening may be performed anywhere alongside the metatarsal, Weil osteotomy, which is performed at the distal end, is more commonly used. The technique is very effective for joint decompression, although complications such as corresponding floating toe are frequent.[27]

Direct plantar plate repair can be performed through either plantar or dorsal approaches. Bouché and Heit[12] retrospectively assessed 18 patients, all of whom

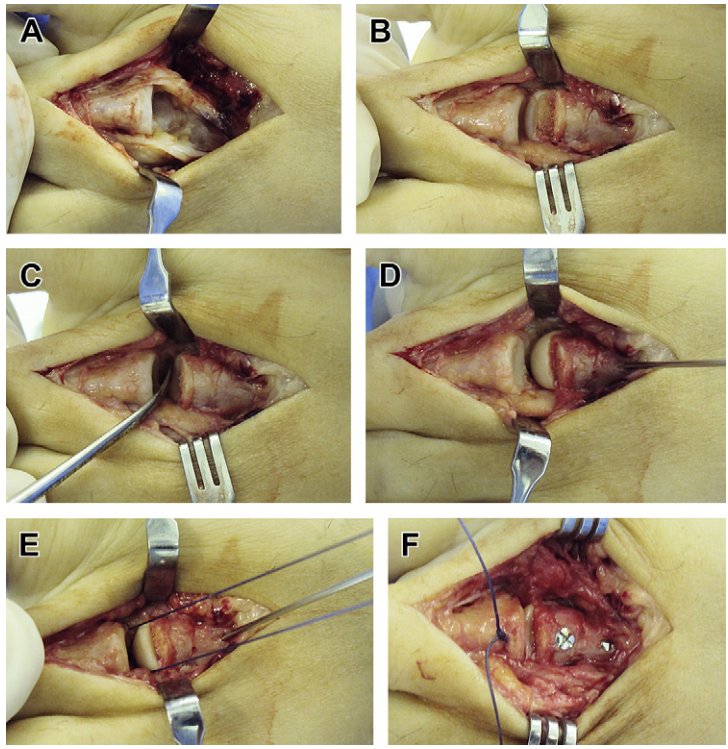


**Fig. 2.** (*A*) Dorsal approach of MTPJ demonstrating joint subluxation. (*B*) Weil osteotomy. (*C, D*) Capital fragment displaced proximal about 15 mm and provisional Kirschner-wire fixation performed to increase plantar plate lesion visualization. (*E*) Suture transversally passed proximal to the plantar plate lesion. (*F*) Final aspect, with Weil osteotomy fixated and plantar plate sutured.

were quite satisfied with the plantar repair of the plate associated to FDL tendon transfer, through a dorsal approach. A plantar plate dorsal approach associated with Weil osteotomy has been shown to be adequate for MTPJ exposure in a cadaver study.[28] Gregg and colleagues[29] retrospectively assessed the results of combined Weil osteotomy and dorsal plantar plate repair. After 26 months of follow-up, 17 of 21 patients were satisfied with the results. Weil and colleagues,[22] using a similar technique, obtained 77% of good and excellent results in 15 cases, with 22.5 months of follow-up. Coughlin and colleagues[30] have recently described a grading classification and repair of plantar plate lesion via Weil osteotomy combined with dorsally performed direct suture of plate lesion.

The proposed technique combines joint decompression by Weil osteotomy with a plantar plate repair using a pull-out technique. The second metatarsal shortening approaches the ray overload and the plantar plate suture of the lesion itself. In the authors' initial series with short-term follow-up, the results seem promising, and the incidence of floating deformity decreased compared with those cases whereby Weil osteotomy was performed without plantar plate repair.

## SURGICAL TECHNIQUE

With the patient supine, under sedation and with ankle pentablock, the MTPJ is approached through a dorsal incision, and the capsule is longitudinally opened.

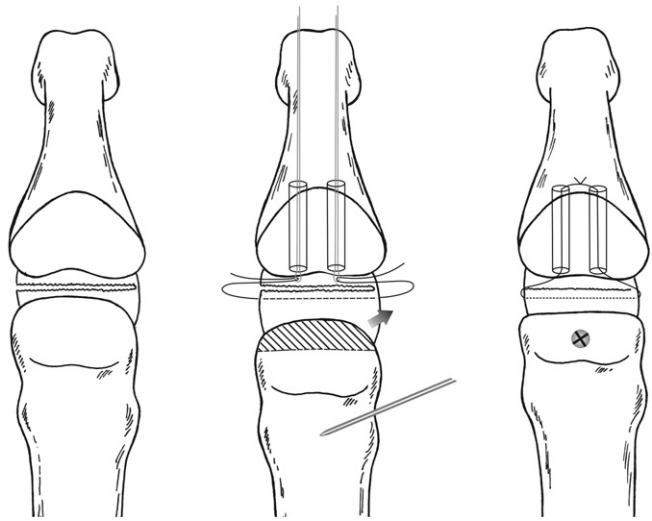

**Fig. 3.** Schematic of the procedure. (*Left*) Plantar plate lesion. (*Middle*) Lesion exposed through Weil osteotomy with metatarsal head retraction and sutures passing through tunnels placed onto the base of the phalanx. (*Right*) Final appearance of the repaired lesion.

Collateral ligaments can be sequentially cut to improve joint visualization. After Weil osteotomy, the metatarsal head is retracted as proximally as possible and temporarily fixated with a 1.2-mm Kirschner wire, exposing the plantar plate lesion. A 2-0 Vicryl suture is transversally applied, proximally to the lesion. Two parallel 1.5-mm holes are placed at the proximal phalanx base, from dorsal to plantar direction. A folded 1-0 steel suture is passed through each hole. The suture is brought dorsally by the steel suture and tied at the top of the proximal phalanx (**Figs. 2–4**).

## POSTOPERATIVE PROTOCOL

Weight bearing with a Barouk shoe is permitted from hospital discharge until 6 weeks postoperatively. Stitches are taken out after 10 to 14 days, and active toe exercises are started from this time.

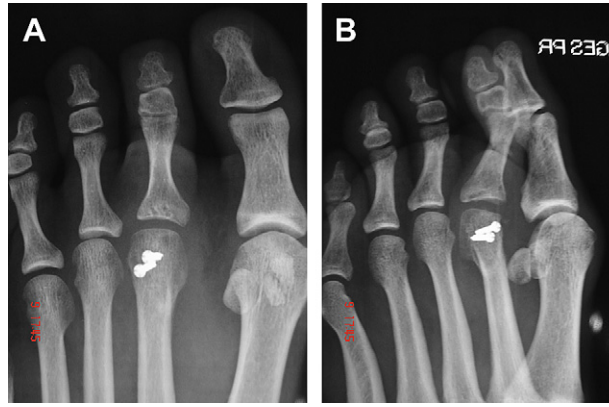


**Fig. 4.** (*A, B*) Postoperative anteroposterior and oblique views of the technique. Note the holes at the proximal phalanx base and the joint alignment obtained.

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