Chapter 17
Plantar Plate Repair via a Plantar Approach

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Clinical Presentation

Subjective Complaints

Typically, patients with plantar plate pathology will describe insidious onset of submetatarsal pain and toe dysfunction that occurs over months to years; however, specific traumatic events can induce acute plantar plate dysfunction. Focal submetatarsal pain consistent with metatarsalgia is typically an early sign of plantar plate inflammation. The patient typically complains of pain with digital range of motion, especially dorsiflexion, swelling, digital deformity, footwear limitations, difficulty walking on hard surfaces, and activity limitations [1]. The pain to the joint can be severe, and the edema can apply increased pressure to the adjacent nerve yielding a clinical presentation similar to that of a neuroma [2, 3]. As the plantar plate degenerates or tears, the toe will lose stability, the patient may simply complain of an isolated hammer or clawtoe, or that the toe no longer purchases the ground. Isolated transverse plane toe deviation is seen with partial tears of the plantar plate. The presence of a hammertoe can exist concomitantly at various stages of plantar plate pathology.

Etiological Mechanisms

The plantar plate is the most important sagittal plane static stabilizer of the metatarsophalangeal joint; however, the deep transverse intermetatarsal and collateral ligaments are also important joint stabilizers as well [4, 5]. The etiological mechanisms that

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Table 17.1 Etiological mechanisms

Long lesser metatarsal
Short first metatarsal
First ray hypermobility
Elevated first metatarsal
Hallux valgus deformity
Mid-/hindfoot hypermobility with medial column overload
Direct trauma or repetitive stress
Localized or systemic arthropathy
Malunion metatarsal fracture
Corticosteroid-induced failure
High-fashion footwear

result in failure are multifactorial (Table 17.1), with the majority of mechanisms caused by an underlying structural abnormality that creates uneven load patterns to the forefoot. Structurally, the deformity is commonly seen with a concomitant hallux abductovalgus deformity (Fig. 17.1). Biomechanically, the instability across the first ray due to the unlocking mechanism imparts overloading on the lesser metatarsals [6]. Progressive abutment pressure of the hallux against the second digit, will eventually cause elevation of the lesser toe which in turn places increased pressure on the plantar plate via retrograde force to the metatarsal head that can over time accelerate the pathology. Although not exclusively seen, accompanying the first ray instability is a long metatarsal to the affected digit with the plantar plate tear [7]. The long metatarsal imparts a greater dorsiflexory force to the digit and over time causes attenuation and tear to the plantar plate along with mechanical trauma to the plate itself from the pressure of the long metatarsal onto the plantar plate tissues (Fig. 17.2). Pronation that leads to overloading of the lesser metatarsophalangeal joints has also been described as a mechanism leading to plantar plate injury. Repetitive stress to the forefoot from shoe gear and activity can also impart damage to the plantar plate leading to injury of the ligament. Crossover toe deformity can involve a partial plate deficiency as well as focal injury to the tie-bar system (deep transverse intermetatarsal ligament and collateral ligaments of the metatarsophalangeal joint) [8, 9]. There is attenuation of the lateral collateral ligaments of the metatarsophalangeal joint along with capsular thinning on the lateral side. The medial structures of the metatarsophalangeal joint are often adapted to shortening of the structures. As the toe is in a dorsomedial position, this puts the pull of the extensor digitorum longus, the flexor digitorum longus, and the interossei medially deviated to the central axis of the metatarsophalangeal joint which further contributes to accentuation of the deformity (Fig. 17.3).

Other non-biomechanical causes of plantar plate tear include inflammatory arthropathies, avascular necrosis of the metatarsal head, neuromuscular disease, and generalized hypermobility syndromes [3]. Injection of steroid into the joint or the intermetatarsal spaces can cause softening of the tissues resulting in iatrogenic attenuation and tearing of the plantar plate or the associated pericapsular structures. Essentially any insult to the joint that causes any form of joint imbalance or overload can potentiate a plantar plate injury.

Fig. 17.1 Patient with hallux valgus (failed previous McBride bunionectomy) and rupture of plantar plate of the second toe. Note the stacked toe deformity of the second and third toes. With the valgus rotation of the hallux, the second toe was unable to cross over the hallux. In this case the third toe crosses under, supporting the second toe deformity

Fig. 17.2 Morton's foot with a relative long second metatarsal. Lesser metatarsal overload predisposes this patient to elevated lesser metatarsal loads during ambulation and is a risk factor for eventual plantar plate dysfunction

Fig. 17.3 Crossover toe deformity that occurred within 6 months after successful bunionectomy. The bunionectomy created shortening of the metatarsal segment exposing the second metatarsal to excess loads

Diagnosis

Objective Findings

When trying to find solutions for digital problems, understanding the functional anatomy and evaluating plantar plate integrity are of critical importance and require manual examination. In the early stages of plantar plate dysfunction, a patient will present with marked inflammation to the area with palpable calor and edema. It is valuable to simulate weightbearing by manually loading the foot and observing relative digital movement of the lesser digits. Persistent dorsiflexion of the proximal phalanx is at minimum, an indicator of central thinning of plantar plate. However, a dorsal drawer test of the lesser metatarsophalangeal joint (lesser digital Lachman's maneuver) should be performed with toe-held rectus (Fig. 17.4). A positive Lachman's is classically described as subluxation of the joint dorsally greater than 50% of the joint space or greater than 2 millimeters [10]. Lachman's maneuver is a confirmatory test for evaluating plantar plate integrity and not if a tear is present or not, as there are situations where the plantar plate is attenuated and not torn.

The static and dynamic digital stabilizers should be examined weightbearing. The plantar plate and the plantar fascia slip are the primary static stabilizers of the toe. When the static stabilization is intact, the digit will firmly contact the ground via the reverse windlass mechanism and will resist any passive dorsiflexion by the examiner. In contrast, an attenuated or torn plantar plate will not tension which affects toe purchase and the reverse windlass, allowing the affected toe to be passively dorsiflexed with ease (Fig. 17.5). Dynamic purchase may be assessed using the "paper pull-out test," where a narrow sheet of paper is inserted under the involved toe and the patient is directed to grasp the sheet with their toe as the examiner attempts to pull the paper away [1].

Fig. 17.4 Demonstration of the lesser digital drawer maneuver (Lachman). Examiner resists digital dorsiflexion with the maneuver. Note the dorsal bulge of the phalanx subluxing on the metatarsal head

Fig. 17.5 (**a**, **b**) Testing of static stabilizers on a patient with clawtoes 2 and 3 on the right foot (**a**); normal-appearing toes on left foot (**b**). The clawtoes pose no resistance to dorsiflexion (suggestive of plantar plate dysfunction), while the normal toes resist dorsiflexion

In the typical crossover toe, there is deviation of the digit which is dorsal and medial and medial drift of the adjacent toe as well. The vast majority of crossover toe deformities have a positive drawer test [11].

Radiographs

The full examination should include proper weight-bearing foot radiographs. Assessment of the structure of the foot includes careful evaluation of the metatarsal parabola, digital position, metatarsophalangeal joint alignment and joint space symmetry, and first ray and hallux position. Structural abnormalities are correlated with associated symptoms.

Arthrogram

Lesser metatarsophalangeal joint arthrogram wherein a radiopaque dye is injected into the joint under fluoroscopic guidance has diagnostic utility when there are tears in the plate [12] (Fig. 17.6). Due to the proximity of the flexor tendon and its sheath to the plantar plate, any tear to the plate will allow dye to leak from the joint space

Fig. 17.6 (**a**) Normal second metatarsophalangeal arthrogram. (**b**) Abnormal second metatarsophalangeal arthrogram. Note the presence and absence of flexor tendon filling from dye leakage

into the flexor tendon sheath. On the fluoroscopic image, one would expect to see radiopaque dye proximal to the expected joint capsule tracking up the flexor tendon sheath or extravasating out of the joint capsule. The main disadvantage of this technique are the false negatives seen in joints with attenuated plantar plates that do not have discrete tears as there is no dye leakage into the flexor sheath.

Ultrasound

Diagnostic ultrasound has utility when screening patients with resistant forms of metatarsalgia and suspected plantar plate tears [2, 13–15]. Longitudinal ultrasound has been shown to be 90% accurate in the diagnosis of a tear to the plantar plate, but there is inaccuracy in being able to locate the tear. Performing dynamic ultrasound seems to increase the accuracy of diagnosis of subtle plantar plate tears [16]. Ultrasound is more cost-effective than advanced imaging techniques. With the popularity of in-office handheld ultrasound machines that provide a consistent and quick assessment, ultrasound has a place in the workup and diagnosis of plantar plate tears. If there is doubt and the patient is a surgical candidate, MRI can always be undertaken for definitive diagnosis.

MRI

MRI is an effective tool to accurately diagnose and locate plantar plate tears as well as evaluate plate attenuation [2, 13–15]. The accuracy was at 96% with MRI, and MRI was concluded to be superior to confirming tears along with localization of the tear.

The addition of contrast dye into the joint can further augment and add to the accuracy of visualization of plantar plate tears with MRI as well (Fig. 17.7 *MRI*) [17].

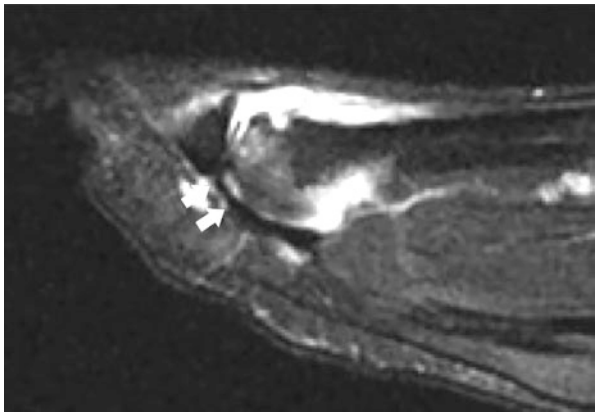

Fig. 17.7 Sagittal MRI slice of the second metatarsophalangeal joint. Note plantar plate attenuation (arrow)

The major drawback to this method is cost and the amount of variation of the joint. Bursa formation, extravasation through the capsule puncture site, and normal variant capsular recesses can attribute to an increased volume of injectable without the presence of a plantar plate tear, and results need to be interpreted carefully.

Surgical Treatment

Treatment Rationale

The plantar plate is a broad disk-shaped structure that extends the cup shape to the osseous portion of the proximal phalanx base where it is firmly attached. It is a unique structure as it is designed to withstand tensile forces via the windlass mechanism alternating with compressive forces via the load path of the metatarsal segment. Plantar plate repair is usually only a part of the surgical plan that also addresses the predisposing mechanical factors that led to the plantar plate failure. These predisposing factors such as long metatarsal, hypermobile first ray, hallux valgus, and gastrocnemius equinus need to be simultaneously addressed at the time of plantar plate repair to ensure a durable repair with less risk for subsequent failure. Direct repair techniques can also address postoperative complications associated with floating toe (Fig. 17.8).

Fig. 17.8 Example of floating digit of the second toe

Surgical Procedure

A direct plantar approach affords the most straightforward method of repair of the plantar plate (Fig. 17.9 a-d). For optimal healing and visualization, it is recommended that the incision is predominantly longitudinal in orientation. It can be

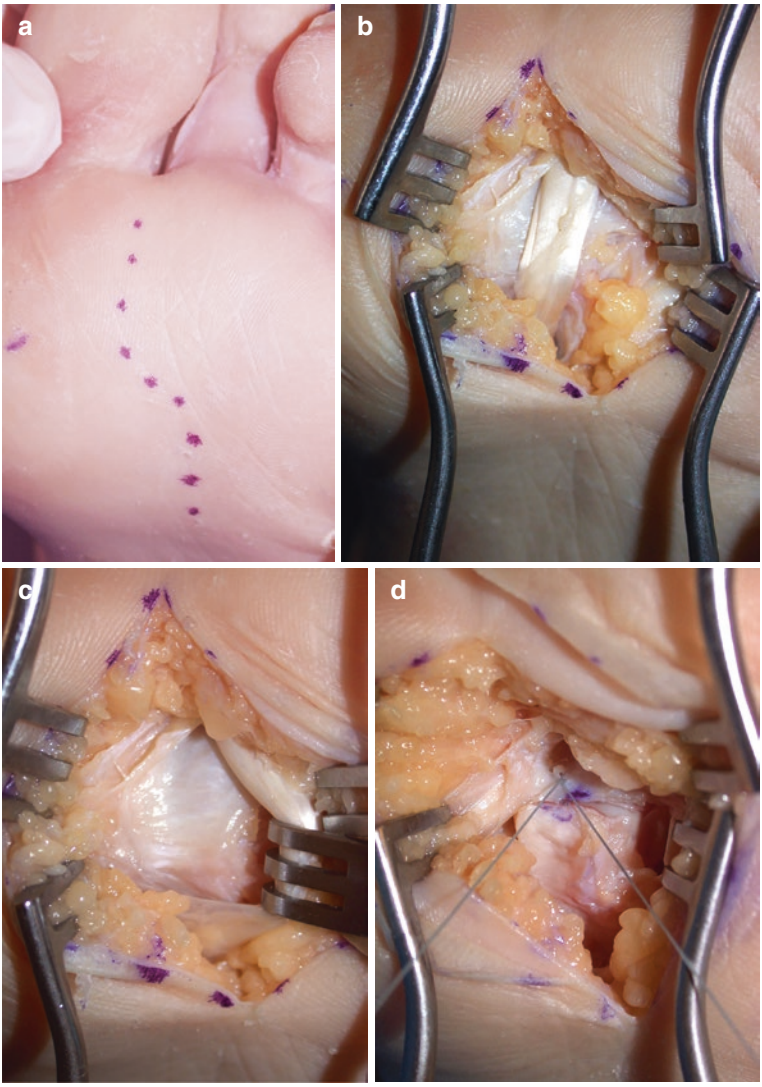

Fig. 17.9 (**a**) Planned incision for direct plantar plate repair. (**b**) Dissection exposing flexor tendon sheath. (**c**) Retraction of flexor tendons exposing attenuated plantar plate. (**d**) Plate was detached and advanced removing thinned attritional zone

longitudinal, s-shaped, or step-down in appearance; however, as the incision crosses the position of the metatarsophalangeal joints, it should cross between the metatarsal heads [1, 18]. Sharp dissection is performed through the fat pad to maintain the fibrous organization as much as possible. The incision is carried obliquely toward the plantar aspect of the head to reach the underlying flexor sheath. The sheath is longitudinally released to allow for tendon retraction, allowing full visualization of the plantar plate. The pathological appearance follows a spectrum of attenuation, partial tear, or complete tear; the tear typically transverses at either mid-substance or at the proximal phalanx insertion [1]. The type of repair is dictated by the pattern of tissue injury and degree of digital deformity. A mid-substance tear is often repaired with a 2–0 or 3–0 absorbable or nonabsorbable orthopedic suture in a figure-eight technique. In this approach, simple and complex tears of the plantar plate can be repaired. A small wedge of plate tissue can be removed during the repair to address mild transverse plane digital deformity. Tears of the base of the proximal phalanx require use of a mini bone anchors or trans-osseous suturing (Fig. 17.10). The same technique is used if the surgeon chooses to reflect the tissues off the base of the proximal phalanx to advance an attenuated plantar plate. It should be noted that with advancement, the collateral ligaments need to be released to achieve enough movement of the plate and then sutured back to the plate pad. It is recommended after placing the first suture that simulated loading of the foot is performed to determine if the toe deformity is reduced [1]. If not, it is recommended that a section of tissue be excised from the plate. Often pinning the toe in a plantarflexed position is necessary to protect the plate repair, particularly in revision situations or when the quality of the tissue is compromised. Protected

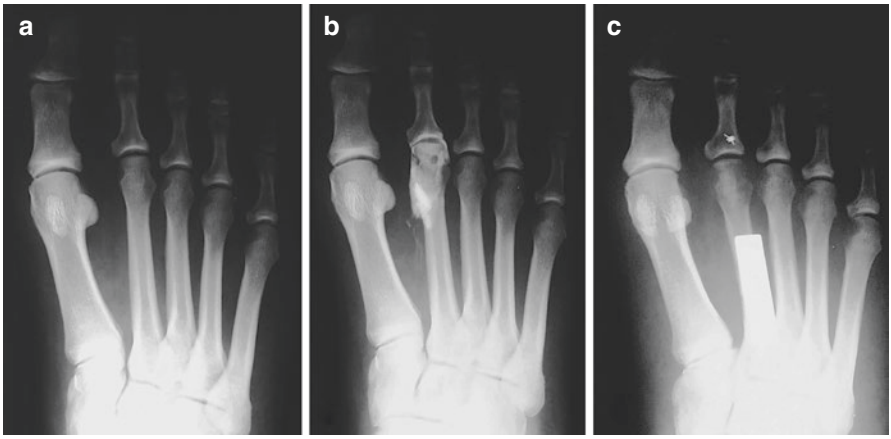

Fig. 17.10 (**a**) Case example patient with relatively long second metatarsal and intractable metatarsalgia. (**b**) Positive arthrogram for plantar plate tear. (**c**) Cylindrical shortening of the second metatarsal combined with mini anchor into the second proximal phalanx base to reattach the plantar plate

Fig. 17.11 Radiograph of the foot with severe hallux valgus and dislocated second toe

non-weightbearing for 4–6 weeks is recommended postoperatively to ensure adequate strength of the repair. Long term, the patient should be supported with orthotics for off-loading to maintain long-term durability.

Digital dislocation is the end stage of hammertoe deformity with complete rupture of the plantar plate (Fig. 17.11). While a direct approach can be made in attempt to repair the plantar plate. It is generally not possible to relocate the toe with a plantar approach. In these situations, the quality of the plantar plate remnants is generally poor. If it is known or discovered that the plantar plate is not repairable, then flexor digitorum longus transfer to the proximal phalanx base is recommended as a substitute for the plantar plate [19].

Clinical Pearls

- Direct repair of the plantar plate is a useful technique in revision hammertoe surgery or floating toe after shortening metatarsal osteotomy where the length-tension relationship of the plantar plate has been altered.
- Flexor digitorum longus tendon transfer to the proximal phalanx can be used to augment a plantar plate repair especially when the quality of the repair is in question.
- In transverse plane digital deformity with plantar plate insufficiency, an oblique transpositional osteotomy is helpful in combination with plantar plate repair to rebalance the soft tissues.
- Some surgeons prefer to use a cylindrical shortening osteotomy when performing direct plantar plate repair to reduce dorsal scaring that could impede sagittal plane digital correction.

Clinical Pitfalls

- Arthrofibrosis and risk for vascular compromise of the digit are complications that may be encountered with the use of dual incisions that cross the metatarsophalangeal joint.
- Fat pad atrophy is a risk of direct plantar plate repair; thus, blunt dissection of the fat pad is discouraged.
- Isolated direct repair of the plantar plate is generally not performed, as this technique is typically combined with other procedures. Neutralizing dynamic deforming forces and normalizing structural and functional defects of the foot can reduce destructive forces crossing the plantar plate.

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